KIITEE Chemistry Sample Paper – 12

Duration: 50 Minutes **Maximum Marks: 160**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct Answer), modelled on the Chemistry portion of **KIITEE** entrance.
- Each correct answer carries **+4 marks**. There is −1 **mark per wrong answer;** unattempted questions score **0**
- Only **one** option is correct. Choose carefully.
- Syllabus level: **Class 11 & 12 (10+2) Chemistry — Organic Chemistry, Physical Chemistry,Inorganic Chemistry and Environmental Chemistry, Polymers & Biomolecules**
- The test is computer based. Personal calculators, log tables, mobile phones, and other electronic gadgets are strictly prohibited.

Q1. An organic compound contains 40% carbon, 6.67% hydrogen, and the rest is oxygen. If the vapor density of the compound is 30, what is its molecular formula?

(A) CH_2O

(B) $C_2H_4O_2$

(C) $C_3H_6O_3$

(D) C_2H_6O

Q2. Which of the following sets of quantum numbers represents the highest energy orbital for a multi-electron atom?

(A) $n = 4, l = 0, m_l = 0, m_s = +\frac{1}{2}$

(B) $n = 3, l = 2, m_l = 1, m_s = -\frac{1}{2}$

(C) $n = 3, l = 1, m_l = -1, m_s = +\frac{1}{2}$

(D) $n = 4, l = 1, m_l = 0, m_s = -\frac{1}{2}$

Q3. For the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, what is the relationship between ΔH and ΔU at a constant temperature T?

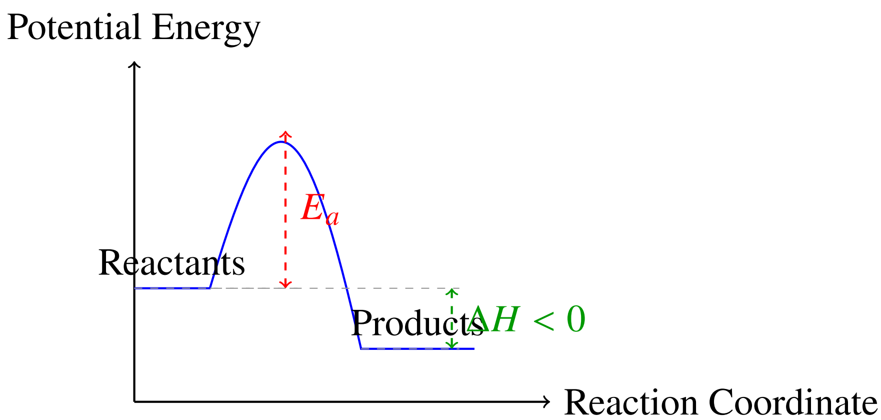
(A) $\Delta H = \Delta U - RT$

(B) $\Delta H = \Delta U + 2RT$

(C) $\Delta H = \Delta U - 2RT$

(D) $\Delta H = \Delta U + RT$

Q4. In a stable chemical equilibrium for the exothermic reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, which of the following changes will increase the yield of SO_3?



(A) Increasing the temperature

(B) Decreasing the total pressure

(C) Adding an inert gas at constant volume

(D) Decreasing the temperature

Q5. During the electrolysis of dilute aqueous H_2SO_4 using inert platinum electrodes, the product liberated at the anode is:

(A) H_2 gas

(B) O_2 gas

(C) SO_2 gas

(D) SO_3 gas

Q6. For a first-order reaction, the time required for 75% completion is how many times the half-life ($t_{1/2}$) of the reaction?

(A) 1.5 times

(B) 2.0 times

(C) 3.0 times

(D) 4.0 times

Q7. What is the van 't Hoff factor (i) for a dilute aqueous solution of $K_4[Fe(CN)_6]$ assuming complete 100% dissociation?

(A) 4

(B) 5

(C) 6

(D) 3

Q8. Arrange the following carbocations in the decreasing order of their stability:

(I) $(CH_3)_3C^+$

(II) $(CH_3)_2CH^+$

(III) $CH_3CH_2^+$

(IV) CH_3^+

(A) I > II > III > IV

(B) IV > III > II > I

(C) I > III > II > IV

(D) III > II > I > IV

Q9. Ozonolysis of 2-methylbut-2-ene followed by treatment with Zn/H_2O yields:

(A) Propanone and Ethanal

(B) Propanal and Ethanal

(C) Two molecules of Ethanal

(D) Two molecules of Propanone

Q10. When bromobenzene is treated with magnesium metal in dry ether, followed by reaction with water, the final product obtained is:

(A) Phenol

(B) Benzene

(C) Diphenyl

(D) Benzene sulfonic acid

Q11. Which of the following reagents is most suitable to distinguish between Benzyl alcohol and Phenol?

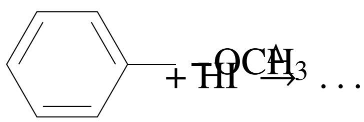
(A) Neutral $FeCl_3$ solution

(B) Aqueous $NaHCO_3$

(C) Brine solution

(D) Tollen's reagent

Q12. The major organic product formed in the reaction of anisole with HI at high temperature is:



(A) Iodobenzene and Methanol

(B) Phenol and Iodomethane

(C) Iodobenzene and Iodomethane

(D) Phenol and Methanol

Q13. Which of the following compounds will undergo the Cannizzaro reaction when treated with concentrated NaOH solution?

(A) Ethanal

(B) Propanal

(C) Benzaldehyde

(D) Acetophenone

Q14. The correct decreasing order of basic strength of the following amines in aqueous solution is:

(A) $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$

(B) $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$

(C) $CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N > NH_3$

(D) $(CH_3)_2NH > (CH_3)_3N > CH_3NH_2 > NH_3$

Q15. Which of the following statements about DNA is correct?

(A) It contains the sugar ribose.

(B) Uracil is one of its nitrogenous bases.

(C) Adenine pairs with Thymine via two hydrogen bonds.

(D) Guanine pairs with Cytosine via two hydrogen bonds.

Q16. Which of the following elements has the highest negative electron gain enthalpy?

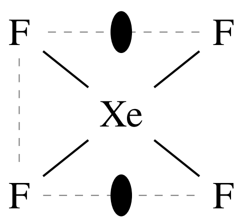
(A) Fluorine

(B) Chlorine

(C) Bromine

(D) Iodine

Q17. According to VSEPR theory, the geometry and shape of XeF_4 molecule are respectively:



(A) Octahedral, Square planar

(B) Square planar, Octahedral

(C) Tetrahedral, Tetrahedral

(D) See-saw, Trigonal bipyramidal

Q18. The correct increasing order of density for alkali metals is:

(A) Li < Na < K < Rb < Cs

(B) Li < K < Na < Rb < Cs

(C) Cs < Rb < K < Na < Li

(D) K < Li < Na < Rb < Cs

Q19. Which of the following oxides is amphoteric in nature?

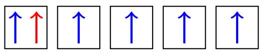
(A) CO_2

(B) Al_2O_3

(C) CaO

(D) SO_2

Q20. The spin-only magnetic moment of Fe^{2+} ion ($Z = 26$) is approximately:



3*d* orbitals

(A) 4.90 BM

(B) 5.92 BM

(C) 3.87 BM

(D) 2.84 BM

Q21. The IUPAC name of the coordination compound $[Co(NH_3)_5(CO_3)]Cl$ is:

(A) Pentaaminecarbonatocobalt(III) chloride

(B) Carbonatopentaaminecobalt(III) chloride

(C) Pentaaminecarbonatocobaltate(III) chloride

(D) Pentaaminecarboxylatocobalt(II) chloride

Q22. Which of the following is a condensation polymer?

(A) Polyethylene

(B) PVC

(C) Nylon-6,6

(D) Teflon

Q23. Which of the following chemical substances functions as a broad-spectrum antibiotic?

(A) Paracetamol

(B) Chloramphenicol

(C) Aspirin

(D) Penicillin G

Q24. Which of the following processes is responsible for the phenomenon of photochemical smog?

(A) High concentration of SO_2 and humidity in cold climates

(B) Action of sunlight on unsaturated hydrocarbons and nitrogen oxides

(C) Release of chlorofluorocarbons into the stratosphere

(D) Excessive accumulation of CO_2 gas trapping infrared radiation

Q25. How many grams of NaOH are required to prepare 250 mL of a 0.1 M aqueous solution?

