JEE Main 2023 Feb 1 Shift-2 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:

(A) The Duration of test is 3 Hours.

(B) This paper consists of 90 Questions.

(C) There are three parts in the paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage.

(D) Each part (subject) has two sections.

(i) Section-A: This section contains 20 multiple choice questions which have only one correct answer. Each carries 4 marks for correct answer and –1 mark for wrong answer.

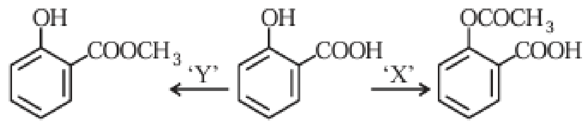
(E) (ii) Section-B: This section contains 10 questions. In Section-B, attempt any five questions out of 10. The answer to each of the questions is a numerical value.

Each carries 4 marks for correct answer and –1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer.

Chemistry

Section A

1: In a reaction,



reagents 'X' and 'Y' respectively are :

(1) $(CH_3CO)_2O/H+$ and $CH_3OH/H+, \Delta$

(2) $(CH_3CO)_2O/H+$ and $(CH_3CO)_2O/H+$

(3) $CH_3OH/H+, \Delta$ and $CH_3OH/H+, \Delta$

(4) $CH_3OH/H+\ \Delta$ and $(CH_3CO)_2O/H+$

Correct Answer: (1) $(CH_3CO)_2O/H+$ and $CH_3OH/H+, \Delta$

Solution:

Reaction from B to C (Reagent 'X')

The transformation from B to C involves the esterification of the phenolic OH group. This can be achieved using acetic anhydride ($(CH_3CO)_2O$) in the presence of an acid catalyst (H+). This reaction is known as Fischer esterification.

Reaction from B to A (Reagent 'Y')

The transformation from B to A involves the esterification of the carboxylic acid group (COOH) with methanol (CH_3OH) in the presence of an acid catalyst (H+) and heat (Δ). This is also a Fischer esterification.

Conclusion: The reagents X and Y are $(CH_3CO)_2O/H+$ and $CH_3OH/H+, \Delta$, respectively, which corresponds to **option (1)**.

Quick Tip

Recognize the functional groups involved and the type of reaction taking place. Fischer esterification is a common method for preparing esters from carboxylic acids or phenolic OH groups.

2: The correct order of bond enthalpy (kJ mol^{-1}) is:

(1) Si – Si > C – C > Sn – Sn > Ge – Ge

(2) Si – Si > C – C > Ge – Ge > Sn – Sn

(3) C – C > Si – Si > Sn – Sn > Ge – Ge

(4) C – C > Si – Si > Ge – Ge > Sn – Sn

Correct Answer: (4) C – C > Si – Si > Ge – Ge > Sn – Sn

Solution:

Consider the Trend Down the Group

Bond enthalpy generally decreases down a group in the periodic table. This is because as the atomic size increases, the bond length increases, and longer bonds are weaker.

Given Elements

The elements in question are C, Si, Ge, and Sn. They all belong to Group 14. Their atomic size increases down the group in the order C < Si < Ge < Sn.

Bond Enthalpy Order

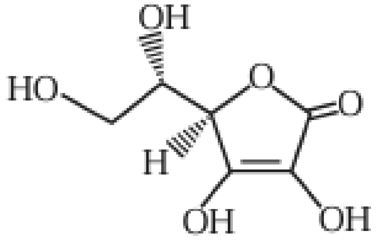
Since bond enthalpy decreases with increasing atomic size, the correct order of bond enthalpy is: C – C > Si – Si > Ge – Ge > Sn – Sn

Conclusion: The correct order is given in **option (4)**.

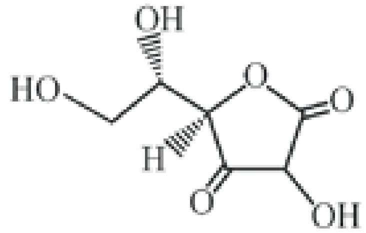
Quick Tip

Remember that bond enthalpy generally decreases down a group due to the increase in atomic size and bond length.

3: All structures given below are of vitamin C. Most stable of them is :



(1)



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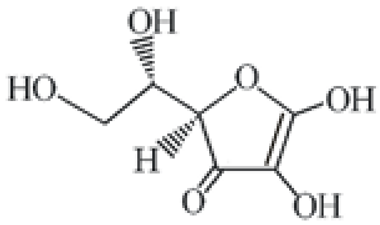

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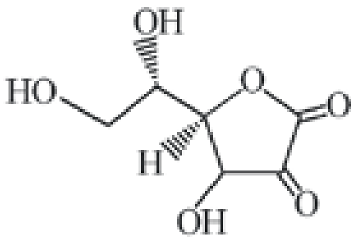
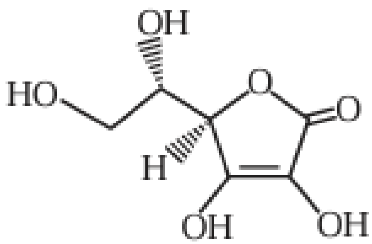


(4)



Correct Answer: (1)

Solution:

Structures

All four structures represent ascorbic acid (vitamin C), but they differ in the position of the double bond within the ring and the configuration of the hydroxyl groups.

Resonance Stabilization

The most stable structure will be the one with the greatest resonance stabilization. Structure (1) has the most resonance structures possible because the double bond is conjugated with the carbonyl group, allowing for delocalization of electrons. This delocalization stabilizes the structure more than the other structures. Also, the hydroxyl group on C2 will donate electron density to the carbonyl group at C1, whereas in structure 2 the carbonyl group will pull electrons making it unstable.

Conclusion: Structure **(1)** is the most stable due to resonance stabilization and intramolecular hydrogen bonding possibility.

Quick Tip

Resonance stabilization is a key factor in determining the stability of molecules. Look for structures with the greatest delocalization of electrons. For Ascorbic acid, the ene-diol system adjacent to the carbonyl group is responsible for stability.

