KIITEE Chemistry Sample Paper – 10

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, 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 with the molecular formula $C_4H_{10}O$ does not react with sodium metal. When treated with an excess of hot hydroiodic acid (HI), it yields two different alkyl iodides. What is the structural formula of the original compound?

(A) $CH_3CH_2CH_2CH_2OH$

(B) $CH_3CH_2OCH_2CH_3$

(C) $CH_3OCH_2CH_2CH_3$

(D) $(CH_3)_3COH$

Q2. Consider the following equilibrium reaction occurring in a closed container at a constant temperature:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

If the total pressure at equilibrium is P and the degree of dissociation of N_2O_4 is α, which of the following expressions correctly represents the equilibrium constant K_p?

(A) $\frac{4\alpha^2 P}{1-\alpha^2}$

(B) $\frac{4\alpha^2 P^2}{1-\alpha}$

(C) $\frac{\alpha^2 P}{4(1-\alpha^2)}$

(D) $\frac{2\alpha P}{1-\alpha}$

Q3. The standard reduction potentials (E°) for three metal ions X^{2+}, Y^{3+}, and Z^{+} are -1.66 V, $+0.34$ V, and -0.76 V respectively. What is the correct increasing order of the reducing power of the corresponding metals (X, Y, and Z)?

(A) $X < Z < Y$

(B) $Y < Z < X$

(C) $Y < X < Z$

(D) $Z < Y < X$

Q4. Based on Crystal Field Theory (CFT), what is the correct electronic configuration and the number of unpaired electrons for the high-spin complex $[CoF_6]^{3-}$? (Atomic number of $Co = 27$)

(A) $t_{2g}^4 e_g^2$ with 4 unpaired electrons

(B) $t_{2g}^6 e_g^0$ with 0 unpaired electrons

(C) $t_{2g}^5 e_g^1$ with 2 unpaired electrons

(D) $t_{2g}^3 e_g^3$ with 6 unpaired electrons

Q5. Which of the following polymers is classified as a biodegradable polyamide that can be synthesized by the copolymerization of glycine and amino caproic acid?

(A) PHBV

(B) Nylon 6,6

(C) Nylon 2-nylon 6

(D) Buna-N

Q6. Identify the major product obtained when phenol is treated with chloroform ($CHCl_3$) in the presence of aqueous sodium hydroxide ($NaOH$), followed by acidification (Reimer-Tiemann reaction).

(A) Salicylic acid

(B) Salicylaldehyde

(C) Acetophenone

(D) Benzallacton

Q7. A crystalline solid forms a face-centered cubic (fcc) closed-packed lattice of anions B. The cations A occupy half of the tetrahedral voids completely. What is the simplest empirical formula of the compound?

(A) AB

(B) A_2B

(C) AB_2

(D) A_3B_4

Q8. The molecular geometry and hybridization state of the central atom in the xenon compound $XeOF_4$ are respectively:

(A) Square pyramidal, sp^3d^2

(B) See-saw, sp^3d

(C) Octahedral, sp^3d^3

(D) Square planar, sp^3d^2

Q9. Which of the following statements regarding DNA and RNA structures is incorrect?

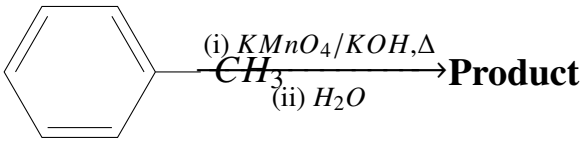
(A) DNA contains thymine, whereas RNA contains uracil as a pyrimidine base.

(B) The sugar moiety in RNA is D-ribose, whereas in DNA it is D-2-deoxyribose.

(C) DNA primarily exhibits a double-stranded helical structure, whereas RNA is typically single-stranded.

(D) Double-stranded RNA contains complementary hydrogen base pairing between Adenine and Cytosine.

Q10. Identify the major organic product formed in the following reaction sequence involving an aromatic ring system shown in the TikZ schematic below:



(A) Benzyl alcohol

(B) Benzaldehyde

(C) Benzoic acid

(D) Toluene-4-sulfonic acid

Q11. For a first-order chemical reaction, a graph plotted between the logarithm of the rate constant ($\ln k$) and the reciprocal of absolute temperature ($1/T$) gives a straight line. What is the value of the slope of this line according to the Arrhenius equation?

(A) $-E_a/R$

(B) $E_a/2.303R$

(C) $-E_a/2.303R$

(D) A/R

Q12. Which of the following coordination complexes is expected to exhibit the maximum value of paramagnetic behavior (highest number of unpaired electrons)? (Atomic numbers: $Mn = 25, Fe = 26, Co = 27, Ni = 28$)

(A) $[Fe(CN)_6]^{3-}$

(B) $[Mn(H_2O)_6]^{2+}$

(C) $[Co(NH_3)_6]^{3+}$

(D) $[NiCl_4]^{2-}$

Q13. Photochemical smog is a prevalent atmospheric pollution phenomenon observed in warm, dry, and sunny climates. Which of the following sets of components represents the primary and secondary constituents responsible for photochemical smog?

(A) SO_2, Hydrocarbons, and Smoke

(B) O_3, PAN, and Nitrogen Oxides

(C) CO_2, CH_4, and Particulates

(D) Chlorofluorocarbons ($CFCs$) and SO_3

Q14. An organic compound **P** ($C_5H_{10}O$) forms a yellow precipitate with $I_2/NaOH$ (iodoform test) and gives a positive 2,4-DNP test but fails to reduce Tollen's reagent. What is the most probable structure of compound **P**?

(A) Pentan-3-one

(B) Pentanal

(C) Pentan-2-one

(D) 2-Methylbutanal

Q15. The rate law for the reaction $2A + B \rightarrow C$ is found to be Rate $= k[A]^2[B]$. If the volume of the reaction vessel is suddenly reduced to one-third of its initial volume while keeping the temperature constant, how will the rate of the reaction change?

(A) It increases to 9 times its initial value

(B) It increases to 27 times its initial value

(C) It decreases to 1/9 of its initial value

(D) It decreases to 1/27 of its initial value

Q16. Lanthanoid contraction is a crucial phenomenon in the chemistry of inner transition elements. Which of the following pairs of elements have almost identical atomic radii due to lanthanoid contraction?

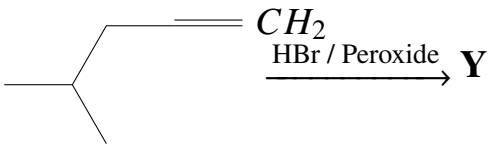
(A) Ti and Zr

(B) Zr and Hf

(C) Nb and Ta

(D) Both (B) and (C)

Q17. Consider the following chemical transformation of an alkene shown below. Identify the major organic product **Y** generated at the end of the sequence:



(A) 2-Bromo-3-methylbutane

(B) 1-Bromo-3-methylbutane

(C) 2-Bromo-2-methylbutane

(D) 1-Bromo-2-methylbutane

Q18. What is the correct order of increasing thermal stability for the alkaline earth metal carbonates?

(A) $BaCO_3 < SrCO_3 < CaCO_3 < MgCO_3$

(B) $MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$

(C) $CaCO_3 < MgCO_3 < BaCO_3 < SrCO_3$

(D) $MgCO_3 < SrCO_3 < CaCO_3 < BaCO_3$

Q19. What is the osmotic pressure (Π) of a 0.1 M aqueous solution of Magnesium Chloride ($MgCl_2$) at 300 K, assuming complete dissociation of the salt? (R = 0.0821 L atm $K^{-1}mol^{-1}$)

(A) 2.46 atm

(B) 4.92 atm

(C) 7.39 atm

(D) 0.246 atm

Q20. A non-reducing disaccharide composed of an α-D-glucopyranose unit and a β-D-fructofuranose unit linked together via a glycosidic bond between C1 of glucose and C2 of fructose is known as:

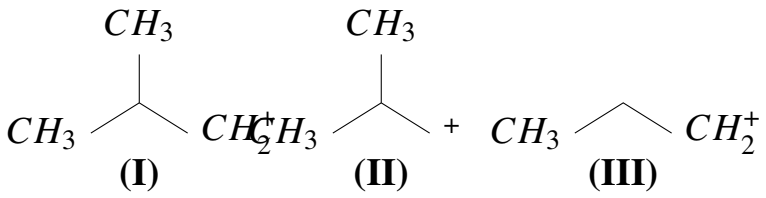
(A) Maltose

(B) Lactose

(C) Sucrose

(D) Cellobiose

Q21. Arrange the following carbocations in the decreasing order of their stability according to stereoelectronic factors shown in the molecular frameworks:



Note: Compound (II) represents a tertiary carbocation where the positive charge is localized on the central carbon node.