(A) 4.0 g

(B) 2.0 g

(C) 1.0 g

(D) 0.4 g

Q26. If the radius of the first Bohr orbit of hydrogen atom is r, the radius of the third Bohr orbit will be:

(A) $3r$

(B) $9r$

(C) $\frac{r}{3}$

(D) $\frac{r}{9}$

Q27. The total entropy change (ΔS_{total}) for a spontaneous process occurring in an isolated system is always:

(A) Zero

(B) Negative

(C) Positive

(D) Equal to $\Delta S_{surroundings}$

Q28. The solubility product (K_{sp}) of a sparingly soluble salt AB_2 is 4×10^{-12}. Its molar solubility in pure water is:

(A) 1×10^{-4} M

(B) 2×10^{-4} M

(C) 1×10^{-6} M

(D) 4×10^{-4} M

Q29. The standard reduction potentials of three metals A, B, and C are +0.5 V, −1.2 V, and −0.4 V respectively. The reducing power of these metals follows the order:

(A) A > C > B

(B) B > C > A

(C) C > B > A

(D) B > A > C

Q30. If the rate constant of a reaction doubles when the temperature is raised from 300 K to 310 K, the activation energy (E_a) of the reaction is closest to: (R = 8.314 J mol^{-1} K^{-1}, $\ln 2 = 0.693$)

(A) 53.6 kJ mol^{-1}

(B) 23.4 kJ mol^{-1}

(C) 102.5 kJ mol^{-1}

(D) 12.3 kJ mol^{-1}

Q31. Which of the following isomeric liquid alkanes has the highest boiling point?

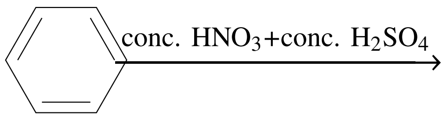
(A) n-pentane

(B) Isopentane

(C) Neopentane

(D) They all have the same boiling point

Q32. Nitration of benzene using a mixture of concentrated HNO_3 and concentrated H_2SO_4 involves the generation of which active electrophile?



(A) NO^+

(B) NO_2^+

(C) NO_2^-

(D) HNO_3

Q33. Which of the following alkyl halides undergoes S_N1 hydrolysis at the fastest rate?

(A) CH_3CH_2Cl

(B) $(CH_3)_2CHCl$

(C) $(CH_3)_3CCl$

(D) CH_3Cl

Q34. Phenol reacts with chloroform in the presence of aqueous sodium hydroxide to form salicylaldehyde as the major product. This organic reaction is named:

(A) Reimer-Tiemann reaction

(B) Kolbe's reaction

(C) Williamson synthesis

(D) Friedel-Crafts acylation

Q35. The reduction of a carbonyl group ($> C = O$) to a methylene group ($-CH_2-$) using zinc amalgam ($Zn - Hg$) and concentrated hydrochloric acid is known as:

(A) Wolff-Kishner reduction

(B) Clemmensen reduction

(C) Rosenmund reduction

(D) Stephen reduction

Q36. Gabriel phthalimide synthesis is exclusively used for the preparation of which class of amines?

(A) Primary aliphatic amines

(B) Primary aromatic amines

(C) Secondary aliphatic amines

(D) Tertiary aliphatic amines

Q37. Which of the following carbohydrates is a non-reducing sugar?

(A) Maltose

(B) Lactose

(C) Sucrose

(D) Glucose

Q38. Among the following molecular species, which one is paramagnetic according to Molecular Orbital Theory?

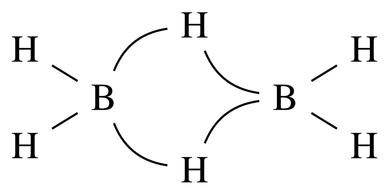
(A) N_2

(B) O_2

(C) C_2

(D) F_2

Q39. The structure of diborane (B_2H_6) contains:



(A) Four 2c – 2e bonds and two 3c – 2e bonds

(B) Two 2c – 2e bonds and four 3c – 2e bonds

(C) Six 2c – 2e bonds and zero 3c – 2e bonds

(D) Four 2c – 2e bonds and two 3c – 4e bonds

Q40. Which of the following pairs of transition metal complexes exhibit ionization isomerism?

(A) $[Co(NH_3)_5Br]SO_4$ and $[Co(NH_3)_5SO_4]Br$

(B) $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$

(C) $[Co(NH_3)_5(NO_2)]Cl_2$ and $[Co(NH_3)_5(ONO)]Cl_2$

(D) $[Pt(NH_3)_2Cl_2]$ cis and trans forms

Detailed Solutions

Q1.

Solution

Concept: The molecular formula of a compound can be determined by finding its empirical formula first from the percentage composition data, and then multiplying the empirical formula subscripts by a whole-number factor n. The molecular weight is related to the vapor density by the expression: Molecular Weight = 2 × Vapor Density.

Solution: Step 1: Write down the percentage composition of each element given in the problem.
Carbon (C) = 40%
Hydrogen (H) = 6.67%
Oxygen (O) = 100% − (40% + 6.67%) = 53.33%

Step 2: Calculate the relative number of moles of each atom by dividing the percentage by its respective atomic mass (C = 12, H = 1, O = 16).
Moles of C = $\frac{40}{12} = 3.33$
Moles of H = $\frac{6.67}{1} = 6.67$
Moles of O = $\frac{53.33}{16} = 3.33$

Step 3: Determine the simplest molar ratio by dividing each value obtained by the smallest value among them, which is 3.33.
Ratio for C = $\frac{3.33}{3.33} = 1$
Ratio for H = $\frac{6.67}{3.33} = 2$
Ratio for O = $\frac{3.33}{3.33} = 1$
Thus, the empirical formula of the compound is CH_2O.

Step 4: Calculate the empirical formula mass.
Empirical Formula Mass = $12 + (2 \times 1) + 16 = 30$ g mol^{-1}

Step 5: Determine the true molecular mass using the given vapor density.
Molecular Mass = $2 \times$ Vapor Density $= 2 \times 30 = 60$ g mol^{-1}

Step 6: Find the value of the scaling integer factor n.
$n = \frac{\text{Molecular Mass}}{\text{Empirical Formula Mass}} = \frac{60}{30} = 2$

Step 7: Multiply the empirical formula by n to establish the final molecular formula.
Molecular Formula = $2 \times (CH_2O) = C_2H_4O_2$

Final Answer: $C_2H_4O_2$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: In a multi-electron atom, the relative energy levels of different atomic orbitals are determined strictly by the $(n + l)$ rule, also widely recognized as Bohr-Bury's rule. According to this principle, an orbital with a higher value of $(n + l)$ possesses a higher energy level. If two distinct orbitals share the exact same value for $(n + l)$, the orbital possessing the larger principal quantum number (n) lies at a higher energy state.

Solution: Step 1: Analyze the given values of principal quantum number (n) and azimuthal quantum number (l) for each option to calculate their respective $(n + l)$ sum values.

Step 2: Evaluate Option (A):
$n = 4, l = 0 \implies (n + l) = 4 + 0 = 4$ (This designates a $4s$ orbital)

Step 3: Evaluate Option (B):
$n = 3, l = 2 \implies (n + l) = 3 + 2 = 5$ (This designates a $3d$ orbital)

Step 4: Evaluate Option (C):
$n = 3, l = 1 \implies (n + l) = 3 + 1 = 4$ (This designates a $3p$ orbital)

Step 5: Evaluate Option (D):
$n = 4, l = 1 \implies (n + l) = 4 + 1 = 5$ (This designates a $4p$ orbital)

Step 6: Compare the calculated total values. The options with the maximum sum of $(n + l) = 5$ are options (B) and (D).

Step 7: Resolve the tie between Option (B) and Option (D) by comparing their principal quantum numbers (n). Option (D) features $n = 4$, whereas Option (B) features $n = 3$. Because $4 > 3$, the $4p$ orbital represented by option (D) is higher in energy than the $3d$ orbital.

Final Answer: $\boxed{n = 4, l = 1, m_l = 0, m_s = -\frac{1}{2}}$

Answer: (D)

Go Back to Question 2

Q3.

Solution

Concept: The fundamental thermodynamic relationship linking the enthalpy change (ΔH) and the internal energy change (ΔU) for a chemical process involving ideal gas components at a constant thermodynamic absolute temperature T is governed by the relation:

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

where Δn_g represents the change in the number of moles of gaseous products minus gaseous reactants, and R is the universal gas constant.

