KIITEE Chemistry Sample Paper – 4

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 (A) with molecular formula $C_4H_{10}O$ does not react with sodium metal. When heated with excess HI, it yields only one organic product (B). What is the major organic product formed when (B) is treated with aqueous KOH?

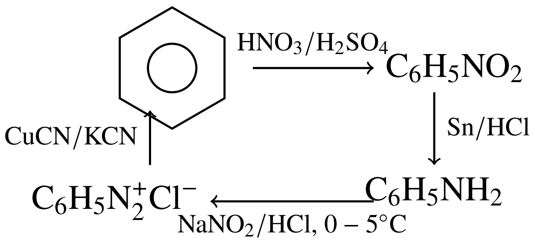
(A) Ethanol

(B) Iodoethane

(C) Diethyl ether

(D) Butan-1-ol

Q2. Consider the following organic transformation sequence:



What is the final major product of this chemical reaction sequence?

(A) Nitrobenzene

(B) Aniline

(C) Benzonitrile

(D) Chlorobenzene

Q3. The standard EMF of a galvanic cell involving 2 moles of electrons is found to be 0.59 V at 298 K. What is the equilibrium constant (K_c) for the cell reaction at this temperature?

(A) 1.0×10^{10}

(B) 1.0×10^{20}

(C) 2.0×10^{10}

(D) 1.0×10^{5}

Q4. Which of the following electronic configurations represents the element with the highest second ionization enthalpy?

(A) $1s^2 2s^2 2p^6 3s^1$

(B) $1s^2 2s^2 2p^6 3s^2$

(C) $1s^2 2s^2 2p^6 3s^2 3p^1$

(D) $1s^2 2s^2 2p^5$

Q5. Which of the following polymers is classified as a biodegradable polyamide condensation polymer?

(A) Nylon-6,6

(B) Nylon-2-nylon-6

(C) PHBV

(D) Buna-N

Q6. When an ideal gas undergoes an isothermal and reversible expansion from an initial volume V_1 to a final volume V_2, the change in entropy of the surroundings (ΔS_{surr}) is given by which expression?

(A) $nR\ln(V_2/V_1)$

(B) $-nR\ln(V_2/V_1)$

(C) Zero

(D) $nRT\ln(V_2/V_1)$

Q7. The correct increasing order of basic strength for the given amines in their aqueous solution phase is which of the following?

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

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

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

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

Q8. According to Crystal Field Theory, what is the correct electronic configuration and spin-only magnetic moment of a high-spin d^6 octahedral coordination complex?

(A) $t_{2g}^4 e_g^2$ and 4.90 BM

(B) $t_{2g}^6 e_g^0$ and 0.00 BM

(C) $t_{2g}^3 e_g^3$ and 5.92 BM

(D) $t_{2g}^5 e_g^1$ and 3.87 BM

Q9. Which of the following sets of atmospheric pollutants is primarily responsible for the phenomenon of photochemical smog formation in urban areas?

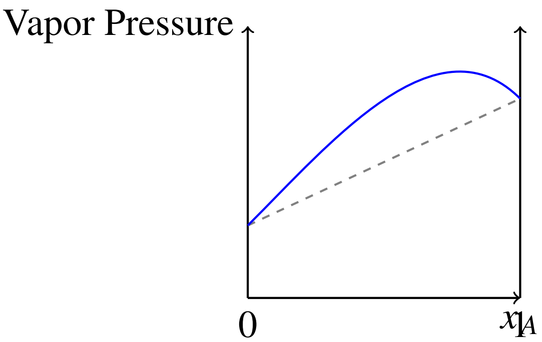
(A) CO_2, SO_2, and particulate matter

(B) NO_x, unburnt hydrocarbons, and ozone

(C) CO, CO_2, and water vapor

(D) $CFCs$, SO_3, and ozone

Q10. The following phase diagram illustrates a binary liquid mixture:



Which pair of liquids is most likely to exhibit the non-ideal behavior shown in this graph?

(A) Acetone and Chloroform

(B) Ethanol and Acetone

(C) Benzene and Toluene

(D) Phenol and Aniline

Q11. The reduction of a benzoyl chloride derivative to a benzaldehyde derivative using hydrogen gas over a palladium catalyst supported on barium sulfate is known as which organic named reaction?

(A) Stephen reduction

(B) Rosenmund reduction

(C) Clemmensen reduction

(D) Wolff-Kishner reduction

Q12. Among the following chemical species, which one has a square pyramidal geometry according to VSEPR theory?

(A) XeF_4

(B) BrF_5

(C) SF_4

(D) PCl_5

Q13. The non-reducing property of sucrose among common disaccharides is due to which structural feature?