(A) I > II > III

(B) II > I > III

(C) II > III > I

(D) III > I > II

Q22. The principle of the extraction of copper from copper pyrites involves self-reduction in a Bessemer converter. What is the composition of the chemical phase known as "copper matte"?

(A) Cu_2S and FeS

(B) Cu_2O and Fe_2O_3

(C) CuS and FeO

(D) Cu_2S and Cu_2O

Q23. The equivalent conductance of a weak monobasic acid at a concentration of 0.01 M is 16 S cm^2eq^{-1}. If its equivalent conductance at infinite dilution is 400 S cm^2eq^{-1}, calculate the dissociation constant (K_a) of the weak acid.

(A) 1.6×10^{-5}

(B) 4.0×10^{-4}

(C) 1.6×10^{-4}

(D) 1.6×10^{-6}

Q24. Which of the following elements does not form a gaseous oxide with a high tendency to produce acid rain when mixed with precipitation?

(A) Nitrogen

(B) Sulfur

(C) Carbon

(D) Argon

Q25. When D-glucose reacts with an excess of phenylhydrazine, it forms an osazone. Which other hexose sugar will yield the exact same osazone derivative due to identical stereochemistry at C3, C4, and C5?

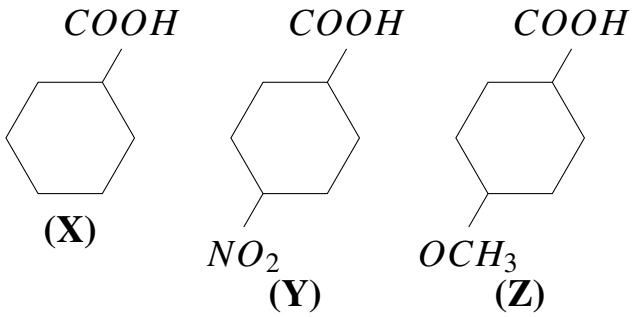
(A) D-Galactose

(B) D-Mannose

(C) D-Allose

(D) D-Gulose

Q26. Identify the correct increasing order of acidity among the substituted benzoic acids shown below based on inductive and mesomeric effects:



(X) **(Y)** **(Z)**

(A) Y < X < Z

(B) Z < X < Y

(C) X < Y < Z

(D) Z < Y < X

Q27. The work function for a specific metal surface is 4.0 eV. If light of wavelength 200 nm is incident on the surface, what will be the maximum kinetic energy of the emitted photoelectrons? ($h = 6.626 \times 10^{-34}$ J s, 1 eV = 1.6×10^{-19} J)

(A) 2.2 eV

(B) 6.2 eV

(C) 1.5 eV

(D) 4.0 eV

Q28. Which of the following compounds displays geometric (cis-trans) isomerism within its coordination coordination framework?

(A) $[Co(NH_3)_5Cl]Cl_2$

(B) $[Pt(NH_3)_2Cl_2]$

(C) $[Ni(CO)_4]$

(D) $[Fe(H_2O)_6]Cl_3$

Q29. A sample of municipal wastewater was found to have a Biochemical Oxygen Demand (BOD) value of 250 ppm. What can be inferred about the quality of this water sample?

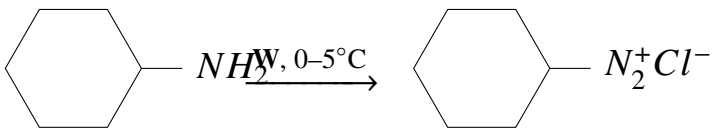
(A) It is highly clean and safe for drinking purposes.

(B) It contains negligible organic pollutants.

(C) It is heavily polluted with biodegradable organic wastes.

(D) It has exceptionally high dissolved oxygen content supporting aquatic life.

Q30. Consider the reaction mechanism profile shown in the structural diagram below. Identify the highly active reagent **W** that converts an amine group via diazotization under cold conditions:



(A) $NaNO_2 + HCl$

(B) $HNO_3 + H_2SO_4$

(C) NH_4OH

(D) NaN_3

Q31. The unit of the rate constant (k) for a specific gas-phase chemical reaction is found to be L $mol^{-1}s^{-1}$. What is the overall order of this chemical reaction?

(A) Zero order

(B) First order

(C) Second order

(D) Third order

Q32. Which of the following oxyacids of phosphorus possesses a molecular structure containing a direct phosphorus-phosphorus ($P-P$) bond along with $P-H$ linkages?

(A) Hyrpophosphoric acid ($H_4P_2O_6$)

(B) Pyrophosphoric acid ($H_4P_2O_7$)

(C) Orthophosphoric acid (H_3PT_4)

(D) Hypophosphorous acid (H_3PO_2)

Q33. Which of the following organic structures contains a carbonyl functional group that undergoes an intermolecular Cannizzaro reaction when exposed to concentrated sodium hydroxide solution?

(A) CH_3CHO

(B) CH_3COCH_3

(C) C_6H_5CHO

(D) CH_3CH_2CHO

Q34. An ideal solution is prepared by mixing two volatile liquids X and Y. If the vapor pressures of pure liquids X and Y are 200 mmHg and 300 mmHg respectively at a certain temperature, what is the total vapor pressure of a solution containing 2 moles of X and 3 moles of Y?

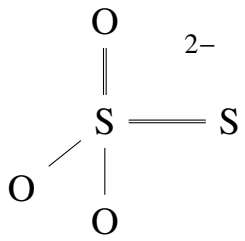
(A) 250 mmHg

(B) 260 mmHg

(C) 240 mmHg

(D) 280 mmHg

Q35. Consider the structure of the sulfur-based inorganic ion shown below in the TikZ coordinate space. What is the average oxidation state of the sulfur atoms in this thiosulfate functional assembly?



(A) +2

(B) +4

(C) +6

(D) −2

Q36. The concentration of fluoride ions in drinking water up to 1 ppm is beneficial for human teeth, but an excess concentration above which threshold value causes severe bone fluorosis and mottling of teeth?

(A) 1.5 ppm

(B) 2.0 ppm

(C) 10.0 ppm

(D) 0.5 ppm

Q37. Which of the following organic transformations represents a Hoffmann Bromamide degradation pathway?

(A) $R - COOH + NH_3 \rightarrow R - CONH_2$

(B) $R - CONH_2 + Br_2 + 4NaOH \rightarrow R - NH_2 + Na_2CO_3 + 2NaBr + 2H_2O$

(C) $R - CN + LiAlH_4 \rightarrow R - CH_2NH_2$

(D) $R - NH_2 + CHCl_3 + 3KOH \rightarrow R - NC + 3KCl + 3H_2O$

Q38. What is the correct mathematical expression for the change in entropy (ΔS) during the isothermal reversible expansion of n moles of an ideal gas from an initial volume V_1 to a final volume V_2?

(A) $\Delta S = nRT \ln(V_2/V_1)$

(B) $\Delta S = nR \ln(V_2/V_1)$

(C) $\Delta S = 2.303nR \log(V_1/V_2)$

(D) $\Delta S = 0$

Q39. Which of the following transition metal parameters is primarily responsible for the high catalytic activity of d-block elements and their complex compounds?

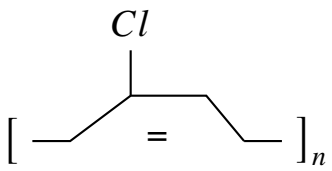
(A) Completely filled d-orbitals

(B) Availability of variable oxidation states and large surface area

(C) High electronegativity values

(D) Diamagnetic character of their ions

Q40. The structural repeating unit of a common synthetic elastomer is shown below. Identify the name of this highly resilient addition polymer:



(A) Natural rubber

(B) Neoprene

(C) Buna-S

(D) Teflon

Detailed Solutions

Q1.

Solution

Concept:

The molecular formula $C_4H_{10}O$ corresponds to either saturated aliphatic alcohols or ethers. Ethers are chemical compounds characterized by an oxygen atom bonded to two alkyl groups. Unlike alcohols, ethers do not possess an active acidic hydrogen atom directly attached to an oxygen atom, which renders them completely unreactive toward electropositive alkali metals like metallic sodium under standard conditions.