Solution: Step 1: Write down the balanced chemical equation provided in the problem:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Step 2: Identify the stoichiometric coefficients of all gaseous components to determine the net change in gaseous moles (Δn_g).
Total moles of gaseous products = 2 (from $2NH_3$)
Total moles of gaseous reactants = 1 + 3 = 4 (from $1N_2$ and $3H_2$)

Step 3: Compute Δn_g explicitly using the formulation:

$$\Delta n_g = \sum n_{\text{products}} - \sum n_{\text{reactants}}$$

$$\Delta n_g = 2 - 4 = -2$$

Step 4: Substitute the value of $\Delta n_g = -2$ back into the foundational equation relating enthalpy and internal energy:

$$\Delta H = \Delta U + (-2)RT$$

$$\Delta H = \Delta U - 2RT$$

Step 5: Compare the finalized derived equation with the given multiple choice options to establish the correct match.

Final Answer: $\boxed{\Delta H = \Delta U - 2RT}$

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept: According to Le Chatelier's Principle, if a dynamic chemical equilibrium is subjected to a disturbance in temperature, pressure, or concentration, the system shifts its equilibrium position in a direction that counteracts the applied change. For an exothermic chemical reaction ($\Delta H < 0$), heat is evolved as a product. Lowering the system temperature shifts the equilibrium in the forward direction.

Solution: Step 1: Analyze the given chemical equation and its thermodynamic state:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad (\Delta H < 0)$$

The potential energy diagram highlights that products are at a lower energy state than reactants, validating that the reaction is highly exothermic.

Step 2: Assess the effect of temperature. Since the forward pathway releases heat energy, raising the temperature would favor the reverse process to absorb heat. Conversely, decreasing the operating temperature forces the reaction to shift forward, increasing the net production yield of SO_3.

Step 3: Analyze the effect of pressure. There are 3 moles of gas on the reactant side and 2 moles of gas on the product side. Decreasing total pressure shifts the equilibrium towards the side with more moles (backward), reducing the yield.

Step 4: Analyze the addition of an inert gas at constant volume. This does not change the partial pressures of the reacting components, meaning it has zero effect on the equilibrium yield.

Step 5: Conclude that lowering the thermal energy environment (decreasing the temperature) is the optimal stress that maximizes the forward shift.

Final Answer: Decreasing the temperature

Answer: (D)

Go Back to Question 4

Q5.

Solution

Concept: During aqueous electrolysis, competitive discharge of ions takes place at the electrode surfaces based on their standard oxidation or reduction potentials. At the positive electrode (anode), oxidation takes place, and the species with the lower discharge potential (higher ease of oxidation) loses electrons preferentially.

Solution: Step 1: Identify all ionic and molecular chemical species present in a dilute aqueous solution of sulfuric acid (H_2SO_4). The species available are H^+, SO_4^{2-}, and water molecules (H_2O).

Step 2: List the competing chemical species that can potentially migrate toward the positively charged anode for oxidation. These are the sulfate anions (SO_4^{2-}) and neutral solvent water molecules (H_2O).

Step 3: Compare the oxidation potentials or ease of discharge between these chemical candidates. Sulfate ions are exceptionally stable because sulfur is already in its maximum +6 oxidation state; hence, their discharge potential is significantly higher than that of water.

Step 4: Formulate the preferential anodic oxidation half-reaction for water molecules:

$$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$$

Step 5: Observe that gaseous oxygen (O_2) is liberated directly at the surface of the inert platinum anode as a direct consequence of this oxidation process.

Final Answer: O_2 gas

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: For a standard first-order chemical reaction, the rate of reaction depends linearly on a single reactant concentration. The time taken for a specific fractional completion can be derived from the integrated first-order rate law expression:

$$k = \frac{2.303}{t} \log\left(\frac{[A]_0}{[A]_t}\right)$$

The half-life period ($t_{1/2}$) is constant and independent of the initial concentration, given by $t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$.

Solution: Step 1: Express the concentration terms for 75% completion of the reaction. If the initial concentration is $[A]_0 = 100$, then the amount reacted is 75. The remaining concentration at time $t_{75\%}$ is:

$$[A]_t = 100 - 75 = 25$$

Step 2: Substitute these specific concentration values into the integrated first-order rate expression to isolate $t_{75\%}$:

$$t_{75\%} = \frac{2.303}{k} \log\left(\frac{100}{25}\right) = \frac{2.303}{k} \log(4)$$

Step 3: Simplify the expression by rewriting 4 as 2^2:

$$t_{75\%} = \frac{2.303}{k} \times 2\log(2) = 2 \times \left(\frac{2.303 \log 2}{k}\right)$$

Step 4: Recognize that the term inside the parentheses is exactly equivalent to the mathematical expression for the reaction's half-life ($t_{1/2}$):

$$t_{1/2} = \frac{2.303 \log 2}{k}$$

Step 5: Substitute this equivalence back into the simplified equation:

$$t_{75\%} = 2 \times t_{1/2}$$

Thus, it takes exactly 2.0 times the half-life period to achieve 75% completion.

Final Answer: 2.0 times

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: The van 't Hoff factor (i) measures the effect of a solute on colligative properties. For an electrolyte undergoing complete dissociation in a highly dilute aqueous medium, the van 't Hoff factor is numerically equal to the total number of moles of ions produced per mole of the solute formula unit dissolved.

Solution: Step 1: Write down the formula of the complex salt coordination compound: $K_4[Fe(CN)_6]$ (Potassium ferrocyanide).

Step 2: Understand the behavior of coordination compounds in water. The species outside the coordination sphere (counter ions) ionize completely, while the complex entity inside the square brackets remains intact as a single structural unit.

Step 3: Write out the complete balanced electrolytic dissociation equation for the salt in water:

$$K_4[Fe(CN)_6](aq) \rightarrow 4K^+(aq) + [Fe(CN)_6]^{4-}(aq)$$

Step 4: Count the total moles of individual ionic particles generated in the solution upon dissociation.
Number of Potassium cations (K^+) = 4
Number of Ferrocyanide complex anions ($[Fe(CN)_6]^{4-}$) = 1

Step 5: Sum these values to get the total number of ions (n):

$$\text{Total ions} = 4 + 1 = 5$$

Step 6: Since the problem specifies complete 100% dissociation, the degree of dissociation $\alpha = 1$. The formula $i = 1 + (n-1)\alpha$ simplifies directly to $i = n = 5$.

Final Answer: $\boxed{5}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The stability of organic carbocations is governed by electronic stabilization mechanisms, primarily hyperconjugation (α-hydrogen orbital overlap) and the electron-donating inductive effect ($+I$) of attached alkyl substituents. More alkyl groups attached to the positive trivalent carbon disperse the positive charge more effectively, increasing structural stability.

Solution: Step 1: Examine the chemical structure and class of each given carbocation species.
(I) $(CH_3)_3C^+$ is a tertiary (3°) carbocation. It has three methyl groups providing $+I$ effect and a total of 9 hyperconjugative α-hydrogens.
(II) $(CH_3)_2CH^+$ is a secondary (2°) carbocation. It has two methyl groups and 6 hyperconjugative α-hydrogens.
(III) $CH_3CH_2^+$ is a primary (1°) carbocation. It features one ethyl group and only 3 hyperconjugative α-hydrogens.
(IV) CH_3^+ is the simple methyl carbocation, which lacks any stabilizing alkyl groups or hyperconjugative pathways.

Step 2: Apply the general rule of carbocation stability derived from these combined electronic factors:

$$\text{Tertiary } (3^\circ) > \text{Secondary } (2^\circ) > \text{Primary } (1^\circ) > \text{Methyl}$$

Step 3: Arrange the structures accordingly using their roman numerals to form the sequence:

$$\text{I} > \text{II} > \text{III} > \text{IV}$$

Final Answer: I > II > III > IV

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: Ozonolysis is an organic reaction where the unsaturated carbon-carbon double bond of an alkene is cleaved with ozone (O_3) to form an ozonide intermediate. Subsequent reductive workup using zinc dust and water (Zn/H_2O) cleaves this ozonide cleanly, yielding corresponding carbonyl compounds (aldehydes or ketones) without further oxidation.

Solution: Step 1: Determine the structural formula of the starting material, 2-methylbut-2-ene:

$$(CH_3)_2C = CH - CH_3$$

Step 2: Visualize the ozonolysis reaction by breaking the carbon-carbon double bond ($C = C$) completely into two halves. Add an oxygen atom to each of the two separated carbons.

Step 3: Identify the fragments produced from the left side of the double bond:

$$(CH_3)_2C \rightarrow (CH_3)_2C = O$$

This molecule is Propanone (commonly known as acetone).