(A) The linkage of two glucose units via α-1,4-glycosidic bond

(B) The involvement of reducing groups of both glucose and fructose in glycosidic bond formation

(C) The absence of a fructose moiety in its structure

(D) The presence of a free hemiacetal group at the C-1 position of fructose

Q14. For a first-order chemical reaction, a graph plotted between log $[A]_t$ (y-axis) and time t (x-axis) yields a straight line. What is the value of the slope of this line?

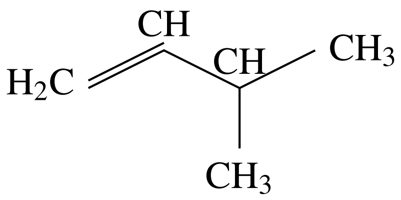
(A) $-k/2.303$

(B) $-k$

(C) $k/2.303$

(D) $2.303/k$

Q15. What is the correct IUPAC name of the organic compound given in the structural illustration below?



(A) 2-Methylbut-3-ene

(B) 3-Methylbut-1-ene

(C) 3-Methylbut-3-ene

(D) Isopentene

Q16. Which of the following structural arrangements represents the correct order of increasing acid strength for the oxoacids of phosphorus?

(A) $H_3PO_2 < H_3PO_3 < H_3PO_4$

(B) $H_3PO_4 < H_3PO_3 < H_3PO_2$

(C) $H_3PO_3 < H_3PO_2 < H_3PO_4$

(D) $H_3PO_4 < H_3PO_2 < H_3PO_3$

Q17. An element crystallizes in a face-centered cubic (fcc) lattice arrangement. If the atomic radius of the element is r, what is the length of the edge (a) of the unit cell?

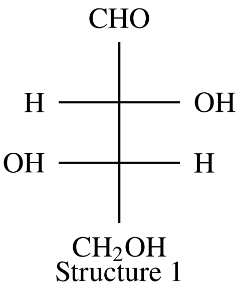
(A) $2r$

(B) $4r/\sqrt{3}$

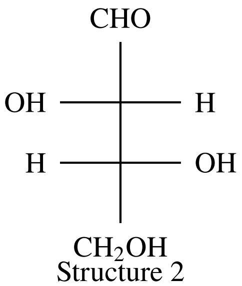
(C) $2\sqrt{2}r$

(D) $\sqrt{3}r/2$

Q18. Which statement about the given pair of molecules is true?



Structure 1



Structure 2

(A) They are diastereomers

(B) They are anomers

(C) They are enantiomers

Q19. The oxidation states of sulfur atoms in a molecule of peroxodisulfuric acid ($H_2S_2O_8$) are respectively which of the following?

(A) +6 and +6

(B) +7 and +7

(C) +6 and +4

(D) +5 and +5

Q20. Which chemical agent is commonly added to commercial soaps to impart antiseptic properties and reduce microbial growth?

(A) Sodium rosinate

(B) Bithionol

(C) Glycerol

(D) Sodium dodecylbenzenesulfonate

Q21. When phenol is treated with chloroform and aqueous sodium hydroxide, followed by acid hydrolysis, a functionalized benzaldehyde is formed. What is the intermediate chemical species driving this substitution reaction?

(A) Carbocation

(B) Carbanion

(C) Dichlorocarbene

(D) Chloroform radical

Q22. What is the total number of unpaired electrons present in a gaseous divalent transition metal ion with atomic number 26 in its ground state?

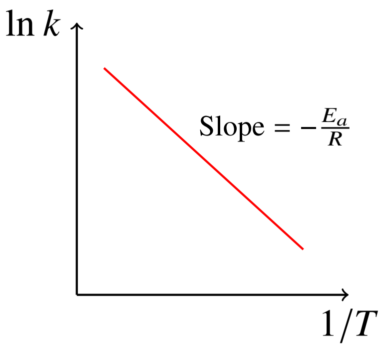
(A) 6

(B) 4

(C) 5

(D) 2

Q23. The rate of a certain chemical reaction doubles when the temperature is raised from 300 K to 310 K. What parameters can be directly derived from this behavior using the Arrhenius plot format shown below?



(A) Activation energy (E_a) from the slope

(B) Rate constant (k) from the x-intercept

(C) Entropy change (ΔS) from the slope

(D) Free energy change (ΔG) from the y-intercept

Q24. Which type of structural isomerism is exhibited by the coordination compounds $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5(Br)]SO_4$?