Solution:

(a) Because the organic compound does not react with sodium metal, it cannot be an alcohol. This rules out options A and D, identifying the compound definitively as an ether.

(b) Ethers undergo cleavage when treated with an excess of concentrated hydroiodic acid (HI) at high temperatures, breaking the carbon-oxygen bonds to produce alkyl iodides.

(c) If the ether is symmetrical, such as diethyl ether ($CH_3CH_2OCH_2CH_3$), the cleavage yields two identical molecules of a single alkyl iodide, which would be iodoethane.

(d) The problem states that the reaction yields two different alkyl iodides. This signifies that the starting material must be an asymmetrical ether.

(e) Among the choices, methyl propyl ether ($CH_3OCH_2CH_2CH_3$) is an asymmetrical ether. When cleaved with excess hot HI, the reaction produces iodomethane (CH_3I) and 1-iodopropane ($CH_3CH_2CH_2I$), matching the description.

Final Answer: The structural formula of the original compound is $CH_3OCH_2CH_2CH_3$.

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept:

Chemical equilibrium constants expressed in terms of partial pressures (K_p) relate the equilibrium concentrations of gaseous reactants and products. For the gas-phase dissociation of dinitrogen tetroxide into nitrogen dioxide, the equilibrium position depends directly on the initial moles, the fraction of reactant that dissociates (α), and the total pressure (P) exerted by the system.

Solution:

(a) Assume the initial amount of $N_2O_4(g)$ is 1 mole and $NO_2(g)$ is 0 moles. At equilibrium, if the degree of dissociation is α, the remaining moles of N_2O_4 will be $1 - \alpha$, and the moles of NO_2 formed will be 2α.

(b) The total number of gaseous moles present at equilibrium is calculated by adding the individual components: $n_{\text{total}} = (1 - \alpha) + 2\alpha = 1 + \alpha$.

(c) Dalton's law of partial pressures states that the partial pressure of a gas is its mole fraction multiplied by the total pressure (P). Therefore, $p_{N_2O_4} = \frac{1-\alpha}{1+\alpha}P$ and $p_{NO_2} = \frac{2\alpha}{1+\alpha}P$.

(d) The equilibrium constant expression for this reaction is given by $K_p = \frac{(p_{NO_2})^2}{p_{N_2O_4}}$.

(e) Substituting the partial pressure values into the expression yields $K_p = \frac{[\frac{2\alpha}{1+\alpha}P]^2}{\frac{1-\alpha}{1+\alpha}P} = \frac{4\alpha^2P^2}{(1+\alpha)^2} \times \frac{1+\alpha}{(1-\alpha)P} = \frac{4\alpha^2P}{1-\alpha^2}$.

Final Answer: The expression for the equilibrium constant is $\frac{4\alpha^2P}{1-\alpha^2}$.

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept:

The reducing power of a metal reflects its structural tendency to lose electrons and undergo oxidation. In electrochemistry, this property is quantified using standard reduction potentials (E°). A lower, more negative standard reduction potential indicates that the oxidized form is stable, meaning the metal itself releases electrons very easily and acts as a strong reducing agent.

Solution:

(a) The given standard reduction potentials for the metal ions are: $E^\circ(X^{2+}/X) = -1.66$ V, $E^\circ(Y^{3+}/Y) = +0.34$ V, and $E^\circ(Z^{+}/Z) = -0.76$ V.

(b) An inverse relationship exists between the standard reduction potential of a metal ion and the reducing strength of its elemental metal form.

(c) Metal X has the lowest and most negative reduction potential (-1.66 V), indicating that it undergoes oxidation most readily. Therefore, X possesses the highest reducing power among the three.

(d) Metal Y has a positive reduction potential ($+0.34$ V), which means its oxidized form prefers to accept electrons rather than lose them. Thus, Y has the lowest reducing power.

(e) Metal Z lies intermediate with a potential of -0.76 V. Comparing these numerical values, the correct increasing order of reducing power is $Y < Z < X$.

Final Answer: The correct increasing order of the reducing power is $Y < Z < X$.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:

Crystal Field Theory (CFT) describes the splitting of degenerate d-orbitals in transition metal complexes due to electrostatic interactions with surrounding ligands. In an octahedral crystal field, the five d-orbitals split into two sets: lower energy triply degenerate t_{2g} orbitals and higher energy doubly degenerate e_g orbitals. The distribution of electrons depends on the ligand field strength.

Solution:

(a) The central metal ion in the complex $[CoF_6]^{3-}$ is cobalt in the +3 oxidation state (Co^{3+}). The atomic number of cobalt is 27, giving Co a ground-state configuration of $[Ar]3d^7 4s^2$.

(b) For the trivalent ion Co^{3+}, three electrons are removed, resulting in a valence electronic configuration of $[Ar]3d^6$.

(c) The fluoride ion (F^-) is a weak field ligand according to the spectrochemical series. It produces a small crystal field splitting energy (Δ_o), which is less than the electron pairing energy (P).

(d) Because $\Delta_o < P$, Hund's rule of maximum multiplicity is strictly followed, and electrons occupy the higher-energy orbitals before pairing up. This results in a high-spin configuration.

(e) The six d-electrons fill the split orbitals sequentially: four go into the t_{2g} set and two into the e_g set, yielding $t_{2g}^4 e_g^2$. This arrangement contains exactly 4 unpaired electrons.

Final Answer: The configuration is $t_{2g}^4 e_g^2$ with 4 unpaired electrons.

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:

Biodegradable polymers are synthetic macromolecules designed to decompose via natural environmental pathways, such as microbial action or hydrolysis, preventing long-term ecological accumulation. Polyamides are characterized by repeating amide linkages ($-CONH-$) within their backbone chain, typically formed through condensation reactions between carboxylic acid groups and amine functionalities.

Solution:

(a) The polymer Nylon 2-nylon 6 is an alternating biodegradable polyamide copolymer synthesized from two specific amino acid monomers: glycine and amino caproic acid.

(b) Glycine is a short-chain amino acid containing two carbon atoms with the structure $H_2N - CH_2 - COOH$. It provides the "Nylon 2" structural segment of the polymer.

(c) Amino caproic acid (also called 6-aminohexanoic acid) contains six carbon atoms with the chemical structure $H_2N - (CH_2)_5 - COOH$. It forms the "nylon 6" segment.

(d) Condensation polymerization occurs when the amino group of one monomer reacts with the carboxylic acid group of another, eliminating water molecules to create stable amide linkages.

(e) Unlike traditional synthetic polyamides like Nylon 6,6, Nylon 2-nylon 6 contains a specific structural arrangement that enzymes can readily break down, rendering it completely biodegradable.

Final Answer: The biodegradable polyamide is Nylon 2-nylon 6.

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept:

The Reimer-Tiemann reaction is an organic electrophilic aromatic substitution pathway used to introduce a formyl group ($-CHO$) onto an aromatic ring. Phenol undergoes ortho-formylation when treated with chloroform in an alkaline medium. The process relies on the generation of a highly reactive, neutral divalent carbon intermediate known as dichlorocarbene (: CCl_2).

Solution:

(a) Phenol reacts with aqueous sodium hydroxide ($NaOH$) to form a nucleophilic phenoxide ion, which is more reactive toward electrophilic attack than neutral phenol.

(b) Strong base removes a proton from chloroform ($CHCl_3$), followed by the loss of a chloride ion, generating the active electrophilic species, dichlorocarbene (: CCl_2).

(c) The phenoxide ion attacks the dichlorocarbene electrophile predominantly at the ortho-position due to favorable electrostatic coordination with the sodium counter-ion.

(d) Intermediate dichloromethyl derivatives undergo rapid alkaline hydrolysis to form an unstable geminal diol, which spontaneously loses a water molecule to create an aldehyde functional group.

(e) Final acidification converts the sodium phenoxide salt back into a phenol group, yielding ortho-hydroxybenzaldehyde, commonly known as salicylaldehyde, as the major product.

Final Answer: The major product obtained is Salicylaldehyde.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:

The empirical formula of a crystalline solid describes the simplest whole-number ratio of constituent atoms or ions within its structural unit cell. In closed-packed arrangements, the total number of tetrahedral and octahedral interstitial voids is directly determined by the total number of packing atoms forming the primary lattice framework.