4: The graph which represents the following reaction is:

$$(C_6H_5)_3C - Cl \xrightarrow[Pyridine]{OH^-} (C_6H_5)_3C - OH$$

(1) [scale=0.4] [-¿] (0,0) – (5,0) node[below] $[(C_6H_5)_3C - Cl]$; [-¿] (0,0) – (0,5) node[left] rate; (0,3) – (4,3);

(2) [scale=0.4] [-¿] (0,0) – (5,0) node[below] $[OH^-]$; [-¿] (0,0) – (0,5) node[left] rate; (0,0) – (4,4);

(3) [scale=0.4] [-¿] (0,0) – (5,0) node[below] $[(C_6H_5)_3C - Cl]$; [-¿] (0,0) – (0,5) node[left] rate; (0,0) – (4,4);

(4) [scale=0.4] [-¿] (0,0) – (5,0) node[below] [Pyridine]; [-¿] (0,0) – (0,5) node[left] rate; (0,0) – (4,4);

Correct Answer: (3) [scale=0.4] [-¿] (0,0) – (5,0) node[below] $[(C_6H_5)_3C - Cl]$**; [-¿] (0,0) – (0,5) node[left] rate; (0,0) – (4,4);**

Solution:

Reaction Mechanism

The given reaction is a nucleophilic substitution reaction, specifically an S$_N$1 reaction. The S$_N$1 mechanism proceeds in two steps:

1. Ionization: The C-Cl bond breaks to form a carbocation intermediate ($(C_6H_5)_3C^+$) and a chloride ion (Cl^-). This step is slow and rate-determining.

2. Nucleophilic Attack: The hydroxide ion (OH^-) attacks the carbocation to form the product ($(C_6H_5)_3C-OH$). This step is fast.

Rate Law

Since the first step is rate-determining, the rate of the reaction depends only on the concentration of the alkyl halide ($(C_6H_5)_3C-Cl$):

$$\text{Rate} = k[(C_6H_5)_3C-Cl]$$

where k is the rate constant. The rate is independent of the concentrations of hydroxide ion (OH^-) and pyridine.

Graphs

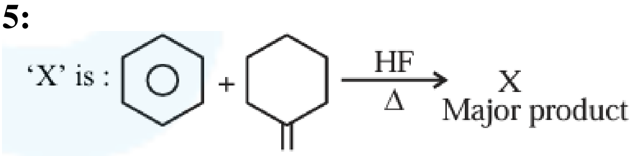
The correct graph should show a linear relationship between the rate and the concentration of $(C_6H_5)_3C-Cl$. This is represented by graph (3).

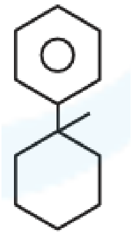
Conclusion: Graph (3) correctly represents the reaction.

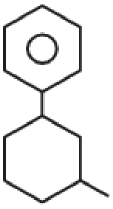
Quick Tip

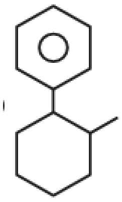
Understanding the reaction mechanism is crucial for determining the rate law and the dependence of the reaction rate on the concentrations of the reactants.

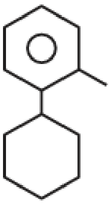
5:

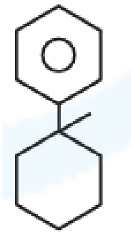


(1) 

(2) 

(3) 

(4) 

Correct Answer: (1) 

Solution:

Reactants

The reactants are tetrahydrofuran (THF) and 2-methylpropene. The reaction is catalyzed by HF and takes place under heat.

Reaction Mechanism

This reaction is an electrophilic addition of THF to the alkene. HF protonates the alkene to form a carbocation. The oxygen in THF acts as a nucleophile and attacks the carbocation. Finally, deprotonation occurs to yield the product.

Major Product

The major product is determined by Markovnikov's rule, which states that the proton adds to the carbon of the double bond with more hydrogens. In this case, the carbocation will form on the more substituted carbon of 2-methylpropene, leading to product (1).

Conclusion: The major product 'X' is represented by structure **(1)**.

Quick Tip

Remember Markovnikov's rule for electrophilic addition reactions. The most stable carbocation intermediate leads to the major product.

6: The complex cation which has two isomers is:

(1) $[Co(H_2O)_6]^{3+}$

(2) $[Co(NH_3)_5Cl]^{2+}$

(3) $[Co(NH_3)_5NO_2]^{2+}$

(4) $[Co(NH_3)_5Cl]^{+}$

Correct Answer: (3) $[Co(NH_3)_5NO_2]^{2+}$

Solution:

Complexes for Isomerism

We are looking for a complex cation that exhibits two isomers. Let's analyze each option:

(1) $[Co(H_2O)_6]^{3+}$: This complex has only one possible structure, as all ligands are the same (H_2O). So, it does not have isomers.

(2) $[Co(NH_3)_5Cl]^{2+}$: This complex can only exhibit ionization isomerism if another counter ion is present within the complex to exchange positions with the Cl ligand. With only one Cl, there's no possibility of isomerism here.

(3) $[Co(NH_3)_5NO_2]^{2+}$: This complex can exhibit linkage isomerism because the NO_2 ligand can coordinate to the metal ion through either the nitrogen atom (nitro isomer) or the oxygen atom (nitrito isomer). Thus, it has two isomers.

(4) $[Co(NH_3)_5Cl]^{+}$: Same explanation as (2), no isomerism is possible.

Conclusion: The complex cation $[Co(NH_3)_5NO_2]^{2+}$ exhibits linkage isomerism and has two isomers. Therefore, the correct answer is **(3)**.

Quick Tip

Consider the different types of isomerism in coordination compounds, such as linkage isomerism, ionization isomerism, geometrical isomerism, and optical isomerism.

7: Given below are two statements :

Statement I : Sulphanilic acid gives esterification test for carboxyl group.

Statement II : Sulphanilic acid gives red colour in Lassaigne's test for extra element detection.

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

(1) Statement I is correct but Statement II is incorrect.

(2) Both Statement I and Statement II are incorrect.

(3) Both Statement I and Statement II are correct.

(4) Statement I is incorrect but Statement II is correct.

Correct Answer: (4) Statement I is incorrect but Statement II is correct.

Solution:

Analyze Statement I

Sulfanilic acid contains an amine group ($-NH_2$) which is attached to the benzene ring, and a sulfonic acid group ($-SO_3H$). It does not contain a carboxyl group (COOH). Esterification is a characteristic reaction of carboxylic acids. Therefore, Statement I is **incorrect**.