Step 4: Identify the fragments produced from the right side of the double bond:

$$CH - CH_3 \rightarrow CH_3 - CH = O$$

This molecule is Ethanal (commonly known as acetaldehyde).

Step 5: Combine the results. The reductive cleavage yields one molecule of Propanone and one molecule of Ethanal.

Final Answer: Propanone and Ethanal

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: Aryl halides react with magnesium metal in an anhydrous ether medium to form organomagnesium halides, universally known as Grignard Reagents. Grignard reagents contain highly polarized carbon-metal bonds, making the organic group strongly basic and nucleophilic. They react rapidly with any protic source (like water) to form hydrocarbons.

Solution: Step 1: Write down the chemical equation for the first step where bromobenzene (C_6H_5Br) is treated with magnesium metal (Mg) in dry ether:

$$C_6H_5Br + Mg \xrightarrow{\text{dry ether}} C_6H_5MgBr$$

The product formed here is phenylmagnesium bromide, a Grignard reagent.

Step 2: Analyze the nature of phenylmagnesium bromide. The phenyl group carries a strong partial negative charge ($C_6H_5^{\delta-}$), making it a powerful carbanion equivalent.

Step 3: Formulate the second step where water (H_2O) is introduced into the system. The carbanion abstracts a proton (H^+) from the water molecule:

$$C_6H_5MgBr + H_2O \rightarrow C_6H_6 + Mg(OH)Br$$

Step 4: Identify the hydrocarbon product C_6H_6, which is Benzene.

Final Answer: Benzene

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: Phenols contain a hydroxyl group attached directly to an aromatic ring, which gives them unique chemical reactivity compared to aliphatic or aralkyl alcohols. One characteristic qualitative test for compounds containing a phenolic enol group is their reaction with a neutral ferric chloride ($FeCl_3$) solution, forming highly colored coordination complexes.

Solution: Step 1: Examine the chemical structures of the two compounds to be distinguished.
Phenol is C_6H_5OH (aromatic hydroxyl).
Benzyl alcohol is $C_6H_5CH_2OH$ (an alcohol where $-OH$ is on an aliphatic carbon).

Step 2: Evaluate the action of neutral $FeCl_3$ solution on both compounds. When Phenol reacts with neutral $FeCl_3$, it forms a characteristic violet-colored water-soluble complex due to the formation of iron phenoxide:

$$6C_6H_5OH + Fe^{3+} \rightarrow [Fe(OC_6H_5)_6]^{3-} + 6H^+$$

Step 3: Note that Benzyl alcohol does not possess a phenolic hydroxyl group; hence, it shows no color change when treated with neutral $FeCl_3$.

Step 4: Conclude that neutral $FeCl_3$ serves as an efficient, specific reagent to distinguish between these two structural classes.

Final Answer: Neutral $FeCl_3$ solution

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: The cleavage of alkyl aryl ethers by concentrated hydrogen halides (like HI) proceeds via an initial protonation step to form an oxonium ion. Subsequent nucleophilic attack by the halide ion (I^-) occurs. Because the $C_{aryl} - O$ bond possesses partial double-bond character due to resonance stabilization with the aromatic ring, it is significantly stronger than the $C_{alkyl} - O$ bond and cannot be cleaved under normal conditions.

Solution: Step 1: Write down the molecular structure of anisole as shown in the diagram: $C_6H_5OCH_3$ (methoxybenzene).

Step 2: Formulate the protonation of anisole by HI. The lone pair of electrons on the oxygen atom accepts a proton (H^+) from HI, yielding a protonated ether intermediate:

$$C_6H_5 - O^+(H) - CH_3$$

Step 3: Analyze the bonds vulnerable to nucleophilic attack by the remaining iodide ion (I^-). The bond between C_6H_5 and oxygen has partial double-bond character due to resonance and cannot be easily broken. The bond between oxygen and the methyl group (CH_3) is a standard single σ-bond.

Step 4: The iodide ion (I^-) attacks the less sterically hindered methyl group via an S_N2 mechanism, breaking the aliphatic $C - O$ bond:

$$C_6H_5 - O^+(H) - CH_3 + I^- \rightarrow C_6H_5OH + CH_3I$$

Step 5: Identify the final stable products of this reaction, which are Phenol (C_6H_5OH) and Iodomethane (CH_3I).

Final Answer: Phenol and Iodomethane

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: The Cannizzaro reaction is a base-catalyzed redox disproportionation reaction characteristic of aldehydes that completely lack any hydrogen atoms on their α-carbon position (α-hydrogens). In the presence of a concentrated strong base, one molecule of such an aldehyde undergoes auto-oxidation to a carboxylic acid salt, while another molecule undergoes reduction to the corresponding primary alcohol.

Solution: Step 1: Analyze the chemical structures of all the options to check for the presence or absence of α-hydrogens.

Step 2: Evaluate Ethanal (CH_3CHO). The α-carbon is attached to 3 hydrogen atoms. Thus, it undergoes aldol condensation instead.

Step 3: Evaluate Propanal (CH_3CH_2CHO). The α-carbon contains 2 hydrogen atoms, making it unsuitable for Cannizzaro.

Step 4: Evaluate Benzaldehyde (C_6H_5CHO). The aldehyde group is attached directly to a benzene ring carbon that does not possess any hydrogen atom. Because it completely lacks α-hydrogens, it undergoes the Cannizzaro reaction.

Step 5: Evaluate Acetophenone ($C_6H_5COCH_3$). This is a ketone, not an aldehyde, and it contains α-hydrogens on the methyl side.

Step 6: Conclude that Benzaldehyde is the correct choice that undergoes disproportionation under concentrated basic conditions.

Final Answer: Benzaldehyde

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept: The basic strength of aliphatic amines in an aqueous medium is determined by a combined interplay of three distinct chemical factors: the electron-donating inductive effect ($+I$) of the alkyl groups, steric hindrance to solvation, and stabilization of the substituted ammonium cation via hydrogen bonding with water molecules (hydration/solvation energy).

Solution: Step 1: Note that for methyl-substituted amines in an aqueous medium, the ordering does not follow a simple linear trend because $+I$ effects and solvation stabilization act in opposing directions.

Step 2: Analyze the secondary amine, Dimethylamine $[(CH_3)_2NH]$. It balances strong $+I$ effects from two methyl groups with minimal steric hindrance, making its conjugate acid highly stabilized by hydration. It is always the strongest base in this series.

Step 3: Compare Methylamine (CH_3NH_2) and Trimethylamine $[(CH_3)_3N]$. In Trimethylamine, the three bulky methyl groups create severe steric hindrance, which significantly blocks effective water solvation of its conjugate acid. As a result, the primary amine (CH_3NH_2) turns out to be a stronger base than the tertiary amine $[(CH_3)_3N]$.

Step 4: Note that Ammonia (NH_3) completely lacks any electron-donating alkyl substituents, making it the weakest base in the group.

Step 5: Assemble the complete sequence in decreasing order:

$$(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$$

Final Answer: $\boxed{(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: Deoxyribonucleic acid (DNA) is a complex biomolecule comprised of a double-stranded helical structure. Its backbone consists of alternating phosphate groups and a specific pentose sugar called 2-deoxyribose. The two strands are held together via highly specific hydrogen bonding between complementary purine and pyrimidine nitrogenous bases, adhering to Chargaff's rules.

Solution: Step 1: Evaluate Option (A). DNA contains 2-deoxyribose, whereas ribose sugar is exclusively found in RNA. Hence, statement A is false.

Step 2: Evaluate Option (B). The nitrogenous bases present in DNA are Adenine (A), Thymine (T), Guanine (G), and Cytosine (C). Uracil (U) is found only in RNA, replacing Thymine. Hence, statement B is false.

Step 3: Evaluate Option (C). According to complementary base pairing, Adenine pairs exclusively with Thymine across the double strands via exactly two (2) specific hydrogen bonds ($A = T$). This statement is completely accurate.

Step 4: Evaluate Option (D). Guanine pairs with Cytosine via three (3) hydrogen bonds, not two. Hence, statement D is incorrect.

Final Answer: Adenine pairs with Thymine via two hydrogen bonds.

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept: Electron gain enthalpy ($\Delta_{eg}H$) is the energy change that occurs when an electron is added to a neutral gaseous atom. Generally, electron gain enthalpy becomes more negative across a period and less negative down a group. However, an anomaly occurs between the second and third periods of groups 16 and 17 due to differences in atomic size and electron density.