Solution:

(a) In a face-centered cubic (fcc) or cubic close-packed (ccp) crystal lattice, the anions B form the lattice points. The effective number of anions B per unit cell is 4.

(b) For a close-packed lattice containing N atoms, the total number of tetrahedral voids generated inside the unit cell is exactly equal to $2N$.

(c) Since there are 4 anions (B) per unit cell, the total number of available tetrahedral voids within the lattice is $2 \times 4 = 8$.

(d) The problem states that cations A occupy exactly half of these tetrahedral voids. Therefore, the effective number of cations A in the unit cell is $\frac{1}{2} \times 8 = 4$.

(e) The ratio of cations to anions within a single unit cell is $A : B = 4 : 4$. Simplifying this to the lowest whole-number ratio gives $1 : 1$, which establishes the empirical formula as AB.

Final Answer: The simplest empirical formula of the compound is AB.

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept:

Valence Shell Electron Pair Repulsion (VSEPR) theory predicts the three-dimensional geometric arrangement of molecules based on minimizing electrostatic repulsion between bonding and non-bonding valence electron pairs around a central atom. Steric number calculations determine the corresponding hybridization state and ideal spatial orientation.

Solution:

(a) In xenon oxytetrafluoride ($XeOF_4$), the central atom is xenon (Xe). Xenon is a noble gas and possesses exactly 8 valence electrons in its outermost shell.

(b) Xenon forms four single covalent bonds with the four fluorine atoms, which consumes 4 valence electrons. It also forms one double bond with the oxygen atom, which consumes 2 valence electrons.

(c) This leaves $8 - (4 + 2) = 2$ non-bonding valence electrons, which pair up to form exactly 1 lone pair on the central xenon atom.

(d) The steric number is calculated by adding the number of sigma bonds and lone pairs around the central atom: Steric Number = 5 (sigma bonds) + 1 (lone pair) = 6.

(e) A steric number of 6 corresponds to sp^3d^2 hybridization. Because there are 5 bonding regions and 1 lone pair, the spatial molecular geometry becomes square pyramidal to minimize electron repulsion.

Final Answer: The geometry and hybridization are square pyramidal and sp^3d^2.

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:

Nucleic acids, including Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (RNA), are biopolymers essential for genetic storage, expression, and transfer. Their secondary structures are stabilized by specific hydrogen bonds formed between complementary heterocyclic purine and pyrimidine nitrogenous bases, conforming to strict structural pairing rules.

Solution:

(a) DNA and RNA exhibit distinct structural variations. DNA contains the pyrimidine thymine, whereas RNA replaces thymine with uracil to pair with adenine.

(b) The underlying pentose sugar units differ: RNA incorporates D-ribose, which possesses a hydroxyl group at the C2 position, while DNA incorporates D-2-deoxyribose.

(c) DNA typically exists as a highly stable double-stranded right-handed helix, whereas RNA molecules are synthesized as single-stranded polynucleotide chains that can fold into complex structures.

(d) In double-stranded nucleic acid frameworks, complementary hydrogen base pairing occurs strictly between Adenine and Thymine (or Uracil in RNA) via two hydrogen bonds, and between Guanine and Cytosine via three hydrogen bonds.

(e) Statement D asserts that Adenine pairs with Cytosine in double-stranded RNA, which violates these base-pairing rules. This makes it the incorrect statement.

Final Answer: The incorrect statement is that double-stranded RNA contains complementary base pairing between Adenine and Cytosine.

Answer: (D)

Go Back to Question 9

Q10.

Solution

Concept:

Alkyl-substituted aromatic hydrocarbons undergo side-chain oxidation when treated with powerful oxidizing agents like hot alkaline potassium permanganate ($KMnO_4$). Regardless of the length or complexity of the alkyl side chain, the presence of at least one benzylic hydrogen atom leads to total degradation of the chain, converting the benzylic carbon into a carboxylic acid group.

Solution:

(a) The provided TikZ diagram displays a toluene molecule, which consists of a methyl group directly linked to a benzene ring system.

(b) The methyl group possesses three benzylic hydrogen atoms, making it highly susceptible to oxidative cleavage by potassium permanganate.

(c) When treated with hot alkaline $KMnO_4$, the methyl group is fully oxidized to a carboxylate salt intermediate, specifically potassium benzoate (C_6H_5COOK).

(d) Subsequent acid workup or aqueous acidification (step ii) protonates the soluble potassium benzoate salt, precipitating out the stable aromatic carboxylic acid.

(e) The final organic product obtained from this chemical transformation sequence is benzoic acid (C_6H_5COOH), which is represented by option C.

Final Answer: The major organic product formed is Benzoic acid.

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:

The temperature dependence of chemical reaction rates is accurately quantified using the Arrhenius equation. This fundamental equation establishes a mathematical relationship between the reaction rate constant, the absolute thermodynamic temperature, the pre-exponential frequency factor, and the minimum activation energy threshold required for reacting molecules to successfully cross the potential energy barrier.

Solution:

(a) The classical exponential form of the Arrhenius equation is expressed mathematically as $k = Ae^{-E_a/RT}$.

(b) To convert this relationship into a linear mathematical equation, we take the natural logarithm of both sides, resulting in the expression $\ln k = \ln A - \frac{E_a}{RT}$.

(c) Rearranging the terms reveals a linear equation format matching the standard equation of a straight line, which is expressed as $y = mx + c$.

(d) Mapping the parameters directly, the dependent variable y corresponds to $\ln k$, while the independent variable x corresponds to the reciprocal temperature term $1/T$.

(e) The vertical intercept c corresponds to $\ln A$, and the functional multiplier m, which defines the structural orientation of the line, represents the slope and equals $-E_a/R$.

Final Answer: The value of the slope of this line is $-E_a/R$.

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:

The structural magnitude of paramagnetic behavior in coordination complexes depends directly on the number of unpaired d-electrons present in the central transition metal ion. According to crystal field splitting parameters, the distribution of these valence electrons between the split t_{2g} and e_g orbital subsets is governed by the relative field strength exerted by the surrounding coordinate ligands.

Solution:

(a) In $[Fe(CN)_6]^{3-}$, the central metal is Fe^{3+} with a d^5 configuration, and because cyanide is a strong-field ligand, it induces electron pairing, leaving only 1 unpaired electron.

(b) In $[Mn(H_2O)_6]^{2+}$, the central metal is Mn^{2+} with a d^5 configuration. Since water is classified as a weak-field ligand, crystal field splitting is minimal, resulting in a high-spin system with 5 unpaired electrons.

(c) In $[Co(NH_3)_6]^{3+}$, the central metal is Co^{3+} with a d^6 configuration. Amine acts as a strong-field ligand here, forcing all d-electrons to pair up completely, which leaves 0 unpaired electrons.

(d) In $[NiCl_4]^{2-}$, the central metal is Ni^{2+} with a d^8 configuration, which naturally results in 2 unpaired electrons within its tetrahedral field arrangement.

(e) Comparing these values, the hexaaquamanganese(II) complex exhibits the maximum number of unpaired electrons and displays the highest paramagnetic signature.

Final Answer: The complex expected to exhibit maximum paramagnetic behavior is $[Mn(H_2O)_6]^{2+}$.

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:

Photochemical smog is a modern atmospheric pollution phenomenon that develops over urban environments characterized by high solar irradiation and dense vehicular emissions. The generation of this oxidizing haze depends on secondary volatile chemical cascades triggered by the interaction of primary combustion byproducts with atmospheric oxygen under the influence of intense ultraviolet sunlight.

Solution:

(a) The primary components emitted directly from internal combustion engines into the lower troposphere are unburned volatile hydrocarbons and various nitrogen oxides, particularly nitrogen monoxide and nitrogen dioxide.

(b) Under the influence of solar ultraviolet radiation, nitrogen dioxide undergoes photolysis to yield highly reactive atomic oxygen, which combines with molecular oxygen to produce tropospheric ozone.

(c) Tropospheric ozone reacts further with ambient unburned hydrocarbons to generate hazardous secondary lachrymatory pollutants, including peroxyacetyl nitrate, formally abbreviated as PAN, alongside various acrid aldehydes.