Analyze Statement II

Lassaigne's test is used to detect the presence of nitrogen, sulfur, halogens, and phosphorus in organic compounds. Sulfanilic acid contains sulfur and nitrogen. The red color in Lassaigne's test is due to the formation of ferric thiocyanate $[Fe(SCN)_3]$ when sulfur is present. Thus, Statement II is **correct**.

Conclusion: Statement I is incorrect, but Statement II is correct. The correct answer is

option (4).

Quick Tip

Know the functional groups present in organic compounds and the tests used to detect them. Lassaigne's test is used for elemental analysis of organic compounds.

8: Given below are two statements : one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : Gypsum is used for making fireproof wall boards.

Reason (R) : Gypsum is unstable at high temperatures.

In the light of the above statements, choose the correct answer from the options given below : (1) Both (A) and (R) are correct but (R) is not the correct explanation of (A).

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

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

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

Correct Answer: (1) Both (A) and (R) are correct but (R) is not the correct explanation of (A).

Solution:

Analyze Assertion (A):

Gypsum ($CaSO_4 \cdot 2H_2O$) is used for making fireproof wall boards. When heated, gypsum loses water and forms plaster of Paris, which is a good fire-resistant material. Hence, assertion (A) is **correct**.

Analyze Reason (R):

Gypsum is unstable at high temperatures as it loses water molecules upon heating. Hence, Reason (R) is also **correct**.

Relationship between (A) and (R)

While both statements are correct, the reason gypsum is used in fireproof wall boards is not simply because it's unstable at high temperatures. It's because the water molecules present in gypsum act as a fire retardant. When exposed to fire, the water molecules are released as

steam, absorbing a significant amount of heat and preventing the spread of the fire. This process makes the wall board fire resistant.
Therefore, (R) is not the correct explanation for (A).

Conclusion: Both (A) and (R) are correct, but (R) is not the correct explanation of (A). The correct option is **(1)**.

> Quick Tip
>
> Carefully consider the relationship between the assertion and the reason. Even if both statements are individually correct, the reason may not necessarily be the correct explanation for the assertion.

9: Which element is not present in Nessler's reagent ?

(1) Mercury

(2) Potassium

(3) Iodine

(4) Oxygen

Correct Answer: (4) Oxygen

Solution:
Nessler's reagent is an alkaline solution of potassium tetraiodomercurate(II) ($K_2[HgI_4]$). Its chemical formula indicates the presence of potassium (K), mercury (Hg), and iodine (I). Oxygen is not present in the reagent itself but might be involved in the reaction when it's used to test for ammonia.

Conclusion: Oxygen is not present in Nessler's reagent. The correct option is **(4)**.

> Quick Tip
>
> Know the composition of common reagents used in chemical analysis. Nessler's reagent is used to detect ammonia.

10: Given below are two statements : one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : α-halocarboxylic acid on reaction with dil. NH_3 gives good yield of α-amino carboxylic acid whereas the yield of amines is very low when prepared from alkyl halides.

Reason (R) : Amino acids exist in zwitter ion form in aqueous medium.

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

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

(2) Both (A) and (R) are correct but (R) is not the correct explanation of (A).

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

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

Correct Answer: (2) Both (A) and (R) are correct but (R) is not the correct explanation of (A).

Solution:

Analyze Assertion (A)

α-halocarboxylic acids react with dilute ammonia (NH_3) to give a good yield of α-amino carboxylic acids. This is because the carboxyl group (-COOH) increases the reactivity of the α-halo group towards nucleophilic substitution. In contrast, the yield of amines from simple alkyl halides reacting with ammonia is low due to overalkylation, where the initially formed amine can react further with the alkyl halide. Therefore, Assertion (A) is **correct**.

Analyze Reason (R)

Amino acids exist as zwitterions in aqueous solutions and in the solid state. A zwitterion has both positive and negative charges within the same molecule, resulting in a net charge of zero. This is due to the acidic carboxyl group and the basic amino group present in amino acids. Thus, Reason (R) is **correct**.

Analyze the Relationship between (A) and (R)

While both statements are individually correct, Reason (R) doesn't explain Assertion (A). The higher yield of amino acids from α-halocarboxylic acids is due to the enhanced reactivity of the α-halo group, not the zwitterionic nature of amino acids.

The zwitterionic form is a characteristic of the product (amino acid) but doesn't explain the higher yield compared to the reaction of alkyl halides with ammonia. The correct explanation is the neighboring group participation of the carboxylic group makes the reaction proceed via a two-step process leading to a higher yield.

Conclusion: Both (A) and (R) are correct, but (R) is not the correct explanation of (A). Therefore, the correct answer is **(2)**.

Quick Tip

Carefully analyze the relationship between the assertion and the reason. Even if both are true independently, the reason might not be the correct explanation for the assertion.

11: The industrial activity held least responsible for global warming is :

(1) manufacturing of cement

(2) steel manufacturing

(3) Electricity generation in thermal power plants.

(4) Industrial production of urea

Correct Answer: (4) Industrial production of urea

Solution:

Manufacturing of cement, steel manufacturing, and electricity generation in thermal power plants are major contributors to greenhouse gas emissions, primarily CO_2, which is a significant driver of global warming.

Cement production releases CO_2 through the calcination of limestone.

Steel manufacturing uses coal, a carbon-intensive fuel, releasing CO_2.

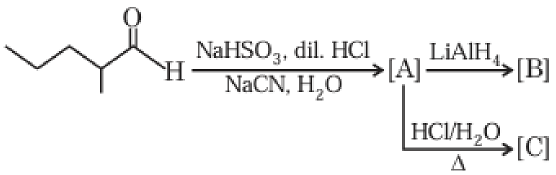
Thermal power plants also burn fossil fuels to generate electricity, leading to substantial CO_2 emissions.

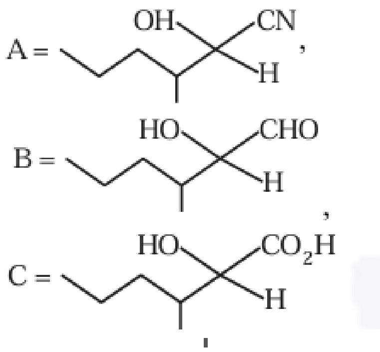
While urea production does have an environmental footprint, its contribution to global warming is much less than the other three activities listed. The primary greenhouse gas emissions associated with urea production are nitrous oxide (N_2O) from fertilizer application and CO_2 from energy use in the production process. However, these emissions are considerably lower compared to those from cement, steel, and electricity generation.