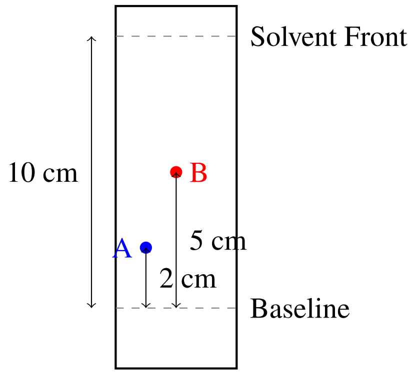
(A) Linkage isomerism

(B) Ionization isomerism

(C) Coordination isomerism

(D) Solvate isomerism

Q25. The quantitative separation of an ester mixture can be evaluated using a chromatographic technique. Consider the following schematic diagram:



What is the retardation factor (R_f) value calculated for component B?

(A) 0.2

(B) 0.5

(C) 2.0

(D) 0.7

Q26. The functional group conversion of an amide into a primary amine containing one less carbon atom using bromine in an aqueous or ethanolic solution of sodium hydroxide is called which reaction?

(A) Gabriel phthalimide synthesis

(B) Hoffmann bromamide degradation reaction

(C) Carbylamine reaction

(D) Friedel-Crafts acylation reaction

Q27. At a given temperature, a 0.5 M solution of an organic electrolyte shows a resistance of 25 ohms when placed in a conductivity cell with a cell constant of 0.5 cm^{-1}. What is the molar conductivity of this electrolyte solution?

(A) 40 S cm^2 mol^{-1}

(B) 20 S cm^2 mol^{-1}

(C) 400 S cm^2 mol^{-1}

(D) 4 S cm^2 mol^{-1}

Q28. Which of the following lanthanoid ions is widely used as a powerful oxidizing agent in volumetric chemical analysis due to its stable alternative oxidation state?

(A) Eu^{2+}

(B) Ce^{4+}

(C) Lu^{3+}

(D) Tb^4

Q29. What type of RNA molecule acts as a structural component and also provides catalytic activity during the process of protein translation inside a cell?

(A) mRNA

(B) tRNA

(C) rRNA

(D) siRNA

Q30. Which of the following conditions corresponds to a spontaneous chemical process occurring at constant temperature and pressure parameters?

(A) $\Delta G > 0$

(B) $\Delta G < 0$

(C) $\Delta H < 0$

(D) $\Delta S_{sys} < 0$

Q31. The quantitative relationship between the solubility of a gas in a liquid solvent and its partial pressure above the liquid surface is mathematically governed by which law?

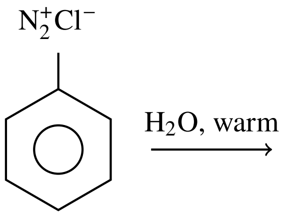
(A) Raoult Law

(B) Henry Law

(C) Dalton Law

(D) Ostwald Dilution Law

Q32. The direct reaction of a primary aromatic amine with nitrous acid at cold temperatures yields a stable intermediate species. Consider the following structural pathway:



What organic molecule is generated as the principal product of this sequence?

(A) Chlorobenzene

(B) Nitrobenzene

(C) Phenol

(D) Benzene

Q33. Which of the following compounds will readily undergo a nucleophilic substitution reaction by an S_N1 mechanism at the fastest relative rate?

(A) CH3Cl

(B) (CH3)2CHCl

(C) (CH3)3CCl

(D) CH3CH2Cl

Q34. The chemical formula of the white precipitate formed when a soluble zinc salt solution is treated with a potassium ferrocyanide reagent is given by which option?

(A) $Zn_2[Fe(CN)_6]$

(B) $K_2Zn_3[Fe(CN)_6]_2$

(C) $Zn[Fe(CN)_6]$

(D) $K_4[Fe(CN)_6]$

Q35. The quantitative concentration of dissolved oxygen in a healthy natural water body sample should ideally be around which value limit?

(A) 2-3 ppm

(B) 6-10 ppm

(C) 50-60 ppm

(D) 100-120 ppm

Q36. An organic molecule contains a chiral center. When it undergoes an S_N2 inversion reaction mechanism, the configuration around the carbon center changes. This stereochemical phenomenon is termed as what?

(A) Racemization

(B) Walden inversion

(C) Retention

(D) Mutarotation

Q37. Which of the following arrangements accurately lists the elements in order of decreasing atomic radii size?

(A) $Na > Mg > Al > Si$

(B) $Si > Al > Mg > Na$

(C) $Al > Si > Mg > Na$

(D) $Na > Al > Mg > Si$

Q38. The quantitative relationship governing the independent migration of ions at infinite dilution conditions for an electrolyte is formulated by which name law?

(A) Faraday Law

(B) Kohlrausch Law

(C) Debye-Huckel Law

(D) Ohm Law

Q39. Which type of intermolecular attractive forces are primarily responsible for stabilizing the secondary structure conformations like α-helix loops in proteins?