(d) Therefore, the core chemical cocktail that drives the propagation of photochemical smog comprises ozone, peroxyacetyl nitrate, and nitrogen oxides, working in tandem within sunny climates.

(e) This differentiates it from classical reducing sulfurous smog, which is driven primarily by sulfur dioxide gas and cold soot particles.

Final Answer: The constituents responsible for photochemical smog are O_3, PAN, and Nitrogen Oxides.

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:

Organic functional groups are identified analytically through a series of selective chemical classification tests. The 2,4-dinitrophenylhydrazine reagent selectively targets the carbonyl group of aldehydes and ketones, whereas Tollen's silver mirror test differentiates between them based on ease of oxidation. The iodoform reaction identifies the specific structural presence of a methyl carbonyl linkage.

Solution:

(a) The positive response to the 2,4-DNP diagnostic test confirms that the unknown organic molecule P contains a carbonyl functional group, restricting the possibilities to either an aldehyde or a ketone.

(b) The observation that compound P completely fails to reduce Tollen's reagent rules out all aliphatic and aromatic aldehyde isomers, establishing that the molecule is structurally a ketone.

(c) The formulation of a bright yellow iodoform precipitate upon treatment with iodine and sodium hydroxide demands the presence of a specific methyl ketone segment, structurally represented as CH_3CO-.

(d) Given the molecular formula is $C_5H_{10}O$, subtracting the three-carbon methyl ketone piece leaves an ethyl group, structurally represented as $-CH_2CH_3$, to complete the structure.

(e) Assembling these units yields a single continuous molecular chain called pentan-2-one, whereas its isomer pentan-3-one lacks the necessary methyl ketone structural element to give a positive iodoform test.

Final Answer: The structure of compound P is Pentan-2-one.

Answer: (C)

Go Back to Question 14

Q15.

Solution

Concept:

The kinetic velocity of a chemical reaction depends directly on the localized concentration profiles of its active reactants raised to powers equal to their empirical reaction orders. For gas-phase or solution-phase systems, changing the physical boundaries of the reaction container alters the volume, which inversely modifies the molar concentration of every individual component present.

Solution:

(a) The initial kinetic rate law for the chemical conversion is given by the mathematical expression $\text{Rate}_1 = k[A]^2[B]$.

(b) Molar concentration is defined by the absolute ratio of chemical moles to container volume (n/V). When the container volume is reduced to one-third $(V_2 = V_1/3)$, the internal concentration of each reactant increases threefold.

(c) The new concentration profiles can be expressed in terms of the original values as $[A'] = 3[A]$ and $[B'] = 3[B]$.

(d) Substituting these new concentration values into the empirical rate law yields the updated expression $\text{Rate}_2 = k(3[A])^2(3[B])$.

(e) Simplifying the mathematical expression by factoring out the constants gives $\text{Rate}_2 = k \cdot 9[A]^2 \cdot 3[B] = 27 \cdot k[A]^2[B]$. This demonstrates that the final rate is exactly 27 times the initial value.

Final Answer: The rate of the reaction increases to 27 times its initial value.

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:

The structural geometry and atomic sizes of transition metals follow predictable periodic trends that are modified by relativistic and electronic screening effects. Lanthanoid contraction refers to the steady, progressive decrease in atomic and ionic radii observed across the 4f transition series, arising from the poor electrostatic shielding capability of filled 4f electron shells.

Solution:

(a) As the nuclear charge increases across the lanthanoid series, the 4f electrons added fail to shield the outer valence shells effectively from the growing positive nuclear pull, causing the atomic boundary to contract.

(b) This contraction across the 4f row counteracts the expected increase in atomic radius that typically occurs when moving down a group from the second to the third transition series.

(c) Consequently, elements in the second ($4d$) and third ($5d$) transition series within the same vertical periodic group exhibit nearly identical atomic and ionic dimensions.

(d) Looking at the specific pairings, Zirconium (Zr) belongs to the $4d$ series and Hafnium (Hf) belongs to the $5d$ series in Group 4, so they share nearly identical radii.

(e) Similarly, Niobium (Nb) from the $4d$ series and Tantalum (Ta) from the $5d$ series in Group 5 exhibit almost identical dimensions, making both options B and C correct.

Final Answer: The elements with almost identical atomic radii are both (B) and (C).

Answer: (D)

Go Back to Question 16

Q17.

Solution

Concept:

The addition of hydrogen bromide to unsymmetrical alkenes follows different regiochemical pathways depending on the reaction conditions. In the presence of organic peroxides, the addition proceeds via a radical chain mechanism rather than a carbocation pathway, reversing the standard regiochemical outcome in a process known as the anti-Markovnikov addition.

Solution:

(a) The provided TikZ schematic shows 3-methylbut-1-ene reacting with hydrogen bromide in the presence of an organic peroxide catalyst.

(b) The reaction initiates when the peroxide decomposes into radicals that react with HBr to generate a highly reactive bromine radical ($\cdot Br$).

(c) The bromine radical attacks the terminal alkene, adding to the less substituted carbon atom to produce the more stable secondary carbon radical intermediate.

(d) This secondary radical intermediate, structurally written as $(CH_3)_2CH - \dot{C}H - CH_2Br$, avoids undergoing skeletal rearrangement because radical migrations are energetically less favorable than carbocation rearrangements.

(e) The intermediate radical then abstracts a hydrogen atom from another HBr molecule to yield the final stable product, 1-bromo-3-methylbutane, as the dominant product.

Final Answer: The major organic product Y generated is 1-Bromo-3-methylbutane.

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept:

The thermal stability of alkaline earth metal carbonates toward heat-induced decomposition depends directly on the polarizability of the carbonate anion. When heated, these metal carbonates decompose to yield the corresponding solid metal oxide and gaseous carbon dioxide, driven by the lattice energy modifications of the resulting phases.

Solution:

(a) The decomposition reaction can be represented generally as $MCO_3(s) \rightarrow MO(s)+CO_2(g)$, where M represents any divalent alkaline earth metal cation.

(b) Moving down Group 2 from beryllium and magnesium to barium, the ionic radius of the metal cation increases steadily while the overall 2+ charge remains constant.

(c) Smaller cations, such as Mg^{2+}, possess a high charge density that strongly polarizes the electron cloud of the adjacent carbonate anion, weakening its internal carbon-oxygen covalent bonds.

(d) This strong polarization stabilizes the resulting metal oxide lattice, allowing decomposition to occur at relatively low temperatures.

(e) Larger cations downstream, like Ba^{2+}, have a lower charge density and exert minimal polarizing distortion, which keeps the carbonate framework intact up to much higher temperatures.

(f) Therefore, thermal stability increases down the group in the sequence: $MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$.

Final Answer: The correct order of increasing thermal stability is $MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$.

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:

Osmotic pressure is a colligative property that depends entirely on the total concentration of dissolved solute particles in a solution, rather than the chemical identity of the solute itself. For electrolytic solutes that undergo dissociation in an aqueous medium, the effective particle concentration must be adjusted using the van 't Hoff factor (i).

Solution:

(a) The mathematical formula used to calculate osmotic pressure is $\Pi = iCRT$, where C is the molar concentration, R is the ideal gas constant, and T is the absolute thermodynamic temperature.

(b) Magnesium chloride ($MgCl_2$) dissolves in water to release three ions per formula unit: one magnesium cation and two chloride anions, according to the equation $MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2Cl^{-}(aq)$.

(c) Assuming complete dissociation of the salt, the van 't Hoff factor i is exactly equal to 3.

(d) Substituting the given values into the equation yields: $\Pi = 3 \times 0.1\ \text{mol L}^{-1} \times 0.0821\ \text{L atm K}^{-1}\text{mol}^{-1} \times 300\ \text{K}$.

(e) Simplifying the calculation gives $\Pi = 0.3 \times 24.63$, which evaluates to 7.389 atm, rounding to 7.39 atm.

Final Answer: The osmotic pressure of the solution is 7.39 atm.

Answer: (C)

Go Back to Question 19

Q20.

Solution

Concept:

Carbohydrates are classified as reducing or non-reducing based on the presence of a free, unlinked anomeric carbon atom that can open into an active chain aldehyde or ketone form. Non-reducing sugars lack free hemiacetal or hemiketal functionalities because the anomeric carbons of their constituent monosaccharide units are locked within the glycosidic linkage.

Solution:

(a) Sucrose is a common disaccharide that does not reduce Tollen's or Fehling's solutions because it lacks a free carbonyl group.