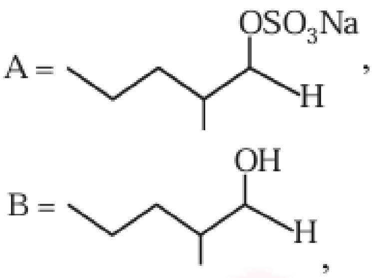
Conclusion: Among the given options, industrial production of urea is the least responsible for global warming.

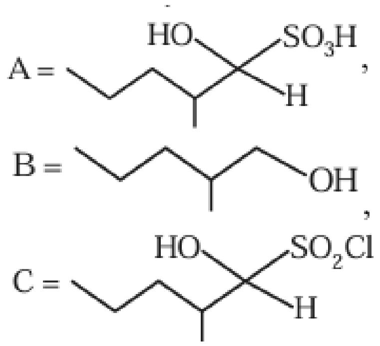
> **Quick Tip**
>
> Understand the industrial processes that contribute to greenhouse gas emissions and their relative impact on global warming.

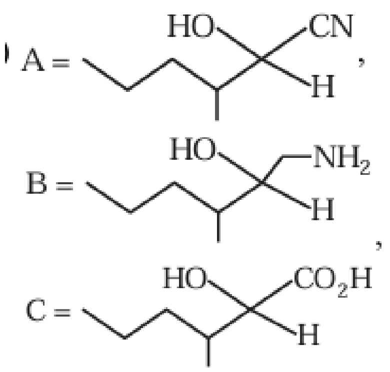
12: The structures of major products A, B and C in the following reaction are sequence.

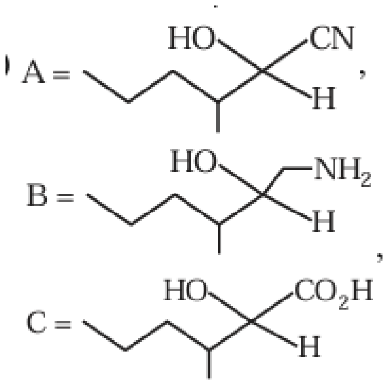


(1) 

(2) 

(3) 

(4) 

Correct Answer: (4) 

Solution:

Reaction with $NaHSO_3$ and Dilute HCl (Formation of A)

The starting compound is butan-2-one. The reaction with $NaHSO_3$ followed by dilute HCl results in the formation of a cyanohydrin. The CN^- ion from NaCN attacks the carbonyl carbon, and the oxygen picks up a proton. The major product A is 2-hydroxy-2-methylbutanenitrile.

Reduction with $LiAlH_4$ (Formation of B)

Lithium aluminum hydride ($LiAlH_4$) is a strong reducing agent. It reduces the nitrile group (CN) to an amine group (NH_2). The product B is 1-amino-2-methylbutan-2-ol.

Hydrolysis with HCl/H_2O and Heat (Formation of C)

The amine group in B is hydrolyzed with HCl/H_2O and heat (Δ) into carboxylic group. The major product C is 2-hydroxy-2-methylbutanoic acid.

Conclusion: The structures of A, B, and C correspond to **option (4)**.

Quick Tip

Pay attention to the reagents and reaction conditions to identify the type of reaction occurring in each step. $LiAlH_4$ is a strong reducing agent, commonly used to reduce nitriles to amines.

13: Given below are two statements : one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : Cu^{2+} in water is more stable than $Cu+$.

Reason (R) : Enthalpy of hydration for Cu^{2+} is much less than that of $Cu+$.

In the light of the above statements, choose the **correct** answer from the options given below : (1) Both (A) and (R) are correct and (R) is the correct explanation of (A).

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

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

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

Correct Answer: **(1)** Both (A) and (R) are correct and (R) is the correct explanation of (A).

Solution:

Analyze Assertion (A)

Cu^{2+} is more stable than Cu^+ in aqueous solution. This is due to the higher hydration enthalpy of Cu^{2+} compared to Cu^+. The hydration enthalpy compensates for the second ionization energy of copper, making Cu^{2+} more stable in an aqueous medium. Thus, Assertion (A) is **correct**.

Analyze Reason (R)

The enthalpy of hydration is the energy released when one mole of gaseous ions is dissolved in water. The hydration enthalpy is directly proportional to the charge density of the ion.

Since Cu^{2+} has a smaller ionic radius and a greater charge than Cu^{+}, its charge density is higher. Consequently, the enthalpy of hydration for Cu^{2+} is much more negative than that of Cu^{+}. Thus, Reason (R) is **correct**.

Conclusion: Both (A) and (R) are correct and (R) is the correct explanation of (A). **option (1)**.

Quick Tip

The stability of ions in aqueous solutions is determined by hydration enthalpy. Higher hydration enthalpy leads to greater stability. Hydration enthalpy is proportional to charge density.

14: The starting material for convenient preparation of deuterated hydrogen peroxide (D_2O_2) in laboratory is:

(1) $K_2S_2O_8$

(2) 2-ethylanthraquinol

(3) BaO_2

(4) BaO

Correct Answer: (1) $K_2S_2O_8$

Solution:

Deuterated hydrogen peroxide (D_2O_2) can be conveniently prepared in the laboratory by reacting $K_2S_2O_8$ with deuterated sulfuric acid (D_2SO_4) in D_2O(heavy water). This method allows for the direct incorporation of deuterium into the hydrogen peroxide molecule.

Conclusion: $K_2S_2O_8$ is the starting material for convenient preparation of D_2O_2 (**Option 1**).

Quick Tip

Remember that deuterated compounds are those where hydrogen atoms are replaced by deuterium (heavy hydrogen) isotopes. $K_2S_2O_8$ is commonly used in the preparation of peroxides.

15: In figure, a straight line is given for Freundrich Adsorption ($y = 3x + 2.505$). The value of $\frac{1}{n}$ and log K are respectively.