(A) Covalent disulfide bonds

(B) Hydrogen bonds

(C) Ionic salt bridges

(D) Van der Waals dispersion forces

Q40. What is the correct molecular formula and shape designation for the chemical compound produced when sulfur dioxide gas is oxidized by atmospheric oxygen in the presence of a vanadium pentoxide catalyst?

(A) SO_3, Trigonal planar

(B) SO_3, Pyramidal

(C) SO_4^{2-}, Tetrahedral

(D) S_2O_3, Linear

Detailed Solutions

Q1.

Solution

Concept:

The chemical properties of ether molecules are characterized by their relatively low reactivity toward most common chemical reagents compared to alcohols. Because they lack a terminal hydroxyl hydrogen atom, ethers do not react with electropositive alkali metals such as sodium under normal condition profiles. However, dialkyl ethers can be cleaved under severe acidic conditions by heated concentrated hydrogen halides like hydrogen iodide via nucleophilic substitution pathways to yield corresponding alkyl iodides.

Solution:

(a) The given molecular formula is $C_4H_{10}O$, which corresponds to the general chemical formula of saturated acyclic monohydric alcohols or aliphatic ethers. Since the compound (A) exhibits completely inert behavior toward sodium metal, it cannot be an alcohol containing an acidic hydrogen atom. Therefore, compound (A) must be a dialkyl ether.

(b) When heated with excess hydrogen iodide, ethers undergo a clean cleavage reaction. The prompt states that only one unique organic product (B) is formed, which chemically signifies that the ether must have a perfectly symmetrical structural configuration around its central oxygen bridge. The only symmetrical aliphatic ether satisfying this molecular formula is diethyl ether, which possesses the structural layout $CH_3CH_2OCH_2CH_3$.

(c) Treatment of diethyl ether with excess heated hydrogen iodide involves protonation of the ether oxygen followed by nucleophilic attack of the iodide ion, which yields two equivalents of ethyl iodide (CH_3CH_2I) as compound (B).

(d) When compound (B), ethyl iodide, is subjected to a substitution reaction using aqueous potassium hydroxide, the strongly nucleophilic hydroxide ion attacks the primary carbon center via a classic biomolecular nucleophilic substitution mechanism, displacing the iodide leaving group cleanly to yield ethanol (CH_3CH_2OH) as the major organic product.

Final Answer: The major product formed is Ethanol.

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 1

Q2.

Solution

Concept:

Aromatic compounds undergo various electrophilic substitution and functional group interconversion reactions that are highly useful in synthetic organic chemistry. The transformation of a functionalized benzene ring into alternative derivatives involves sequential modification of substituents through highly selective reduction, diazotization, and substitution processes. Understanding these sequential changes enables the prediction of the ultimate structural layout.

Solution:

(a) The initial stage of the given multi step reaction sequence starts with a simple unsubstituted benzene ring molecule. When benzene is treated with a mixture of concentrated nitric acid and concentrated sulfuric acid, it undergoes a classic electrophilic aromatic substitution reaction called nitration to produce nitrobenzene as the major component.

(b) In the second phase, nitrobenzene is exposed to tin metal in the presence of concentrated hydrochloric acid. This reagent combination acts as a powerful reducing system that converts the highly oxidized nitro functional group into a fully reduced primary aromatic amine, generating aniline as the next intermediate.

(c) In the third stage, aniline is subjected to a low temperature diazotization process using sodium nitrite and hydrochloric acid maintained strictly between 0 and 5 degrees Celsius. This specific transformation converts the primary amino group attached to the aromatic core into a highly reactive benzene diazonium chloride salt.

(d) In the final stage, the benzene diazonium chloride intermediate is treated with a mixture of cuprous cyanide and potassium cyanide. This process is known as the Sandmeyer reaction, where the excellent diazonium leaving group is easily displaced by the nucleophilic cyanide ion to yield benzonitrile as the final major product.

Final Answer: The final major product of this chemical reaction sequence is Benzonitrile.

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept:
Electrochemistry builds a direct mathematical bridge linking thermodynamic variables with electrical measurements through fundamental expressions. The standard electromotive force of a galvanic setup reflects the maximum electrical work obtainable under ideal state parameters. This quantitative potential can be related directly to the thermodynamic equilibrium constant of the chemical reaction using the Nernst equation framework at standard ambient temperature conditions.

Solution:

(a) The universal relationship that links the standard cell potential with the chemical equilibrium constant of a redox process is derived from the core equation linking Gibbs free energy with both parameters simultaneously. At a standard temperature of 298 Kelvin, this full relationship can be simplified to a practical numerical layout.