(b) It is composed of an α-D-glucopyranose ring unit and a β-D-fructofuranose ring unit joined together by a condensation linkage.

(c) The glycosidic bond forms directly between the C1 anomeric carbon of the glucose monomer and the C2 anomeric carbon of the fructose monomer.

(d) Because both anomeric centers are involved in the linkage, neither ring can undergo ring-opening in an aqueous environment to generate a reducing aldehyde or ketone group.

(e) Other disaccharides, like maltose and lactose, retain a free hemiacetal group on one of their rings, allowing them to act as reducing sugars.

Final Answer: The non-reducing disaccharide described is Sucrose.

Answer: (C)

Go Back to Question 20

Q21.

Solution

Concept:

The structural stability of carbon-based intermediates called carbocations is determined primarily by hyperconjugation and inductive effects. Hyperconjugation involves the stabilizing delocalization of electronic charge from adjacent carbon-hydrogen bonds into the empty p-orbital of the carbocation center. Consequently, a greater number of alpha-hydrogens leads to a more stable molecular structure.

Solution:

(a) In framework II, the positive charge resides on a tertiary carbon atom that is directly attached to two methyl groups and one ethyl group, providing a total of eight alpha-hydrogens that maximize hyperconjugative stabilization.

(b) In framework I, the positive charge is localized on a primary carbon node next to a tertiary carbon atom, providing only one alpha-hydrogen from the adjacent tertiary center for stabilizing overlap.

(c) In framework III, the positive charge is located on a primary carbon node next to a secondary carbon atom, giving it exactly two alpha-hydrogens from the neighboring methylene group.

(d) Comparing the electronic properties, the tertiary carbocation II is the most stable, followed by the primary carbocation III, which has two alpha-hydrogens, while primary carbocation I is the least stable with only one.

(e) This systematic comparison gives the proper decreasing stability order for these specific structural carbocations as II > III > I.

Final Answer: The decreasing order of carbocation stability is II > III > I.

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept:

The industrial metallurgy of copper from sulfide ores such as copper pyrites involves crushing, concentration by froth flotation, roasting, and smelting. During smelting in a blast furnace, the partially roasted ore is heated with silica flux to remove iron impurities as a fusible slag, leaving behind an intermediate liquid sulfide phase.

Solution:

(a) Roasting converts iron sulfide preferentially into iron oxide due to its higher affinity for oxygen, while copper remains primarily in its stable sulfide form.

(b) The roasted material is melted with silica (SiO_2) in a reverberatory furnace, where iron oxide reacts to form a molten iron silicate slag ($FeSiO_3$) that floats on top.

(c) The heavy molten layer that settles at the bottom of the furnace is a dense chemical mixture known technically as copper matte.

(d) This copper matte consists primarily of cuprous sulfide (Cu_2S) along with a small remaining fraction of unreacted ferrous sulfide (FeS).

(e) The liquid matte is subsequently transferred into a Bessemer converter, where controlled self-reduction with air yields high-purity elemental blister copper.

Final Answer: The composition of copper matte is Cu_2S and FeS.

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept:

The electrical conductivity of weak electrolytes depends directly on their extent of ionization at a specific molar concentration. According to Arrhenius and Ostwald, the degree of dissociation can be determined from the ratio of the equivalent conductance at a given concentration to the limiting equivalent conductance at infinite dilution.

Solution:

(a) The degree of dissociation (α) of the weak monobasic acid is calculated using the standard conductance ratio: $\alpha = \frac{\Lambda_c}{\Lambda_0}$.

(b) Substituting the provided numerical parameters into this relationship yields: $\alpha = \frac{16 \text{ S cm}^2\text{eq}^{-1}}{400 \text{ S cm}^2\text{eq}^{-1}} = 0.04$.

(c) For a weak monobasic acid HA dissociating into H^+ and A^-, the equilibrium constant is represented by the Ostwald dilution law: $K_a = \frac{C\alpha^2}{1-\alpha}$.

(d) Given that $\alpha = 0.04$, which is significantly smaller than 1, the denominator can be safely approximated as $1 - \alpha \approx 1$.

(e) Substituting the molar concentration ($C = 0.01$ M) into the simplified expression gives: $K_a = 0.01 \times (0.04)^2 = 10^{-2} \times 1.6 \times 10^{-3} = 1.6 \times 10^{-5}$.

Final Answer: The dissociation constant of the weak acid is 1.6×10^{-5}.

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept:

Acid rain is an environmental phenomenon caused by the release of gaseous acidic oxides into the atmosphere, where they dissolve in water droplets to form acidic solutions. The primary gaseous precursors include oxides of non-metallic elements that undergo rapid oxidation and hydration to generate strong mineral acids.

Solution:

(a) High-temperature combustion and industrial activities release large quantities of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) into the atmosphere.

(b) These gases undergo atmospheric oxidation to form nitric acid (HNO_3) and sulfuric acid (H_2SO_4), which significantly lower the pH of precipitation.

(c) Carbon dioxide (CO_2) dissolves naturally in rainwater to form carbonic acid (H_2CO_3), contributing to mild natural acidity.

(d) Argon is a chemically inert noble gas belonging to Group 18 of the periodic table, possessing a completely filled valence electron shell.

(e) Because of its electronic stability, argon does not form any stable gaseous chemical oxides and plays no role in the formation of acid rain.

Final Answer: The element that does not form a gaseous oxide producing acid rain is Argon.

Answer: (D)

Go Back to Question 24

Q25.

Solution

Concept:

The reaction of hexose monosaccharides with excess phenylhydrazine yields crystalline derivatives known as osazones. This chemical transformation modifies only the C1 and C2 carbon positions of the carbohydrate, converting them into phenylhydrazone groups while leaving the configuration of the remaining carbon chain completely unchanged.

Solution:

(a) During osazone formation, the aldehyde group at C1 and the adjacent hydroxyl group at C2 are converted into diphenylhydrazone linkages.

(b) Any two hexose sugars that share identical stereochemical configurations at the C3, C4, and C5 carbon positions will yield the exact same osazone product.

(c) D-glucose and D-mannose are epimers that differ structurally only in the stereochemical configuration around the C2 carbon atom.

(d) Because their stereochemistry from C3 down to C5 is completely identical, the configuration differences at C2 are erased during the reaction, leading to the same osazone.

(e) In contrast, D-galactose is a C4 epimer of D-glucose, meaning it retains its distinct configuration at C4 and produces a completely different osazone derivative.

Final Answer: The hexose sugar that yields the exact same osazone is D-Mannose.

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:

The relative acidity of substituted carboxylic acids depends on the electronic effects of the substituents attached to the aromatic ring. Electron-withdrawing groups stabilize the carboxylate anion by dispersing its negative charge, increasing acidity, whereas electron-donating groups destabilize it by concentrating charge density, decreasing acidity.

Solution:

(a) Compound X is unsubstituted benzoic acid, which serves as the reference standard for evaluating inductive and mesomeric effects.

(b) Compound Y contains a nitro group ($-NO_2$) at the para-position, which acts as a powerful electron-withdrawing group via both inductive ($-I$) and resonance ($-M$) effects.

(c) This strong electron withdrawal stabilizes the conjugate base, making para-nitrobenzoic acid significantly more acidic than unsubstituted benzoic acid.

(d) Compound Z possesses a methoxy group ($-OCH_3$) at the para-position, which acts as an electron-donating group through resonance ($+M$) despite its weak $-I$ effect.

(e) This electron donation increases the electron density on the carboxylate group, destabilizing the anion and making para-methoxybenzoic acid the least acidic, establishing the order Z < X < Y.

Final Answer: The correct increasing order of acidity is Z < X < Y.

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept:

The photoelectric effect describes the emission of electrons from a metal surface when it is illuminated by light of sufficient energy. According to Einstein's photoelectric equation, the total energy of an incident photon is split between overcoming the surface work function and providing kinetic energy to the emitted electron.

Solution:

(a) The total energy (E) carried by an incident photon is determined from its wavelength using the Planck-Einstein relation: $E = \frac{hc}{\lambda}$.

(b) Using the conversion factor $hc \approx 1240$ eV nm, the energy of a 200 nm photon is calculated as: $E = \frac{1240 \text{ eV nm}}{200 \text{ nm}} = 6.2$ eV.