[scale=0.6] [-¿] (0,0) – (4,0) node[below] log P; [-¿] (0,0) – (0,4) node[left] $\log\frac{x}{m}$; (0,1) – (3,3); [¡-¿] (0.2,0) – (0.2,1) node[midway, right] log K; [¡-¿] (3,1.2) – (3,3) node[midway, left] 1; [¡-¿] (1.5,1.5) – (3,1.5) node[midway, below] $\frac{1}{n}$; at (4,-0.3) X; at (0,4.3) Y;

(1) 0.3 and log 2.505

(2) 0.3 and 0.7033

(3) 3 and 2.505

(4) 3 and 0.7033

Correct Answer: (3) 3 and 2.505

Solution:

Recall the Freundlich Adsorption Isotherm

The Freundlich adsorption isotherm is given by:

$$\frac{x}{m} = KP^{\frac{1}{n}}$$

where x is the mass of adsorbate, m is the mass of adsorbent, P is the pressure, K is the Freundlich constant, and n is a constant.

Linearize the Equation

Taking the logarithm of both sides, we get:

$$\log\frac{x}{m} = \log K + \frac{1}{n}\log P$$

This equation represents a straight line with slope $\frac{1}{n}$ and y-intercept log K.

Compare with the Given Equation

The given equation is $y = 3x + 2.505$, where $y = \log \frac{x}{m}$ and $x = \log P$. Comparing this with the linearized Freundlich equation, we have:

$$\frac{1}{n} = 3$$

$$\log K = 2.505$$

Conclusion: The value of $\frac{1}{n}$ is 3, and log K is 2.505 (**Option 3**).

Quick Tip

Linearizing the Freundlich adsorption isotherm equation by taking the logarithm helps determine the values of $\frac{1}{n}$ and K from the slope and intercept of the graph.

16: Given below are two statements : one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : An aqueous solution of KOH when for volumetric analysis, its concentration should be checked before the use.

Reason (R) : On aging, KOH solution absorbs atmospheric CO_2.

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

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

(2) Both (A) and (R) are correct but (R) is not the correct explanation of (A)

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

(4) (A) is correct but (R) is not correct

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

Solution:

Analyze Assertion (A)

In volumetric analysis, the concentration of the solutions used must be known accurately. KOH solutions are commonly used as titrants in acid-base titrations. The concentration of a KOH solution can change over time due to various factors. Therefore, it's crucial to check and standardize its concentration before use. Assertion (A) is **correct**.

Analyze Reason (R)

KOH solutions absorb atmospheric carbon dioxide (CO_2). The reaction between KOH and CO_2 forms potassium carbonate (K_2CO_3) and water:

$$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$$

This reaction consumes KOH, reducing its concentration in the solution. Hence, Reason (R) is **correct**.

Analyze the Relationship between (A) and (R)

The absorption of atmospheric CO_2 by KOH solution directly affects its concentration. This is the primary reason why the concentration of a KOH solution needs to be checked before use, especially if it's an older solution. Thus, Reason (R) is the correct explanation for Assertion (A).

Conclusion: Both (A) and (R) are correct, and (R) is the correct explanation for (A). The correct answer is **(3)**.

> **Quick Tip**
>
> Understanding the reactivity of common reagents and their potential reactions with atmospheric gases is essential in volumetric analysis. KOH solutions should be standardized regularly.

17: Which one of the following sets of ions represents a collection of isoelectronic species? (Given : Atomic Number : F :9, Cl : 17, Na = 11, Mg = 12, Al = 13, K = 19, Ca = 20, Sc = 21)

(1) ($Li+$, $Na+$, Mg^{2+}, Ca^{2+})

(2) (Ba^{2+}, Sr^{2+}, $K+$, Ca^{2+})

(3) (N^{3-}, O^{2-}, $F-$, S^{2-})

(4) (K^+, Cl^-, Ca^{2+}, Sc^{3+})

Correct Answer: (4) (K^+, Cl^-, Ca^{2+}, Sc^{3+})

Solution:

Understand Isoelectronic Species

Isoelectronic species are atoms or ions that have the same number of electrons.

Calculate the Number of Electrons in Each Ion

(1) $Li+$(2 electrons), $Na+$(10 electrons), Mg^{2+}(10 electrons), Ca^{2+}(18 electrons)

(2) Ba^{2+}(54 electrons), Sr^{2+}(36 electrons), $K+$(18 electrons), Ca^{2+}(18 electrons)

(3) N^{3-}(10 electrons), O^{2-}(10 electrons), $F-$(10 electrons), S^{2-}(18 electrons)

(4) $K+$(18 electrons), $Cl-$(18 electrons), Ca^{2+}(18 electrons), Sc^{3+}(18 electrons)

Conclusion: The set of ions in option (4) ($K+$, $Cl-$, Ca^{2+}, Sc^{3+}) all have 18 electrons and are therefore isoelectronic.

Quick Tip

For isoelectronic species, the number of electrons should be the same. Calculate the number of electrons for each ion by considering the atomic number and the charge.

18: The effect of addition of helium gas to the following reaction in equilibrium state, is :

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

(1) the equilibrium will shift in the forward direction and more of Cl_2 and PCl_3 gases will be produced.

(2) the equilibrium will go backward due to suppression of dissociation of PCl_5.

(3) helium will deactivate PCl_5 and reaction will stop.

(4) addition of helium will not affect the equilibrium.

Correct Answer: (1) & (4)

Solution:

Adding an inert gas like helium at constant volume does not affect the equilibrium position. This is because the partial pressures of the reactants and products remain unchanged. However, if helium is added at constant pressure, the volume of the system will increase.

This decrease in concentration affects all gaseous products equally and therefore it shifts the equilibrium towards the side with more gas molecules, according to Le Chatelier's principle. In this case, that is the forward direction, producing more Cl_2 and PCl_3.

Conclusion: Since the question does not specify if it was done at constant volume or constant pressure, the answer will be both **(1) and (4)**.

> **Quick Tip**
> Adding an inert gas at constant volume doesn't affect the equilibrium. At constant pressure, the equilibrium shifts towards the side with more gas molecules.

19: For electron gain enthalpies of the elements denoted as $\Delta_{eg}H$, the incorrect option is :

(1) $\Delta_{eg}H$ (Cl) $<$ $\Delta_{eg}H$ (F)
(2) $\Delta_{eg}H$ (Se) $<$ $\Delta_{eg}H$ (S)
(3) $\Delta_{eg}H$ (I) $<$ $\Delta_{eg}H$ (At)
(4) $\Delta_{eg}H$ (Te) $<$ $\Delta_{eg}H$ (Po)

Correct Answer: **(2)** $\Delta_{eg}H$ (Se) $<$ $\Delta_{eg}H$ (S)

Solution:
Electron Gain Enthalpy Trend
Electron gain enthalpy generally becomes less negative (less exothermic) down a group due to increasing atomic size. However, there can be exceptions due to factors like electron-electron repulsion and shielding effects. Fluorine has a smaller atomic size and therefore greater electron density and experiences inter electronic repulsions more than chlorine and hence its magnitude is smaller than that of Cl.
Analyzing the Options
(1) Cl $>$ F (Correct, due to small size and inter electronic repulsions of F) (2) S $>$ Se (Incorrect, electron gain enthalpy becomes less negative down the group; therefore, S should have a more negative electron gain enthalpy than Se. This is an exception). (3) At $>$ I

(Correct) (4) Po > Te (Correct)

Conclusion: The incorrect option is **(2)**.