(b) The operational equation is written as standard electromotive force equals the ratio of 0.0591 volts to the number of moles of transferred electrons multiplied by the common logarithm of the equilibrium constant. For this specific calculation, the problem states that the standard electromotive force is equal to 0.59 volts.

(c) The number of moles of electrons participating in the balanced redox equation is given as 2. Substituting these values into the simplified Nernst expression gives the mathematical setup where 0.59 equals the product of 0.059 divided by 2 and the logarithm of the equilibrium constant.

(d) Rearranging this expression to solve for the logarithmic term shows that the log of the equilibrium constant equals 0.59 multiplied by 2 and divided by 0.059, which simplifies exactly to 20. Taking the antilogarithm of both sides of this equation isolates the equilibrium constant, yielding a final value of 1.0 times 10 raised to the power of 20.

Final Answer: The equilibrium constant for the cell reaction is 1.0×10^{20}.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:
Ionization enthalpy measures the precise quantity of energy required to remove an electron from a gaseous atom or ion in its ground electronic state. The second ionization enthalpy specifically quantifies the energy cost of removing a single electron from a univalent positive cation. The absolute magnitude of this energy profile depends heavily on the stability of the starting electronic configuration and the effective nuclear charge.

Solution:

(a) To identify which element exhibits the highest second ionization energy value, we must inspect the electronic configurations remaining after the removal of the very first electron from each individual candidate.

(b) Option A represents an element with the ground state electronic configuration of $1s^2 2s^2 2p^6 3s^1$, which corresponds to sodium. Removing the first electron from a neutral sodium atom requires relatively low energy because it easily generates a highly stable, closed shell noble gas core configuration identical to neon, expressed as $1s^2 2s^2 2p^6$.

(c) Removing a second electron from this univalent sodium cation requires breaking into a fully filled, highly stable principal energy level, which experiences a massive effective nuclear charge and holds its core electrons very tightly. This structural barrier creates an exceptionally high energy requirement for the second ionization step.

(d) In contrast, the other choices either retain valence electrons or do not possess a exceptionally stable inert gas core configuration after single ionization. For instance, magnesium initially becomes a stable single valence ion but its second electron comes from a outer shell. Therefore, sodium demands the maximum energy input for its second ionization.

Final Answer: The configuration representing the highest second ionization enthalpy is $1s^2 2s^2 2p^6 3s^1$.

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:
Polymers are macromolecular architectures formed by linking together repeating monomeric structural units via robust chemical bonds. While conventional synthetic polymers pose a significant environmental challenge due to their immense resistance toward natural degradation pathways, specialized biodegradable polymers can be synthesized to break down under natural biological processes. These ecofriendly macromolecules often incorporate hydrolyzable linkages such as ester or amide connections within their primary structural backbones.

Solution:

(a) A polyamide is a specific class of condensation macromolecule characterized by the presence of repeating amide linkages (-CONH-) along its primary structural framework. These links are typically formed through the condensation reaction between carboxylic acid groups and amino functional groups.

(b) Among the choices provided, Nylon-6,6 is a conventional synthetic polyamide synthesized from hexamethylenediamine and adipic acid. While it contains amide bonds, it possesses a highly crystalline, hydrophobic hydrocarbon structure that prevents micro organisms from breaking it down, making it non biodegradable.

(c) PHBV is a well known biodegradable copolymer, but it belongs structurally to the polyester family because its monomeric units are held together via ester linkages rather than amide bonds. Buna-N is a synthetic rubber copolymer generated through addition polymerization of butadiene and acrylonitrile.

(d) Nylon-2-nylon-6 is a synthetic alternating polyamide copolymer produced through the condensation polymerization of glycine, which contains two carbon atoms, and aminocaproic acid, which contains six carbon atoms. Because it possesses regular, enzymatic cleavable amide linkages interspersed with short aliphatic segments, it undergoes clean degradation in the environment, classifying it as a true biodegradable polyamide.

Final Answer: The polymer classified as a biodegradable polyamide condensation polymer is Nylon-2-nylon-6.

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:

Thermodynamics provides a detailed mathematical framework for tracking entropy modifications within a chemical system and its associated surrounding environment during any physical transformation. For any process, the total change in entropy of the universe is the sum of the entropy changes inside the system and the surroundings. In a perfectly reversible thermodynamic pathway, this total entropy variation of the universe must equal zero.

Solution:

(a) When an ideal gas undergoes a perfectly reversible expansion process under strictly isothermal conditions, the temperature remains totally uniform and constant throughout both the system and its immediate surroundings.

(b) For any reversible pathway, the total entropy change of the universe is equal to zero, which means the entropy change of the system plus the entropy change of the surroundings must equal zero. This fundamental relationship can be rearranged to show that the entropy change of the surroundings must be equal in magnitude but opposite in sign to the entropy change of the system.