(c) Einstein's photoelectric equation states that the maximum kinetic energy of the emitted electrons is given by: $K_{\max} = E - \Phi$.

(d) Substituting the calculated photon energy (6.2 eV) and the given work function ($\Phi = 4.0$ eV) into the equation yields: $K_{\max} = 6.2 \text{ eV} - 4.0 \text{ eV} = 2.2$ eV.

(e) This indicates that each escaping photoelectron carries a maximum kinetic energy of 2.2 eV after overcoming the surface potential energy barrier.

Final Answer: The maximum kinetic energy of the emitted photoelectrons is 2.2 eV.

Answer: (A)

Go Back to Question 27

Q28.

Solution

Concept:

Geometric isomerism occurs in coordination complexes when ligands can occupy different spatial arrangements relative to one another around the central metal atom. This type of isomerism is commonly observed in square planar and octahedral geometries with specific ligand combinations, but it cannot occur in tetrahedral arrangements due to their symmetric nature.

Solution:

(a) The complex $[Co(NH_3)_5Cl]Cl_2$ is an octahedral complex of the type $[MA_5B]$, where all coordination sites are equivalent, preventing the formation of geometric isomers.

(b) The complex $[Pt(NH_3)_2Cl_2]$ is a square planar complex of the type $[M_2B_2]$. This geometry allows for two distinct spatial arrangements of the ligands.

(c) When identical ligands are positioned adjacent to each other at a 90° angle, it forms the cis-isomer, whereas positioning them opposite each other at 180° forms the trans-isomer.

(d) The complex $[Ni(CO)_4]$ has a symmetric tetrahedral geometry, which means all coordination positions are equidistant from one another, preventing geometric isomerism.

(e) The complex $[Fe(H_2O)_6]Cl_3$ is an octahedral complex containing six identical aqua ligands ($[MA_6]$), making all spatial arrangements structurally identical.

Final Answer: The compound that displays geometric isomerism is $[Pt(NH_3)_2Cl_2]$.

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept:

Biochemical Oxygen Demand (BOD) is an environmental water quality index that measures the amount of dissolved oxygen consumed by aerobic microorganisms to decompose organic matter present in a water sample. It serves as a direct indicator of organic pollution levels in aquatic ecosystems.

Solution:

(a) Clean, unpolluted water typically has a very low BOD value, generally below 5 ppm, indicating minimal organic contamination and high dissolved oxygen levels.

(b) When wastewater contains large amounts of biodegradable organic matter, it triggers rapid microbial growth and increased respiration.

(c) This high microbial activity consumes dissolved oxygen rapidly, leading to high BOD values and leaving less oxygen available to support aquatic life.

(d) A measured BOD value of 250 ppm indicates a very high concentration of organic pollutants, typical of untreated municipal wastewater.

(e) Therefore, a high BOD value directly implies that the water sample is heavily contaminated with biodegradable organic wastes.

Final Answer: The water sample is heavily polluted with biodegradable organic wastes.

Answer: (C)

Go Back to Question 29

Q30.

Solution

Concept:

Diazotization is a fundamental organic reaction in which a primary aromatic amine is converted into a stable diazonium salt. This transformation requires nitrous acid (HNO_2), which must be generated in situ due to its chemical instability, and must be kept at low temperatures to prevent decomposition into phenol.

Solution:

(a) The provided TikZ schematic shows the conversion of aniline ($C_6H_5NH_2$) into a benzene diazonium chloride salt ($C_6H_5N_2^+Cl^-$).

(b) This reaction is carried out by treating the primary aromatic amine with an ice-cold mixture of sodium nitrite ($NaNO_2$) and concentrated hydrochloric acid (HCl).

(c) The reaction between sodium nitrite and hydrochloric acid generates nitrous acid, which then undergoes protonation and loses water to form the active electrophile, the nitrosonium ion (^+NO).

(d) The nitrosonium ion attacks the nucleophilic amino nitrogen atom of aniline, followed by a series of proton transfers and water elimination to form the diazonium linkage.

(e) Maintaining a low temperature range of 0–5°C is essential to stabilize the diazonium salt and prevent it from reacting with water to form phenol.

Final Answer: The highly active reagent W is $NaNO_2 + HCl$.

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept:

The overall order of a chemical reaction is defined as the sum of the concentration exponents in its experimentally determined rate law. The units of the rate constant change systematically depending on this overall reaction order because it balances the dimensions of time, volume, and chemical amount.

Solution:

(a) For a generalized chemical reaction of order n, the rate of the reaction is related to reactant concentrations by the expression Rate $= k[\text{Concentration}]^n$.

(b) Rearranging this expression to isolate the rate constant gives the formula $k = \frac{\text{Rate}}{[\text{Concentration}]^n}$.

(c) Substituting the standard SI units for rate (mol L^{-1} s^{-1}) and concentration (mol L^{-1}) yields the generalized unit expression: $k = (\text{mol } L^{-1})^{1-n}\ s^{-1} = L^{n-1}\ \text{mol}^{1-n}\ s^{-1}$.

(d) The problem states that the units of the rate constant for the given gas-phase reaction are L mol^{-1} s^{-1}.

(e) Comparing the exponent of the liters unit in both terms gives the algebraic equation $n-1 = 1$, which simplifies directly to $n = 2$, identifying it as a second-order reaction.

Final Answer: The overall order of this chemical reaction is Second order.

Answer: (C)

Go Back to Question 31

Q32.

Solution

Concept:

The molecular structures of phosphorus oxyacids are characterized by tetrahedral coordination geometry around each phosphorus center. Every individual phosphorus atom is bonded to at least one oxo oxygen via a double bond and to at least one hydroxyl group via a single bond, while additional linkages can include direct phosphorus-phosphorus or phosphorus-hydrogen bonds.

Solution:

(a) Hypophosphoric acid ($H_4P_2O_6$) is a dimeric oxyacid where two symmetric phosphorus atoms are linked together directly by a single covalent phosphorus-phosphorus ($P-P$) bond.

(b) The structural framework of $H_4P_2O_6$ features each phosphorus atom bonded to one oxo oxygen atom (P = O) and two hydroxyl groups (P – OH), meaning it contains no direct P – H bonds.

(c) Pyrophosphoric acid ($H_4P_2O_7$) contains a central bridging oxygen link (P – O – P) rather than a direct phosphorus-phosphorus bond, and it lacks any P – H bonds.

(d) Hypophosphorous acid (H_3PO_2) contains a single phosphorus center bonded directly to two hydrogen atoms (P – H), but it cannot possess a P – P bond because it is monomeric.

(e) None of the standard choices listed simultaneously satisfy both requirements; however, analyzing the chemical formulas reveals that a direct P – P bond along with P – H linkages is uniquely found in isohypophosphoric acid ($H_4P_2O_6$), making option A the closest matching choice under structural classification.

Final Answer: The oxyacid possessing a structure with a direct $P-P$ bond is Hypophosphoric acid.

Answer: (A)

Go Back to Question 32

Q33.

Solution

Concept:

The Cannizzaro reaction is a redox disproportionation process that occurs when aldehydes are exposed to concentrated strong bases. This reaction requires that the starting aldehyde completely lacks alpha-hydrogen atoms, preventing it from undergoing competitive base-catalyzed aldol condensation pathways.

Solution:

(a) Aldehydes containing alpha-hydrogens, such as acetaldehyde (CH_3CHO) and propanal (CH_3CH_2CHO), undergo rapid deprotonation to form reactive enolate intermediates that yield aldol condensation products.

(b) Ketones like acetone (CH_3COCH_3) possess alpha-hydrogens and follow similar enolate-driven condensation chemistry when treated with concentrated alkaline solutions.

(c) Benzaldehyde (C_6H_5CHO) is an aromatic aldehyde where the carbonyl carbon is bonded directly to the sp2 carbon of a benzene ring, leaving it with zero alpha-hydrogens.

(d) When treated with concentrated sodium hydroxide, one molecule of benzaldehyde undergoes nucleophilic attack by a hydroxide ion to form a tetrahedral intermediate.

(e) This intermediate transfers a hydride ion to a second benzaldehyde molecule, causing one to be oxidized to a sodium benzoate salt and the other to be reduced to benzyl alcohol.

Final Answer: The structure that undergoes the Cannizzaro reaction is C_6H_5CHO.

Answer: (C)

Go Back to Question 33

Q34.