Solution: Step 1: Note the general group trend for Halogens (Group 17). Moving down from Fluorine to Iodine, atomic size increases, which typically makes the incoming electron less strongly attracted to the nucleus, leading to a less negative electron gain enthalpy.

Step 2: Examine the exception between Fluorine (F) and Chlorine (Cl). Fluorine is located in the second period and has an exceptionally small atomic radius. As a result, its $2p$ valence subshell is compact with a high electron density.

Step 3: Understand the impact of this high electron density. When an extra electron approaches a Fluorine atom, it experiences strong inter-electronic repulsion from the electrons already present in the compact $2p$ orbital. This repulsion dampens the energy released.

Step 4: Look at Chlorine (Cl). It has a larger $3p$ orbital where the electron density is more spread out. The incoming electron experiences far less inter-electronic repulsion, allowing the nucleus to bind it tightly and release more energy.

Step 5: Conclude that Chlorine possesses the highest negative electron gain enthalpy in the entire periodic table.

Final Answer: Chlorine

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: The Valence Shell Electron Pair Repulsion (VSEPR) theory dictates that the geometry and shape of a molecule depend on the total number of valence shell electron pairs (both bonding and non-bonding) around the central atom. The steric number equation can be applied to find the hybridisation and electronic geometry:

$$\text{Steric Number} = \frac{1}{2}\left[V + M - C + A\right]$$

where V is valence electrons of central atom, M is monovalent atoms, C is cationic charge, and A is anionic charge.

Solution: Step 1: Identify the central atom in XeF_4, which is Xenon (Xe). Xenon is a noble gas and has 8 valence electrons ($V = 8$).

Step 2: Count the number of surrounding monovalent Fluorine atoms ($M = 4$). The molecule has no net electrical charge ($C = 0, A = 0$).

Step 3: Compute the steric number using the values:

$$\text{Steric Number} = \frac{1}{2}[8 + 4 - 0 + 0] = \frac{12}{2} = 6$$

Step 4: A steric number of 6 corresponds to an sp^3d^2 hybridization state, which yields an Octahedral electronic geometry.

Step 5: Determine the split between bond pairs and lone pairs. The number of bond pairs equals the number of bonded fluorine atoms (4).

$$\text{Number of Lone Pairs} = \text{Steric Number} - \text{Bond Pairs} = 6 - 4 = 2$$

Step 6: To minimize lone pair-lone pair repulsions according to VSEPR theory, the two lone pairs occupy positions opposite to each other (180° apart), pointing along the vertical axis as shown in the diagram. This leaves the four fluorine atoms arranged in a flat plane.

Step 7: Conclude that the electronic geometry is Octahedral, while the actual molecular shape is Square Planar.

Final Answer: Octahedral, Square planar

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: The physical density of a solid elemental substance is defined by the ratio of its atomic mass to its atomic volume (Density = Mass/Volume). Down Group 1 (alkali metals), both atomic mass and atomic volume increase simultaneously. Generally, the increase in atomic mass outweighs the increase in volume, causing density to increase down the group. However, an anomaly occurs at potassium due to structural changes.

Solution: Step 1: Look at the standard trend for alkali metals (Li, Na, K, Rb, Cs). Typically, density increases from the top of the group to the bottom.

Step 2: Identify the anomaly between Sodium (Na) and Potassium (K). When moving from Sodium to Potassium, there is a large, abnormal expansion in atomic volume. This happens because electrons begin filling the $4s$ shell, and the empty $3d$ orbitals cause a significant increase in the atom's cross-sectional space.

Step 3: Compare the mass-to-volume ratios. The volume increase from Na to K is much larger relative to the mass increase, which causes the density of Potassium to drop below that of Sodium.

$$\text{Density of Li} \approx 0.53 \text{ g/cm}^3$$

$$\text{Density of K} \approx 0.86 \text{ g/cm}^3$$

$$\text{Density of Na} \approx 0.97 \text{ g/cm}^3$$

$$\text{Density of Rb} \approx 1.53 \text{ g/cm}^3$$

$$\text{Density of Cs} \approx 1.90 \text{ g/cm}^3$$

Step 4: Arrange the alkali metals in order of increasing density based on these values:

$$\text{Li} < \text{K} < \text{Na} < \text{Rb} < \text{Cs}$$

Final Answer: $\boxed{\text{Li} < \text{K} < \text{Na} < \text{Rb} < \text{Cs}}$

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept: Chemical oxides are classified as acidic, basic, neutral, or amphoteric based on their acid-base behavior. Most non-metal oxides are acidic, whereas electropositive alkali and alkaline earth metal oxides are basic. Amphoteric oxides are unique because they can react chemically as both an acid and a base to form salt and water.

Solution: Step 1: Analyze Option (A). CO_2 is a non-metal oxide that dissolves in water to form carbonic acid (H_2CO_3). It reacts only with bases, making it an acidic oxide.

Step 2: Analyze Option (B). Aluminum oxide (Al_2O_3) is a metal oxide where the metal sits on the border between metallic and non-metallic character. It reacts readily with both strong acids and strong bases, demonstrating its amphoteric nature.
Reaction with acid (HCl):

$$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$$

Reaction with base (NaOH):

$$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2Na[Al(OH)_4]$$

Step 3: Analyze Option (C). CaO is a highly electropositive metal oxide that reacts with water to form calcium hydroxide. It reacts only with acids, making it a basic oxide.

Step 4: Analyze Option (D). SO_2 is a non-metal oxide that forms sulfurous acid in water, acting as a purely acidic oxide.

Step 5: Conclude that Al_2O_3 is the clear amphoteric oxide among the choices.

Final Answer: $\boxed{Al_2O_3}$

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: The magnetic properties of transition metal ions are primarily determined by their spin-only magnetic moment (μ). This value can be calculated directly from the total number of unpaired d-electrons (n) using the spin-only formula:

$$\mu = \sqrt{n(n+2)} \text{ BM}$$

where BM stands for Bohr Magneton units.

Solution: Step 1: Identify the atomic number of Iron (Fe), which is $Z = 26$. Write down its ground state electronic configuration:

$$\text{Fe} = [\text{Ar}]3d^6 4s^2$$

Step 2: Determine the electronic configuration of the divalent iron cation (Fe^{2+}) by removing two electrons from the outermost $4s$ orbital:

$$\text{Fe}^{2+} = [\text{Ar}]3d^6 4s^0$$

Step 3: Sketch the distribution of the 6 electrons across the five degenerate $3d$ orbitals following Hund's Rule of Maximum Multiplicity and the Pauli Exclusion Principle, as illustrated in the provided orbital diagram.

Step 4: Count the resulting electron arrangement. The first orbital receives a pair of electrons, while the remaining four orbitals each hold a single, unpaired electron.

$$\text{Number of unpaired electrons } (n) = 4$$

Step 5: Substitute $n = 4$ into the spin-only magnetic moment formula:

$$\mu = \sqrt{4(4+2)} = \sqrt{4 \times 6} = \sqrt{24} \text{ BM}$$

Step 6: Calculate the numerical square root value:

$$\sqrt{24} \approx 4.8989 \text{ BM} \approx 4.90 \text{ BM}$$

Final Answer: 4.90 BM

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: According to IUPAC nomenclature rules for coordination compounds, ligands must be named first in alphabetical order, preceding the central metal atom. Anionic ligands end in "-o", while neutral ligands retain their standard molecular names with specific exceptions (like ammine for NH_3). The oxidation state of the central metal is indicated by a Roman numeral in parentheses immediately following the metal's name.

Solution: Step 1: Analyze the coordination formula provided: $[Co(NH_3)_5(CO_3)]Cl$. This compound consists of a complex cation $[Co(NH_3)_5(CO_3)]^+$ and a simple chloride counter anion (Cl^-).

Step 2: Identify and name all the ligands located inside the coordination sphere.
There are 5 neutral ammonia molecules, named as "pentaamine".
There is 1 divalent carbonato group (CO_3^{2-}), named as "carbonato".

Step 3: Arrange the names of the ligands alphabetically. "Ammine" comes before "carbonato", giving the combined ligand prefix: "pentaaminecarbonato".

Step 4: Determine the oxidation state of the central cobalt metal atom (x).
Charge of $NH_3 = 0$
Charge of $CO_3 = -2$
Charge of $Cl = -1$

$$x + 5(0) + 1(-2) + 1(-1) = 0 \implies x - 3 = 0 \implies x = +3$$

The metal is Cobalt(III). Since the complex is a cation, the name of the metal remains "cobalt".

Step 5: Combine all parts to form the full IUPAC name: Pentaaminecarbonatocobalt(III) chloride.