(c) The entropy modification experienced by an ideal gas system expanding reversibly from an initial volume to a final volume at a constant temperature is derived from the heat absorbed reversibly, yielding the standard equation where delta S of the system equals the product of the number of moles, the universal gas constant, and the natural logarithm of the final volume divided by the initial volume.

(d) Because the entropy change of the surroundings is the negative of the entropy change of the system, we can substitute this expression directly to find that delta S of the surroundings equals negative n R multiplied by the natural logarithm of V2 divided by V1. This negative value reflects the loss of thermal energy from the surroundings to drive the expansion work of the system.

Final Answer: The change in entropy of the surroundings is given by $-nR\ln(V_2/V_1)$.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:

The basic strength of aliphatic amines in an aqueous solution phase is governed by a subtle and complex interplay of multiple physical and chemical factors. Unlike gaseous state basicity, which is determined solely by the electron donating inductive effect of alkyl groups, the basic behavior of amines in water depends concurrently on the inductive effect, the steric hindrance exerted by the alkyl groups, and the extent of stabilization via hydrogen bonding with water molecules.

Solution:

(a) In an aqueous medium, an amine acts as a base by accepting a proton to form an ammonium cation. The stability of this resulting conjugate acid determines the relative base strength of the starting amine.

(b) The positive inductive effect of methyl groups increases electron density on the nitrogen atom and stabilizes the cation. This factor alone would predict that tertiary amines are stronger bases than secondary amines, which are stronger than primary amines.

(c) However, as the number of methyl groups increases, steric hindrance around the nitrogen atom restricts access for protonation and disrupts the surrounding solvation sphere. Furthermore, fewer hydrogen atoms on the cation mean less stabilization through hydrogen bonding with water molecules.

(d) When all three competing effects are balanced for methyl substituted amines in an aqueous phase, dimethylamine emerges as the strongest base due to minimal steric clash and effective solvation. Trimethylamine experiences severe crowding, which drops its basicity below that of methylamine, though it remains stronger than unsubstituted ammonia. This creates the increasing order where ammonia is weakest, followed by trimethylamine, methylamine, and finally dimethylamine.

Final Answer: The correct increasing order of basic strength is $NH_3 < (CH_3)_3N < CH_3NH_2 < (CH_3)_2NH$.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

Crystal Field Theory describes the electronic structure of transition metal complexes by considering the electrostatic interactions between the metal d orbitals and surrounding ligands. In an octahedral coordination field, the five degenerate d orbitals split into two distinct energy levels: a lower energy triply degenerate set and a higher energy doubly degenerate set. The distribution of electrons across these levels depends heavily on the relative magnitude of the crystal field splitting energy compared to the electron pairing energy.

Solution:

(a) A high-spin octahedral complex occurs when the coordination ligands are weak field components, meaning the crystal field splitting energy is smaller than the energy required to pair two electrons within the same orbital.

(b) For a transition metal ion with a d6 electronic configuration, the first five electrons must occupy the available splitting levels singly in accordance with Hund's rule of maximum multiplicity to minimize electrostatic repulsion. Thus, three electrons fill the lower set singly, and two electrons fill the upper set singly.

(c) The sixth electron must then pair up in one of the lower energy orbitals because all five d orbitals already contain at least one electron. This electronic distribution results in an exact crystal field configuration designated as four electrons in the lower level and two electrons in the higher level.

(d) Counting the remaining unpaired electrons reveals a total of four unpaired spins. The spin-only magnetic moment is calculated using the standard formula equal to the square root of the product of the number of unpaired electrons and that number plus two. Plugging in four yields the square root of twenty-four, which evaluates to approximately 4.90 Bohr Magnetons.

Final Answer: The correct electronic configuration and spin-only magnetic moment are $t_{2g}^4 e_g^2$ and 4.90 BM.

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:

Environmental chemistry monitors the complex chemical changes that take place within the atmosphere due to human activities. Photochemical smog is a modern type of air pollution that develops predominantly in warm, sunny urban areas with heavy vehicular traffic. Unlike traditional reducing smog, photochemical smog is highly oxidizing in nature and is driven by complex secondary chemical reactions initiated by solar radiation acting upon primary chemical pollutants.

Solution:

(a) Photochemical smog does not rely on sulfur dioxide or carbon dioxide emissions. Instead, its primary chemical precursors are compounds expelled from internal combustion engines, which release substantial quantities of nitrogen oxides and volatile unburnt hydrocarbons into the lower atmosphere.