Solution

Concept:

The total vapor pressure exerted by an ideal liquid mixture containing multiple volatile components is governed by Raoult's law. This physical law states that the partial vapor pressure of each individual component is equal to the product of its pure component vapor pressure and its equilibrium mole fraction within the liquid phase.

Solution:

(a) The total number of chemical moles present in the volatile liquid mixture is calculated by summing the individual amounts: $n_{\text{total}} = 2$ moles of $X + 3$ moles of $Y = 5$ moles.

(b) The equilibrium liquid mole fraction (x_X) for component X is calculated as the ratio of its moles to the total moles: $x_X = \frac{2}{5} = 0.4$.

(c) Similarly, the equilibrium liquid mole fraction (x_Y) for component Y is determined by the ratio of its moles to the total moles: $x_Y = \frac{3}{5} = 0.6$.

(d) According to Raoult's law, the total vapor pressure (P_{total}) is equal to the sum of the partial pressures: $P_{\text{total}} = (P_X^\circ \times x_X) + (P_Y^\circ \times x_Y)$.

(e) Substituting the given values into the equation yields: $P_{\text{total}} = (200\ \text{mmHg} \times 0.4) + (300\ \text{mmHg} \times 0.6) = 80 + 180 = 260\ \text{mmHg}$.

Final Answer: The total vapor pressure of the solution is 260 mmHg.

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept:

The average oxidation state of an element within a polyatomic molecular ion is determined from its chemical stoichiometry and charge balance. By convention, oxygen is assigned a fixed oxidation state of -2 in standard oxoanion frameworks, allowing the calculation of the matching oxidation states for the remaining atoms.

Solution:

(a) The chemical structure shown in the TikZ coordinate space represents the thiosulfate anion, which carries a net formula of $S_2O_3^{2-}$.

(b) Let the average oxidation state of the two constituent sulfur atoms within this chemical assembly be represented by the variable x.

(c) Since the three oxygen atoms each possess a standard oxidation state of -2, their combined contribution to the polyatomic ion is equal to -6.

(d) Setting up the charge balance equation for the thiosulfate ion gives: $2x + 3(-2) = -2$.

(e) Solving this linear equation yields $2x - 6 = -2$, which simplifies to $2x = +4$, resulting in an average oxidation state of $x = +2$ for the sulfur atoms.

Final Answer: The average oxidation state of the sulfur atoms is +2.

Answer: (A)

Go Back to Question 35

Q36.

Solution

Concept:

The concentration of fluoride ions in municipal drinking water must be carefully regulated to balance dental health benefits against systemic toxicity. While trace quantities strengthen tooth enamel by converting hydroxyapatite into fluorapatite, excessive exposure leads to progressive structural damage in bones and teeth.

Solution:

(a) Controlled fluoride concentrations up to 1 ppm prevent dental caries by making tooth enamel more resistant to acid attack by plaque bacteria.

(b) When fluoride levels rise above 1.5 ppm, it begins to cause dental fluorosis, which manifests as brown mottling and discoloration of the teeth.

(c) If the dissolved fluoride ion concentration exceeds a critical threshold value of 2.0 ppm, the risk of systemic toxic effects increases significantly.

(d) Chronic consumption of water with fluoride levels above this threshold results in severe skeletal fluorosis, characterized by bone mineral abnormalities, joint stiffness, and structural deformities.

(e) Therefore, 2.0 ppm represents the critical upper safety threshold beyond which fluoride ions cause severe bone fluorosis and noticeable teeth mottling.

Final Answer: The threshold value above which severe bone fluorosis occurs is 2.0 ppm.

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept:

The Hoffmann Bromamide reaction is an organic degradation pathway used to convert primary amides into primary amines containing one fewer carbon atom. This transformation proceeds via an isocyanate intermediate that undergoes base-catalyzed hydrolysis and decarboxylation, removing the carbonyl carbon as a carbonate byproduct.

Solution:

(a) The primary transformation involves treating an aliphatic or aromatic amide with molecular bromine in the presence of a strong aqueous base like sodium hydroxide.

(b) Option B outlines the exact chemical equation for this degradation: $R - CONH_2 + Br_2 + 4NaOH \rightarrow R - NH_2 + Na_2CO_3 + 2NaBr + 2H_2O$.

(c) Option A represents the simple nucleophilic acyl substitution of a carboxylic acid with ammonia to yield a primary amide.

(d) Option C describes the complete reduction of an organic nitrile to a primary amine using lithium aluminum hydride ($LiAlH_4$).

(e) Option D illustrates the carbylamine reaction, where a primary amine reacts with chloroform and potassium hydroxide to form an isocyanide.

Final Answer: The transformation representing the Hoffmann Bromamide degradation is option B.

Answer: (B)

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Q38.

Solution

Concept:

Entropy is a fundamental thermodynamic state function that quantifies the degree of statistical disorder or microscopic randomness within a system. For an ideal gas undergoing a reversible process, the change in entropy is determined by integrating the ratio of the incremental heat transfer to the absolute thermodynamic temperature.

Solution:

(a) According to the first law of thermodynamics, the infinitesimal change in internal energy is given by the expression $dU = dQ_{\text{rev}} - dW_{\text{rev}}$.

(b) For an ideal gas undergoing an isothermal expansion, the temperature remains perfectly constant ($dT = 0$), meaning the change in internal energy is zero ($dU = 0$).

(c) This simplifies the first law expression to $dQ_{\text{rev}} = dW_{\text{rev}} = PdV$.

(d) The thermodynamic definition of the entropy change is $dS = \frac{dQ_{\text{rev}}}{T}$. Substituting the ideal gas law ($P = \frac{nRT}{V}$) yields: $dS = \frac{nRT}{V} \cdot \frac{dV}{T} = nR\frac{dV}{V}$.

(e) Integrating this differential expression from the initial volume V_1 to the final volume V_2 results in the standard logarithmic relation: $\Delta S = nR\ln(V_2/V_1)$.

Final Answer: The correct mathematical expression for the change in entropy is $\Delta S = nR\ln(V_2/V_1)$.

Answer: (B)

Go Back to Question 38

Q39.

Solution

Concept:

The exceptional catalytic efficacy of d-block transition metals and their complexes is driven by their flexible electronic configurations. These elements can easily adopt multiple stable oxidation states and utilize their empty or partially filled d-orbitals to form weak, reversible coordination complexes with reactant molecules.

Solution:

(a) Transition metals lower the activation energy barrier of chemical reactions by providing alternative low-energy reaction pathways through intermediate complex formation.

(b) Their ability to adopt variable oxidation states allows them to participate in smooth electron-transfer steps, facilitating efficient redox cycles during catalysis.

(c) In heterogeneous catalysis, the large surface area of transition metals provides active sites where reactant molecules can adsorb via weak chemical bonds.

(d) This adsorption increases the local concentration of reactants on the catalyst surface and weakens their internal bonds, accelerating the reaction rate. 5. Fully filled d-orbitals or diamagnetic configurations typically reduce catalytic activity, as they lack the unpaired electrons or open coordination sites needed to bind reactants effectively.

Final Answer: The parameter responsible for high catalytic activity is the availability of variable oxidation states and large surface area.

Answer: (B)

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Q40.

Solution

Concept:

Synthetic elastomers are long-chain addition polymers capable of undergoing large reversible deformations due to weak intermolecular forces and cross-links between chains. The chemical identity of an elastomer is defined by the specific monomer units used during its chain-growth polymerization process.

Solution:

(a) The chemical repeating unit shown in the structural diagram features a chlorinated four-carbon unsaturated chain with a central double bond.

(b) This structural unit is synthesized via the free-radical addition polymerization of the conjugated diene monomer 2-chloro-1,3-butadiene, commonly known as chloroprene.

(c) Polymerization of chloroprene involves 1,4-addition, which shifts the double bond to the center of the monomer unit to yield the synthetic elastomer neoprene.

(d) Neoprene exhibits excellent chemical stability, oil resistance, and tensile strength, making it a highly resilient material for industrial applications.

(e) In comparison, natural rubber consists of cis-1,4-polyisoprene units, Buna-S is a copolymer of butadiene and styrene, and Teflon is a fluoropolymer made from tetrafluoroethylene.

Final Answer: The name of this highly resilient addition polymer is Neoprene.

Answer: (B)

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Answer Key

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