Final Answer: Pentaaminecarbonatocobalt(III) chloride

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: Polymers are classified into addition or condensation types based on their polymerization mechanism. Condensation polymerization involves the reaction of bi-functional or tri-functional monomer units, accompanied by the elimination of small molecular by-products such as water (H_2O), alcohol (CH_3OH), or hydrochloric acid (HCl).

Solution: Step 1: Evaluate Option (A). Polyethylene is formed by the chain-growth addition polymerization of ethene monomers ($CH_2 = CH_2$) without the loss of any small molecules. It is an addition polymer.

Step 2: Evaluate Option (B). PVC (Polyvinyl chloride) is produced by the radical addition polymerization of vinyl chloride monomers ($CH_2 = CHCl$). It is an addition polymer.

Step 3: Evaluate Option (C). Nylon-6,6 is synthesized via a step-growth condensation reaction between two distinct monomer units: Adipic acid ($HOOC-(CH_2)_4-COOH$) and Hexamethylenediamine ($H_2N-(CH_2)_6-NH_2$). This reaction eliminates water molecules at each linkage step, forming an amide bond. This classifies it as a condensation polymer.

Step 4: Evaluate Option (D). Teflon (Polytetrafluoroethylene) is formed by the addition polymerization of tetrafluoroethylene ($CF_2 = CF_2$). It is an addition polymer.

Final Answer: Nylon-6,6

Answer: (C)

Go Back to Question 22

Q23.

Solution

Concept: Antibiotics are chemical substances used to treat bacterial infections. They are classified as narrow-spectrum or broad-spectrum based on the range of bacteria they target. Broad-spectrum antibiotics are effective against a wide range of both Gram-positive and Gram-negative bacteria.

Solution: Step 1: Analyze Option (A). Paracetamol is an antipyretic (fever reducer) and analgesic (pain reliever). It does not possess any antibacterial properties.

Step 2: Analyze Option (B). Chloramphenicol is a powerful antibiotic that works by inhibiting bacterial protein synthesis. It is highly effective against a wide variety of Gram-positive and Gram-negative bacteria, classifying it as a broad-spectrum antibiotic.

Step 3: Analyze Option (C). Aspirin is an analgesic, antipyretic, and anti-inflammatory drug. It belongs to the class of non-steroidal anti-inflammatory drugs (NSAIDs).

Step 4: Analyze Option (D). Penicillin G has a narrow spectrum of activity, targeting primarily a specific group of Gram-positive bacteria.

Step 5: Conclude that Chloramphenicol is the broad-spectrum antibiotic among the choices.

Final Answer: Chloramphenicol

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept: Photochemical smog is a modern atmospheric pollution phenomenon that occurs in warm, dry, and sunny urban climates. It is formed through primary and secondary photochemical reactions driven by the action of solar ultraviolet radiation on primary pollutants emitted by vehicular exhaust.

Solution: Step 1: Identify the primary components required for the initiation of photochemical smog. These are unburnt unsaturated hydrocarbons and various oxides of nitrogen (NO_x).

Step 2: Analyze the role of sunlight. When solar radiation interacts with these primary pollutants, nitrogen dioxide (NO_2) undergoes photolysis to produce nitric oxide (NO) and highly reactive atomic oxygen (O).

Step 3: Trace the subsequent secondary reactions. Atomic oxygen reacts with atmospheric molecular oxygen to form ozone (O_3). This ozone then reacts with unburnt hydrocarbons to yield toxic secondary pollutants like peroxyacetyl nitrate (PAN) and acrolein.

Final Answer: Action of sunlight on unsaturated hydrocarbons and nitrogen oxides

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: Molarity (M) of a solution is defined as the total number of moles of solute dissolved per liter (1000 mL) of solution volume. The standard equation linking mass, molar mass, volume, and molarity is:

$$\text{Molarity } (M) = \frac{\text{Mass of solute } (W)}{\text{Molar Mass of solute } (M_w)} \times \frac{1000}{\text{Volume of solution in mL } (V)}$$

Solution: Step 1: Identify the given values from the problem statement:
Target Molarity $(M) = 0.1$ M
Volume of solution $(V) = 250$ mL
Solute = NaOH

Step 2: Calculate the molar mass (M_w) of Sodium Hydroxide (NaOH).

$$M_w = \text{Atomic mass of Na + O + H} = 23 + 16 + 1 = 40 \text{ g mol}^{-1}$$

Step 3: Substitute all these values into the molarity formula to solve for the unknown mass (W):

$$0.1 = \frac{W}{40} \times \frac{1000}{250}$$

Step 4: Simplify the volume fraction on the right side:

$$\frac{1000}{250} = 4$$

$$0.1 = \frac{W}{40} \times 4$$

Step 5: Isolate and solve for W:

$$0.1 = \frac{W}{10}$$

$$W = 0.1 \times 10 = 1.0 \text{ g}$$

Thus, exactly 1.0 gram of solid NaOH is required.

Final Answer: 1.0 g

Answer: (C)

Go Back to Question 25

Q26.

Solution

Concept: According to Niels Bohr's atomic model, the physical radius of an electron's stationary orbit (r_n) in a hydrogenic atom depends on the principal quantum number (n) and the atomic number (Z). The radius is governed by the expression:

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

where a_0 is the Bohr radius for the ground state of a hydrogen atom (0.529 Å).

Solution: Step 1: Note that for a standard hydrogen atom, the atomic number is constant ($Z = 1$). This means the orbit radius depends entirely on the square of the principal quantum number:

$$r_n \propto n^2$$

Step 2: Write the expression for the first Bohr orbit ($n = 1$). The problem states this radius is equal to r:

$$r_1 \propto (1)^2 \implies r_1 = c \times 1 = r$$

Step 3: Write the expression for the third Bohr orbit ($n = 3$):

$$r_3 \propto (3)^2 \implies r_3 = c \times 9$$

Step 4: Substitute r into the equation for the third orbit:

$$r_3 = 9 \times r = 9r$$

Thus, the radius of the third Bohr orbit is exactly 9 times the radius of the first orbit.

Final Answer: $\boxed{9r}$

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept: The Second Law of Thermodynamics governs the direction of spontaneous chemical and physical processes. It states that the total entropy change of the universe ($\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$) must increase for any spontaneous process. An isolated system cannot exchange energy or matter with its surroundings, meaning the surroundings experience no change.

Solution: Step 1: State the definition of an isolated system. Because it is completely cut off from its environment, no heat can be transferred into or out of the surroundings.

$$\Delta S_{\text{surroundings}} = 0$$

Step 2: Express the formula for the total net change in entropy:

$$\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$$

Step 3: Substitute the value for the surroundings into the equation:

$$\Delta S_{\text{total}} = \Delta S_{\text{system}} + 0 = \Delta S_{\text{system}}$$

Step 4: Apply the Second Law of Thermodynamics for a spontaneous change. The total entropy of the universe must increase, meaning $\Delta S_{\text{total}} > 0$. Therefore, for an isolated system, the total entropy change must always be positive.

Final Answer: Positive

Answer: (C)

Go Back to Question 27

Q28.

Solution

Concept: The solubility product constant (K_{sp}) is an equilibrium constant that describes the dissolution of a sparingly soluble ionic salt in water. For a salt with the general formula AB_2, the equilibrium expression can be written in terms of its molar solubility (s).

Solution: Step 1: Write out the balanced chemical equation for the dynamic dissolution of the generic salt AB_2 in pure water:

$$AB_2(s) \rightleftharpoons A^{2+}(aq) + 2B^-(aq)$$

Step 2: Set up the equilibrium concentrations of the ions in terms of the molar solubility (s).
$[A^{2+}] = s$
$[B^-] = 2s$

Step 3: Write out the mathematical expression for the solubility product constant (K_{sp}):

$$K_{sp} = [A^{2+}][B^-]^2 = (s)(2s)^2 = s \times 4s^2 = 4s^3$$

Step 4: Substitute the given value of $K_{sp} = 4 \times 10^{-12}$ into this simplified equation:

$$4 \times 10^{-12} = 4s^3$$

Step 5: Divide both sides by 4 to isolate s^3:

$$s^3 = 10^{-12}$$

Step 6: Take the cube root of both sides to find the molar solubility (s):

$$s = \sqrt[3]{10^{-12}} = 1 \times 10^{-4}\ \text{M}$$

Final Answer: $\boxed{1 \times 10^{-4}\ \text{M}}$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept: The standard reduction potential (E°) measures how easily a chemical species gains electrons and undergoes reduction. A lower or more negative reduction potential means the species loses electrons more readily, making it a stronger reducing agent. Therefore, reducing power is inversely proportional to the standard reduction potential.