(b) Under the intense influence of solar ultraviolet radiation, nitrogen dioxide undergoes rapid photolysis to produce nitric oxide and highly reactive atomic oxygen. This atomic oxygen immediately combines with ambient molecular oxygen to form ozone.

(c) The generated ozone is a powerful chemical oxidant that reacts with unburnt hydrocarbons present in the air to yield an array of toxic secondary pollutants, including peroxyacetyl nitrates, formaldehyde, and acrolein.

(d) Therefore, the characteristic mix of photochemical smog consists of nitrogen oxides, unburnt hydrocarbons, and ozone moving through a cycle of continuous regeneration driven by sunlight. This combination creates a dense, irritating brownish haze that poses serious health risks to respiratory systems and causes widespread damage to plant life in heavily populated urban areas.

Final Answer: The pollutants primarily responsible are NO_x, unburnt hydrocarbons, and ozone.

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:
Liquid solutions can be categorized as ideal or non-ideal based on their adherence to Raoult's law across a full composition range. Non-ideal solutions arise when the intermolecular attractive forces operating between the distinct components differ significantly from the cohesive forces present within the pure liquids. A positive deviation from ideality occurs when the new adhesive interactions are weaker than the original cohesive forces, causing a noticeable increase in total vapor pressure.

Solution:

(a) The provided phase diagram depicts a binary liquid mixture where the solid blue curve bows significantly upward, reaching a clear maximum point above the linear dashed line that represents ideal behavior. This trend indicates a strong positive deviation from Raoult's law.

(b) A positive deviation means that the molecules in the mixture find it easier to escape into the vapor phase than they would in an ideal solution because the heteromolecular attractive forces are weaker than the homomolecular interactions.

(c) Pure ethanol is characterized by an extensive, highly organized network of intermolecular hydrogen bonding that holds the molecules tightly together in the liquid state. When acetone is added to pure ethanol, the acetone molecules insert themselves into this structured network, effectively disrupting many of the existing hydrogen bonds without forming comparable replacement attractions.

(d) Because the overall intermolecular forces are weakened in the resulting mixture, the escaping tendency of both components increases, leading to a total vapor pressure that is higher than predicted by Raoult's law. In contrast, acetone and chloroform exhibit a negative deviation due to new hydrogen bond formation between them.

Final Answer: The pair of liquids is Ethanol and Acetone.

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:
Organic functional group transformations include highly selective reductions of acyl halides into alternative oxidized states such as aldehydes. Direct reductions often require specialized conditions because aldehydes are prone to over-reduction to form primary alcohols. Modifying standard transition metal catalytic systems with structural poisons reduces their initial catalytic activity, permitting clean stopping points at intermediate carbonyl stages.

Solution:

(a) Acyl chlorides are highly reactive carboxylic acid derivatives that undergo rapid nucleophilic acyl substitution reactions. When treated with standard reducing agents like lithium aluminum hydride, they are completely reduced to primary alcohols.

(b) To halt the reduction precisely at the aldehyde functional group stage, a modified catalytic system must be employed. The selective transformation of a benzoyl chloride derivative into a corresponding benzaldehyde derivative uses hydrogen gas in combination with a palladium catalyst.

(c) The palladium metal catalyst is purposefully supported on barium sulfate and partially deactivated by adding specific chemical poisons such as sulfur or quinoline. This modified hydrogenating configuration is universally referred to as Lindlar's catalyst or the poisoned palladium system.

(d) Deactivation lowers the reactivity of the catalyst so that it remains strong enough to reduce the highly reactive acyl carbon-chlorine bond but remains completely inert toward the newly formed carbonyl group of the benzaldehyde. This classical organic transformation is defined as the Rosenmund reduction.

Final Answer: The organic named reaction is Rosenmund reduction.

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:

The Valence Shell Electron Pair Repulsion theory provides a predictive framework for determining the spatial arrangement of covalent molecules. According to this model, the geometry around a central atom is dictated by minimizing electrostatic repulsions between all valence electron groups, including bonding pairs and non-bonding lone pairs. The steric number defines the total coordination environment and determines the idealized electron pair geometry.

Solution:

(a) To find the species with a square pyramidal molecular geometry, we determine the steric number by summing the total valence electrons, assigning bonding connections, and counting lone pairs on the central atom.

(b) Xenon tetrafluoride has eight valence electrons from xenon and four from fluorine bonds, leaving two lone pairs. Its steric number is six, giving an octahedral electron geometry with a square planar molecular shape.

(c) Bromine pentafluoride has seven valence electrons from bromine. It forms five single covalent bonds with fluorine atoms, leaving two remaining electrons that form a single lone pair. The total steric number is six, which generates an octahedral electron pair arrangement.