> **Quick Tip**
>
> Remember the general trend of electron gain enthalpy down a group. Be aware of exceptions, particularly between the second and third periods.

20: O-O bond length in H_2O_2 is _X_ than the O-O bond length in F_2O_2. The O – H bond length in H_2O_2 is ___Y__ than that of the O-F bond in F_2O_2. Choose the correct option for _X_ and _Y_ from the given below.

(1) X – shorter, Y – shorter

(2) X – shorter, Y – longer

(3) X – longer, Y – longer

(4) X – longer, Y – shorter

Correct Answer: (4) X – longer, Y – shorter

Solution:

Analyze the O-O bond length

In H_2O_2, the oxygen atoms are bonded to hydrogen atoms. In F_2O_2, the oxygen atoms are bonded to fluorine atoms. Fluorine is more electronegative than hydrogen. The higher electronegativity of fluorine in F_2O_2 leads to a greater pull of electron density towards the fluorine atoms, which weakens the O-O bond and increases its bond length. Therefore, the O-O bond length in H_2O_2 is **longer** than in F_2O_2. So, X is longer.

Analyze the O-H and O-F bond lengths

The O-H bond is formed between oxygen and hydrogen, while the O-F bond is formed between oxygen and fluorine. Fluorine has a smaller atomic radius than hydrogen. Also, oxygen and fluorine have much closer electronegativities, leading to a shorter O-F bond compared to the O-H bond where there's a larger electronegativity difference. Therefore, the O-H bond length in H_2O_2 is **shorter** than the O-F bond length in F_2O_2. So, Y is shorter.

Conclusion: The O-O bond length in H_2O_2 is longer than in F_2O_2, and the O-H bond length is shorter than the O-F bond length. This corresponds to **option (4)**.

Quick Tip

Electronegativity and atomic size influence bond lengths. Higher electronegativity differences lead to shorter bonds, and smaller atomic radii also contribute to shorter bond lengths.

Section B

21: 0.3 g of ethane undergoes combustion at 27°C in a bomb calorimeter. The temperature of calorimeter system (including the water) is found to rise by 0.5°C. The heat evolved during combustion of ethane at constant pressure is _____ kJ mol^{-1}. (Nearest integer)
[Given : The heat capacity of the calorimeter system is 20 kJ K^{-1}, R = 8.3 JK^{-1} mol^{-1}. Assume ideal gas behaviour. Atomic mass of C and H are 12 and 1 g mol^{-1} respectively]

Correct Answer: (1006)

Solution:
The balanced chemical equation for the combustion of ethane is:

$$C_2H_6(g) + \frac{7}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

Heat evolved at constant volume (q_v): The heat absorbed by the calorimeter is given by:

$$q_v = C\Delta T$$

Where C is the heat capacity of the calorimeter system and ΔT is the temperature change.

$$q_v = 20\,\text{kJ K}^{-1} \times 0.5\,\text{K} = 10\,\text{kJ}$$

Since the combustion is exothermic, the heat evolved is -10 kJ. This is for 0.3 g of ethane.
Moles of ethane: Molar mass of ethane (C_2H_6) = $2 \times 12 + 6 \times 1 = 30\,\text{g mol}^{-1}$

Moles of ethane = $\frac{\text{mass}}{\text{molar mass}} = \frac{0.3\,\text{g}}{30\,\text{g mol}^{-1}} = 0.01\,\text{mol}$

Heat evolved per mole at constant volume (ΔU):

$$\Delta U = \frac{-10\,\text{kJ}}{0.01\,\text{mol}} = -1000\,\text{kJ mol}^{-1}$$

Heat evolved at constant pressure (ΔH): For the given reaction, the change in the number of gaseous moles is:

$$\Delta n_g = n_{\text{products}} - n_{\text{reactants}} = (2) - (1 + \frac{7}{2}) = -2.5$$

The relationship between ΔH and ΔU is:

$$\Delta H = \Delta U + \Delta n_g RT$$

$$\Delta H = -1000\,\text{kJ mol}^{-1} + (-2.5) \times 8.3 \times 10^{-3}\,\text{kJ K}^{-1}\text{mol}^{-1} \times 300\,\text{K}$$

$$\Delta H = -1000 - 6.225 = -1006.225\,\text{kJ mol}^{-1}$$

The nearest integer is -1006 kJ/mol.

Quick Tip

Remember the relationship between ΔH and ΔU: $\Delta H = \Delta U + \Delta n_g RT$. Be careful with units and conversions. Also, be aware of the sign conventions for heat evolved or absorbed. Double-check the balanced chemical equation, as different stoichiometric coefficients will impact the Δn_g value.

22: Among following compounds, the number of those present in copper matte is ____________.

A. $CuCO_3$

B. Cu_2S

C. Cu_2O

D. FeO

Correct Answer: 1

Solution:

Copper matte is a molten mixture primarily composed of Cu_2S and FeS. It is an intermediate product in the smelting of copper ore. Of the given compounds, only Cu_2S is present in copper matte.

Conclusion: Only one of the listed compounds (Cu_2S) is present in copper matte.

> **Quick Tip**
>
> Remember the composition of copper matte. It is mainly Cu_2S and FeS.

23: Among the following, the number of tranquilizer/s is/are ____________.

A. Chlordiazepoxide

B. Veronal

C. Valium

D. Salvarsan

Correct Answer: 3

Solution:

Tranquilizers Tranquilizers are drugs used to treat anxiety and mental disorders. They work by depressing the central nervous system.

Analyzing the Given Compounds

Chlordiazepoxide: This is a benzodiazepine and is used as a tranquilizer.

Veronal: This is a barbiturate and acts as a sedative-hypnotic, not a tranquilizer.