Solution: Step 1: List the given standard reduction potentials for the three metals:
Metal A: $E^\circ = +0.5$ V
Metal B: $E^\circ = -1.2$ V
Metal C: $E^\circ = -0.4$ V

Step 2: Arrange the metals in order of their standard reduction potentials, from the lowest (most negative) to the highest (most positive):

$$-1.2 \text{ V (Metal B)} < -0.4 \text{ V (Metal C)} < +0.5 \text{ V (Metal A)}$$

Step 3: Apply the inverse relationship to determine the reducing power. The metal with the lowest reduction potential (Metal B) loses electrons most easily and is the strongest reducing agent. The metal with the highest potential (Metal A) is the weakest.

Step 4: Write out the final sequence of decreasing reducing power:

$$B > C > A$$

Final Answer: $\boxed{B > C > A}$

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept: The relationship between the rate constant of a chemical reaction and its temperature is described by the integrated form of the Arrhenius Equation:

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left[\frac{T_2 - T_1}{T_1 T_2}\right]$$

where E_a is the activation energy, R is the universal gas constant, and T is the absolute temperature in Kelvin.

Solution: Step 1: Identify the values given in the problem statement:
$T_1 = 300$ K
$T_2 = 310$ K
The rate constant doubles, so $\frac{k_2}{k_1} = 2$.
$R = 8.314$ J mol^{-1} K^{-1}
$\ln 2 = 0.693$

Step 2: Substitute these values into the integrated Arrhenius equation:

$$0.693 = \frac{E_a}{8.314}\left[\frac{310 - 300}{300 \times 310}\right]$$

Step 3: Simplify the temperature terms inside the brackets:

$$0.693 = \frac{E_a}{8.314}\left[\frac{10}{93000}\right] = \frac{E_a}{8.314} \times \frac{1}{9300}$$

Step 4: Isolate the activation energy (E_a):

$$E_a = 0.693 \times 8.314 \times 9300$$

$$E_a = 5.7616 \times 9300 = 53582.9 \text{ J mol}^{-1}$$

Step 5: Convert the calculated energy from Joules to kilojoules (kJ):

$$E_a = \frac{53582.9}{1000} \approx 53.6 \text{ kJ mol}^{-1}$$

Final Answer: 53.6 kJ mol^{-1}

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept: Alkanes are non-polar molecules held together by weak intermolecular van der Waals dispersion forces. The strength of these forces depends directly on the surface area of the molecule. For structural isomers, increasing branching changes the molecular shape from linear to spherical, which reduces its surface area and lowers its boiling point.

Solution: Step 1: Examine the chemical structures of the three structural isomers of pentane (C_5H_{12}).
n-pentane is a straight-chain alkane.
Isopentane (2-methylbutane) has one branch.
Neopentane (2,2-dimethylpropane) is highly branched and nearly spherical.

Step 2: Compare their surface areas. The straight-chain isomer, n-pentane, has a continuous, linear structure that provides the maximum surface area. This allows for strong intermolecular contacts.

Step 3: Analyze the effect of branching. As branching increases in isopentane and neopentane, the molecules become more compact and spherical. This reduces their surface area, weakening the intermolecular van der Waals forces.

Step 4: Conclude that n-pentane requires the most thermal energy to overcome these intermolecular forces, giving it the highest boiling point among the isomers.

Final Answer: n-pentane

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept: The nitration of benzene is a classic example of an Electrophilic Aromatic Substitution (S_EAr) reaction. It requires a nitrating mixture containing concentrated nitric acid (HNO_3) and concentrated sulfuric acid (H_2SO_4). In this mixture, sulfuric acid acts as a strong Brønsted-Lowry acid to protonate the nitric acid, generating a powerful electrophile.

Solution: Step 1: Analyze the acid-base interaction between the two concentrated acids. Because sulfuric acid (H_2SO_4) is a stronger acid than nitric acid (HNO_3), it protonates the hydroxyl group of the nitric acid molecule:

$$HNO_3 + H_2SO_4 \rightleftharpoons H_2O^+ - NO_2 + HSO_4^-$$

Step 2: Trace the decomposition of this protonated intermediate. The protonated oxonium species is unstable and readily loses a neutral water molecule (H_2O):

$$H_2O^+ - NO_2 \rightleftharpoons H_2O + NO_2^+$$

Step 3: Note that the released water molecule is immediately protonated by a second molecule of sulfuric acid to form a hydronium ion (H_3O^+). The overall reaction is:

$$HNO_3 + 2H_2SO_4 \rightleftharpoons NO_2^+ + H_3O^+ + 2HSO_4^-$$

Step 4: Identify the active electrophile responsible for attacking the electron-rich π-cloud of the benzene ring. This species is the nitronium ion, represented as NO_2^+.

Final Answer: $\boxed{NO_2^+}$

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept: The unimolecular nucleophilic substitution (S_N1) mechanism occurs in two distinct operational steps. The first and rate-determining step involves the slow heterolytic cleavage of the carbon-halogen bond to form a carbocation intermediate. Therefore, the overall rate of an S_N1 reaction depends directly on the thermodynamic stability of the carbocation formed.

Solution: Step 1: Identify the carbocation intermediate that forms when each alkyl halide loses its chloride leaving group (Cl^-).

$CH_3CH_2Cl \rightarrow CH_3CH_2^+$ (Primary, 1° carbocation)
$(CH_3)_2CHCl \rightarrow (CH_3)_2CH^+$ (Secondary, 2° carbocation)
$(CH_3)_3CCl \rightarrow (CH_3)_3C^+$ (Tertiary, 3° carbocation)
$CH_3Cl \rightarrow CH_3^+$ (Methyl carbocation)

Step 2: Compare the stability of these carbocations. The tertiary butyl carbocation, $(CH_3)_3C^+$, is highly stabilized by the inductive electron-donation of three methyl groups and a total of 9 hyperconjugative α-hydrogens.

Step 3: Apply the standard stability trend for carbocations:

$$\text{Tertiary } (3^\circ) > \text{Secondary } (2^\circ) > \text{Primary } (1^\circ) > \text{Methyl}$$

Step 4: Conclude that because $(CH_3)_3CCl$ forms the most stable carbocation intermediate, it lowers the activation energy barrier for the rate-determining step, allowing it to undergo S_N1 hydrolysis at the fastest rate.

Final Answer: $(CH_3)_3CCl$

Answer: (C)

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Q34.

Solution

Concept: The conversion of phenol to ortho-hydroxybenzaldehyde (commonly known as salicylaldehyde) using chloroform ($CHCl_3$) and an aqueous base (NaOH) is a classic organic named reaction. This substitution process involves the generation of an uncharged, highly reactive electron-deficient reactive intermediate known as dichlorocarbene ($:CCl_2$).

Solution: Step 1: Analyze the reaction conditions described. Phenol is treated with chloroform ($CHCl_3$) in a concentrated aqueous sodium hydroxide (NaOH) environment.

Step 2: Understand the role of the base with chloroform. The hydroxide ion (OH^-) abstracts an acidic proton from chloroform, producing a trichlorocarbanion ($^-CCl_3$) which rapidly loses a chloride ion to generate dichlorocarbene:

$$CHCl_3 + OH^- \rightarrow CCl_3^- + H_2O$$

$$CCl_3^- \rightarrow : CCl_2 + Cl^-$$

Step 3: Trace the attack on phenol. Phenol is converted by the base into a nucleophilic phenoxide ion. The dichlorocarbene intermediate attacks this phenoxide ion primarily at the ortho position. Subsequent hydrolysis yields salicylaldehyde.

Step 4: Identify the name of this classic chemical transformation, which is the Reimer-Tiemann reaction.

Final Answer: Reimer-Tiemann reaction

Answer: (A)

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Q35.

Solution

Concept: The direct reduction of an aldehyde or ketone carbonyl group ($> C = O$) into a hydrocarbon methylene group ($-CH_2-$) can be achieved using specific acidic or basic reducing systems. When this reduction is carried out under strongly acidic conditions using a zinc amalgam catalyst and concentrated hydrochloric acid, the transformation is called the Clemmensen Reduction.

Solution: Step 1: Analyze the specific reagents mentioned in the problem: zinc amalgam ($Zn - Hg$) combined with concentrated hydrochloric acid (HCl).

Step 2: Determine the function of these reagents. This mixture acts as a strong reducing system under highly acidic conditions, specifically targeting the carbonyl group of aldehydes and ketones.

Step 3: Trace the structural change. The oxygen atom of the carbonyl group ($> C = O$) is completely removed and replaced by two hydrogen atoms, converting it into a methylene group ($-CH_2-$):

$$> C = O \xrightarrow{\text{Zn-Hg / conc. HCl}} > CH_2$$

Step 4: Match this mechanism with the correct organic named reaction. This specific combination of reagents and conditions defines the Clemmensen reduction.

Step 5: Note for contrast that the Wolff-Kishner reduction achieves the same structural result but uses hydrazine (NH_2NH_2) under strongly basic conditions (KOH/glycol).

Final Answer: Clemmensen reduction

Answer: (B)

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Q36.

Solution

Concept: The Gabriel Phthalimide Synthesis is a reliable chemical method used to prepare pure primary amines without contamination from secondary or tertiary amines. This reaction relies on the nucleophilic substitution (S_N2) of an alkyl halide by a potassium phthalimide anion. Because aryl halides do not readily undergo nucleophilic substitution, this method cannot be used to prepare aromatic amines.

Solution: Step 1: Understand the mechanism of the Gabriel phthalimide synthesis. Phthalimide is treated with potassium hydroxide (KOH) to generate a nucleophilic potassium phthalimide anion.

Step 2: Analyze the nucleophilic substitution step. The phthalimide anion attacks an introduced alkyl halide ($R - X$) via an S_N2 pathway, forming an N-alkylphthalimide.

Step 3: Trace the final hydrolysis step. Alkaline hydrolysis of the N-alkylphthalimide cleaves the amide bonds, releasing a pure primary aliphatic amine ($R - NH_2$).

Step 4: Consider why primary aromatic amines (like aniline, $C_6H_5NH_2$) cannot be prepared this way. Preparing an aromatic amine would require using an aryl halide (like chlorobenzene). However, aryl halides do not undergo the necessary S_N2 nucleophilic attack by the phthalimide anion due to the partial double-bond character of the $C - Cl$ bond and steric hindrance from the benzene ring.

Step 5: Conclude that Gabriel phthalimide synthesis is exclusively used to prepare primary aliphatic amines.

Final Answer: Primary aliphatic amines

Answer: (A)

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Q37.

Solution

Concept: Carbohydrates are classified as reducing or non-reducing sugars based on their ability to reduce mild oxidizing agents like Tollen's or Fehling's reagents. A sugar acts as a reducing sugar if it contains a free, unlinked anomeric aldehyde or ketone group that can open into a straight-chain form. In non-reducing sugars, these anomeric carbons are locked within a glycosidic linkage.

Solution: Step 1: Evaluate Maltose. Maltose is a disaccharide composed of two glucose units where the glycosidic bond links C_1 of one glucose to C_4 of the second. The second glucose unit retains a free, unlinked anomeric carbon at C_1, making it a reducing sugar.

Step 2: Evaluate Lactose. Lactose consists of galactose and glucose units linked by a $\beta(1 \rightarrow 4)$ glycosidic bond. The anomeric carbon of the glucose unit remains free, classifying it as a reducing sugar.

Step 3: Evaluate Sucrose. Sucrose is a disaccharide composed of α-D-glucose and β-D-fructose. The glycosidic linkage is formed between the anomeric carbon C_1 of glucose and the anomeric carbon C_2 of fructose. Because both reducing centers are locked in the glycosidic bond, sucrose cannot form an open-chain structure with a free carbonyl group. This makes it a non-reducing sugar.

Step 4: Evaluate Glucose. Glucose is a monosaccharide with a free aldehyde group at C_1, making it a strong reducing sugar.

Final Answer: Sucrose

Answer: (C)

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Q38.

Solution

Concept: According to Molecular Orbital (MO) Theory, a molecular chemical species is paramagnetic if its electronic configuration contains one or more unpaired electrons. If all electrons are completely paired within the molecular orbitals, the species is diamagnetic.

Solution: Step 1: Determine the total number of valence and core electrons for molecular oxygen (O_2). Each oxygen atom contributes 8 electrons, giving a total of 16 electrons.

Step 2: Write out the complete molecular orbital configuration for the 16 electrons of O_2 in order of increasing energy:

$$\sigma_{1s}^2\ \sigma_{1s}^{*2}\ \sigma_{2s}^2\ \sigma_{2s}^{*2}\ \sigma_{2p_z}^2\ (\pi_{2p_x}^2 = \pi_{2p_y}^2)\ (\pi_{2p_x}^{*1} = \pi_{2p_y}^{*1})$$

Step 3: Examine the distribution of the final two electrons in the highest occupied molecular orbitals (HOMO). Following Hund's rule, these two electrons enter the degenerate antibonding π^* orbitals individually with parallel spins:

$$\pi_{2p_x}^{*1} = \pi_{2p_y}^{*1}$$

Step 4: Note that because molecular oxygen contains two unpaired electrons in its antibonding orbitals, it displays significant paramagnetism.

Step 5: For contrast, checking N_2 (14 electrons), C_2 (12 electrons), and F_2 (18 electrons) reveals that all their electrons are completely paired, making them diamagnetic.

Final Answer: $\boxed{O_2}$

Answer: (B)

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Q39.

Solution

Concept: Diborane (B_2H_6) is an electron-deficient boron hydride with an unusual covalent bonding structure. It cannot be rationalized by conventional Lewis structures because it lacks a sufficient number of valence electrons to form standard two-center two-electron shared bonds between all adjacent atoms.

Solution: Step 1: Analyze the structural layout of the diborane molecule as shown in the provided diagram. The molecule contains two central boron atoms and six hydrogen atoms.

Step 2: Identify the terminal bonds. There are four terminal hydrogen atoms located at the outer edges of the molecule ($H_{terminal}$). Each of these hydrogens is bonded to a boron atom via a standard, conventional two-center two-electron ($2c - 2e$) covalent single bond. This accounts for a total of four $2c - 2e$ bonds.

Step 3: Identify the bridging bonds. The remaining two hydrogen atoms (H_{bridge}) are located in a central plane perpendicular to the terminal atoms, bridging the two boron atoms together.

Step 4: Examine the nature of these bridging bonds. Each boron atom shares its remaining electron density with a bridging hydrogen, creating a delocalized three-center two-electron ($3c - 2e$) bond, often called a banana bond. The two bridging hydrogens form a total of two $3c - 2e$ bonds.

Step 5: Combine these observations to conclude that the structure contains exactly four $2c - 2e$ bonds and two $3c - 2e$ bonds.

Final Answer: Four $2c - 2e$ bonds and two $3c - 2e$ bonds

Answer: (A)

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Q40.

Solution

Concept: Ionization isomerism is a form of structural isomerism in coordination chemistry. It occurs when a coordination compound and its isomer produce different ions in an aqueous solution. This happens because a counter ion from outside the coordination sphere switches places with a ligand bonded inside the coordination sphere.

Solution: Step 1: Evaluate the pair in Option (A): $[Co(NH_3)_5Br]SO_4$ and $[Co(NH_3)_5SO_4]Br$.

Step 2: Analyze how the first compound dissolves in water. The sulfate group acts as the counter ion outside the brackets and ionizes completely:

$$[Co(NH_3)_5Br]SO_4(s) \rightarrow [Co(NH_3)_5Br]^{2+}(aq) + SO_4^{2-}(aq)$$

This solution reacts with $BaCl_2$ to form a white precipitate of $BaSO_4$.

Step 3: Analyze how the second compound dissolves in water. The bromide group acts as the counter ion and ionizes completely:

$$[Co(NH_3)_5SO_4]Br(s) \rightarrow [Co(NH_3)_5SO_4]^{+}(aq) + Br^{-}(aq)$$

This solution reacts with $AgNO_3$ to form a pale yellow precipitate of AgBr. Because they generate different ions in solution due to switching positions, they are ionization isomers.

Final Answer: $\boxed{[Co(NH_3)_5Br]SO_4 \text{ and } [Co(NH_3)_5SO_4]Br}$

Answer: (A)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	D	3	C	4	D	5	B
6	B	7	B	8	A	9	A	10	B
11	A	12	B	13	C	14	A	15	C
16	B	17	A	18	B	19	B	20	A
21	A	22	C	23	B	24	B	25	C
26	B	27	C	28	A	29	B	30	A
31	A	32	B	33	C	34	A	35	B
36	A	37	C	38	B	39	A	40	A