Valium (Diazepam): This is also a benzodiazepine and is used as a tranquilizer.

Salvarsan: This is an organoarsenic compound historically used to treat syphilis, not a tranquilizer.

Conclusion: Three of the given compounds (Chlordiazepoxide, Valium) are tranquilizers.

Quick Tip

Know the classification and uses of different types of drugs. Tranquilizers are used to treat anxiety and mental disorders.

24: A $\rightarrow$ B

The above reaction is of zero order. Half life of this reaction is 50 min. The time taken for the concentration of A to reduce to one-fourth of its initial value is ____ min. (Nearest integer)

Correct Answer: (75)

Solution:

For a zero-order reaction, the integrated rate law is given by:

$$[A]_t = [A]_0 - kt$$

where $[A]_t$ is the concentration of A at time t, $[A]_0$ is the initial concentration of A, and k is the rate constant.

The half-life ($t_{1/2}$) of a zero-order reaction is given by:

$$t_{1/2} = \frac{[A]_0}{2k}$$

Given that $t_{1/2}$ = 50 min, we can find the rate constant k:

$$k = \frac{[A]_0}{2 \times t_{1/2}} = \frac{[A]_0}{2 \times 50} = \frac{[A]_0}{100}$$

We are asked to find the time taken for the concentration of A to reduce to one-fourth of its initial value. Let this time be t. So, $[A]_t = \frac{[A]_0}{4}$. Substituting this into the integrated rate law:

$$\frac{[A]_0}{4} = [A]_0 - kt$$

$$\frac{3[A]_0}{4} = kt$$

Substituting the value of k we found earlier:

$$\frac{3[A]_0}{4} = \frac{[A]_0}{100} \times t$$

$$t = \frac{3[A]_0}{4} \times \frac{100}{[A]_0} = 3 \times 25 = 75 \text{ min}$$

Quick Tip

For zero-order reactions, the half-life is directly proportional to the initial concentration. Remember the integrated rate law and the half-life formula for zero-order reactions.

25: 20% of acetic acid is dissociated when its 5 g is added to 500 mL of water. The depression in freezing point of such water is ____ $\times 10^{-3}\,°C$. Atomic mass of C, H and O are 12, 1 and 16 a.m.u. respectively.
[Given : Molal depression constant and density of water are 1.86 K kg mol^{-1} and 1 g cm^{-3} respectively.]

Correct Answer: (372)

Solution:
Moles of acetic acid: Molar mass of acetic acid (CH_3COOH) =
$2 \times 12 + 4 \times 1 + 2 \times 16 = 60\,\text{g/mol}$
Moles of acetic acid = $\frac{5\,\text{g}}{60\,\text{g/mol}} = \frac{1}{12}$ mol
Molality of acetic acid: Mass of water = Volume × Density = 500 mL × 1 g/mL = 500 g = 0.5 kg
Molality (m) = $\frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{1/12\,\text{mol}}{0.5\,\text{kg}} = \frac{1}{6}$ mol/kg
van't Hoff factor (i):
Acetic acid dissociates as follows:
$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$
Since 20% of acetic acid dissociates, the degree of dissociation (α) = 0.2 For dissociation, $i = 1 + \alpha(n-1)$, where n is the number of particles formed after dissociation. Here, n = 2.
$i = 1 + 0.2(2-1) = 1 + 0.2 = 1.2$
Depression in freezing point (ΔT_f):
$\Delta T_f = iK_f m$ where K_f is the molal depression constant.
$\Delta T_f = 1.2 \times 1.86\,\text{K kg mol}^{-1} \times \frac{1}{6}\,\text{mol/kg} = 0.372\,\text{K}$

Since the change in temperature in Kelvin and Celsius are the same,

$\Delta T_f = 0.372\,°C = 372 \times 10^{-3}\,°C$

Quick Tip

Remember the formula for freezing point depression and how to calculate the van't Hoff factor for weak electrolytes. Pay attention to units and ensure they are consistent throughout the calculation.

26: The molality of a 10% (v/v) solution of di-bromine solution in CCl_4 (carbon tetrachloride) is 'x'. x = ____ $\times 10^{-2}$ M. (Nearest integer)

Given:

- Molar mass of Br_2 = 160 g mol^{-1}
- Atomic mass of C = 12 g mol^{-1}
- Atomic mass of Cl = 35.5 g mol^{-1}
- Density of dibromine = 3.2 g cm^{-3}
- Density of CCl_4 = 1.6 g cm^{-3}

Correct Answer: (139)

Solution:

Let's assume we have 100 mL of the solution. Since it's a 10% v/v solution, the volume of Br_2 is 10 mL and the volume of CCl_4 is 90 mL.

Mass of Br_2 = Volume × Density = 10 mL × 3.2 g/mL = 32 g

Moles of Br_2 = Mass / Molar Mass = 32 g / 160 g/mol = 0.2 mol

Mass of CCl_4 = Volume × Density = 90 mL × 1.6 g/mL = 144 g

Molar mass of CCl_4 = 12 + (4 × 35.5) = 12 + 142 = 154 g/mol

Molality (m) = Moles of solute / Mass of solvent (in kg)

m = 0.2 mol / (144 g / 1000 g/kg) = 0.2 mol / 0.144 kg = 1.3888... mol/kg

m $\approx$ 1.39 mol/kg

Therefore, x = 139.

Quick Tip

Remember the formula for molality: Molality (m) = Moles of solute / Mass of solvent (in kg). Pay close attention to the units provided and required for the final answer. A v/v percentage means volume of solute per volume of solution.

27: 1 $\times 10^{-5}$ M $AgNO_3$ is added to 1 L of saturated solution of AgBr. The conductivity of this solution at 298 K is ____ $\times 10^{-8}$ S m^{-1}.

Given:

- K_{sp}(AgBr) = 4.9 $\times 10^{-13}$ at 298K
- $\lambda^0_{Ag^+}$ = 6 $\times 10^{-3}$ Sm^2 mol^{-1}
- $\lambda^0_{Br^-}$ = 8 $\times 10^{-3}$ Sm^2 mol^{-1}
- $\lambda^0_{NO_3^-}$ = 7 $\times 10^{-3}$ Sm^2 mol^{-1}

Correct Answer: (14)

Solution:

AgBr(s) $\rightleftharpoons$ Ag^+(aq) + Br^-(aq)

K_{sp} = $[Ag^+][Br^-]$ = 4.9×10^{-13}

Let the solubility of AgBr be 's' mol/L. Then, $[Ag^+]$ = s and $[Br^-]$ = s.

$s^2 = 4.9 \times 10^{-13}$ $s = \sqrt{4.9 \times 10^{-13}} = 7 \times 10^{-7}$ M

Since 1 L of saturated AgBr solution is taken, the concentration of Ag^+ and Br^- from AgBr are both 7×10^{-7} M. We are adding 1×10^{-5} M $AgNO_3$.

The Ag^+ from $AgNO_3$ will be significantly greater than the Ag^+ from AgBr, so we can approximate the total $[Ag^+]$ as 1×10^{-5} M.

The common ion effect will suppress the solubility of AgBr, so the $[Br^-]$ remains approximately 7×10^{-7} M. The $[NO_3^-]$ will be 1×10^{-5} M.

Conductivity (κ) = $\sum \lambda_i c_i$

$\kappa = \lambda_{Ag^+}[Ag^+] + \lambda_{Br^-}[Br^-] + \lambda_{NO_3^-}[NO_3^-]$

$\kappa = (6 \times 10^{-3}(1 \times 10^{-5}) + (8 \times 10^{-3}(7 \times 10^{-7}) + (7 \times 10^{-3}(1 \times 10^{-5})$

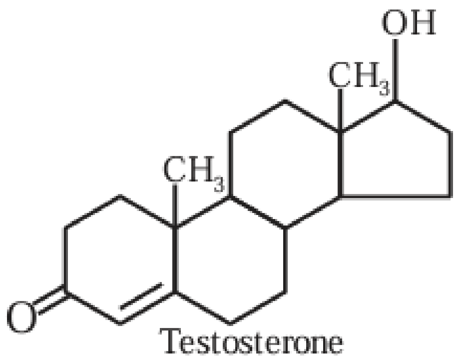
$\kappa = 6 \times 10^{-8} + 5.6 \times 10^{-9} + 7 \times 10^{-8}$

$\kappa \approx 13.56 \times 10^{-8} \approx 14 \times 10^{-8}$ Sm^{-1}

Quick Tip

Remember the relationship between conductivity, molar conductivity, and concentration: $\kappa = \sum \lambda_i c_i$. Also, be mindful of the common ion effect when dealing with solubility equilibria.

28: Testosterone, which is a steroidal hormone, has the following structure.



Testosterone

The total number of asymmetric carbon atom/s in testosterone is ______

Correct Answer: (6)

Solution:

An asymmetric carbon atom (chiral center) is a carbon atom that is bonded to four different groups. Let's examine the structure of testosterone:

Looking at the structure, we can identify the carbon atoms that have four different groups attached. These are chiral centers.

1. The carbon atom at the junction of the six-membered ring with the ketone group (C=O) and the five-membered ring.

2. The carbon atom in the five-membered ring attached to the methyl group (CH3) and the hydroxyl group (OH).

3. The carbon atom at the top of the other six-membered ring that forms a bridge.

4. The carbon atom at the bottom of the other six-membered ring that forms a bridge.

5. The carbon atom at the top of the six-membered ring with the double bond.

6. The carbon atom at the bottom of the six-membered ring with the double bond.

Therefore, there are a total of six asymmetric carbon atoms in testosterone.

Quick Tip

To identify a chiral carbon, check if it's bonded to four different groups. Careful examination of the molecule's 3D structure is often necessary.

29: The spin only magnetic moment of [Mn(H_2O)$_6$]$^{2+}$ complexes is ____ B.M. (Nearest integer)

Given: Atomic no. of Mn is 25

Correct Answer: (6)

Solution:

The electronic configuration of Mn is [Ar] $3d^5$ $4s^2$.

In [Mn(H_2O)$_6$]$^{2+}$, Mn is in +2 oxidation state. Water is a weak field ligand.

Electronic configuration of Mn^{2+} is [Ar] $3d^5$.

Since H_2O is a weak field ligand, there will be no pairing of electrons in the d orbitals.

Number of unpaired electrons (n) = 5

Spin only magnetic moment (μ_{spin}) = $\sqrt{n(n+2)}$ B.M. μ_{spin} = $\sqrt{5(5+2)}$ = $\sqrt{35} \approx 5.92$ B.M.

Nearest integer is 6.

Quick Tip

Remember the formula for spin-only magnetic moment: $\mu_{spin} = \sqrt{n(n+2)}$ B.M., where n is the number of unpaired electrons. The strength of the ligand determines the pairing of d-electrons.

30: A metal M crystallizes into two lattices: face centred cubic (fcc) and body centred cubic (bcc) with unit cell edge length of 2.0 and 2.5 $\mathring{A}$ respectively. The ratio of densities of lattices fcc to bcc for the metal M is ______. (Nearest integer)

Correct Answer: (4)

Solution:

Density (ρ) = $\frac{Z \times M}{N_A \times a^3}$

where Z = number of atoms per unit cell, M = molar mass, N_A = Avogadro's number, a = edge length

For fcc, Z = 4, a = 2.0 $\mathring{A}$ = 2.0 × 10^{-10} m

For bcc, Z = 2, a = 2.5 $\mathring{A}$ = 2.5 × 10^{-10} m

Let M be the molar mass of the metal M. Then the density for fcc is:

$\rho_{fcc} = \frac{4M}{N_A(2 \times 10^{-10})^3}$

And for bcc is:

$\rho_{bcc} = \frac{2M}{N_A(2.5 \times 10^{-10})^3}$

The ratio of densities is:

$\frac{\rho_{fcc}}{\rho_{bcc}} = \frac{\frac{4M}{N_A(2 \times 10^{-10})^3}}{\frac{2M}{N_A(2.5 \times 10^{-10})^3}} = \frac{4}{2} \times \frac{(2.5 \times 10^{-10})^3}{(2 \times 10^{-10})^3} = 2 \times \left(\frac{2.5}{2}\right)^3 = 2 \times \left(\frac{5}{4}\right)^3 = 2 \times \frac{125}{64} = \frac{125}{32} \approx 3.9$

Nearest integer is 4.

Quick Tip

Remember the formula for density in crystallography: $\rho = \frac{Z \times M}{N_A \times a^3}$. For fcc, Z=4; for bcc, Z=2. Pay close attention to units.