(d) With five bonding pairs and one lone pair, the lone pair occupies an axial position to minimize steric repulsion. The remaining five fluorine atoms form a planar square base with one vertex extending axially, producing a square pyramidal geometry. Sulfur tetrafluoride forms a see-saw shape, while phosphorus pentachloride adopts a trigonal bipyramidal geometry.

Final Answer: The chemical species with a square pyramidal geometry is BrF_5.

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:
Carbohydrates are classified as reducing or non-reducing based on their structural capacity to act as reducing agents in standard chemical assays, such as Tollen's or Fehling's tests. This chemical reactivity depends entirely on the availability of a free, unmasked anomeric carbon atom. When cyclic monosaccharides form disaccharide linkages, the specific carbon positions involved dictate whether the resulting carbohydrate retains its reducing character.

Solution:

(a) Reducing sugars possess a free hemiacetal or hemiketal group at their anomeric carbon center, which readily equilibrates to an open-chain form containing a reactive aldehyde or alpha-hydroxy ketone group capable of reducing mild metal oxidants.

(b) Sucrose is a common disaccharide composed of an alpha-D-glucose unit and a beta-D-fructose unit joined together by a glycosidic bond. To evaluate its reducing properties, we must identify the specific carbon atoms participating in this bond.

(c) In sucrose, the glycosidic linkage forms between the C-1 anomeric carbon atom of the D-glucose ring and the C-2 anomeric carbon atom of the D-fructose ring. This linkage locks both potential reducing centers into a stable acetal-ketal functional framework.

(d) Because both reducing groups are mutually consumed during glycosidic bond formation, neither monosaccharide ring can open to regenerate a free carbonyl group. The absence of a free hemiacetal or hemiketal center renders sucrose completely inert toward standard oxidation assays, classifying it as a non-reducing sugar.

Final Answer: The non-reducing property of sucrose is due to the involvement of reducing groups of both glucose and fructose in glycosidic bond formation.

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:
Chemical kinetics involves the mathematical modeling of reaction progress over time. For a first-order chemical reaction, the rate depends linearly on the concentration of a single reactant component. Integrating this differential rate law provides a functional relationship that tracks concentration changes over time, which can be rearranged into a standard linear equation to determine kinetic parameters graphically.

Solution:

(a) The integrated rate equation for a first-order chemical transformation is written as the natural logarithm of the initial reactant concentration divided by the concentration at time t equals the product of the rate constant k and time.

(b) To match the given graphical axes, this expression is converted from natural logarithms to common logarithms by introducing the conversion factor of 2.303. This modification yields the equation where the base ten logarithm of the initial concentration divided by the concentration at time t equals kt divided by 2.303.

(c) Using logarithmic properties to separate the terms produces the linear relationship where the common logarithm of the concentration at time t equals the negative ratio of the rate constant k to 2.303, multiplied by time, plus the common logarithm of the initial concentration.

(d) Comparing this expression to the standard equation for a straight line ($y = mx + c$) reveals that the common logarithm of concentration represents the dependent variable along the y-axis, while time represents the independent variable along the x-axis. The resulting slope of this straight line corresponds precisely to the negative quotient of the rate constant divided by 2.303.

Final Answer: The value of the slope of this line is $-k/2.303$.

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:

The systematic nomenclature of organic molecules follows rigid rules established by the International Union of Pure and Applied Chemistry. Assigning an accurate IUPAC designation requires identifying the principal carbon chain, identifying the highest-priority functional groups, and numbering the chain to grant the lowest possible locants to unsaturated bonds and substituents.

Solution:

(a) The provided skeletal drawing contains a carbon backbone with a double bond and a single methyl branch. The first step requires identifying the longest continuous carbon chain that encompasses the carbon-carbon double bond.

(b) The longest continuous chain containing the alkene functional group consists of four sequential carbon atoms, establishing butane as the root alkane chain. This rules out options containing alternative parent chains.

(c) Numbering must begin from the end that gives the lowest locant to the principal functional group. In this structure, the alkene takes priority over alkyl substituents. Therefore, we number from the left side, placing the double bond between carbon-1 and carbon-2.

(d) Following this numbering sequence, the methyl substituent is attached to the third carbon atom of the principal chain. Combining these structural components in alphabetical order yields the complete IUPAC designation: 3-methylbut-1-ene.

Final Answer: The correct IUPAC name of the organic compound is 3-Methylbut-1-ene.

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:
The acid strength of the oxoacids of phosphorus depends on the stability of their conjugate bases and the specific bonding environments of their hydrogen atoms. Phosphorus forms several oxoacids where the central phosphorus atom is bound to oxygen atoms via double bonds, hydroxyl groups, or direct phosphorus-hydrogen single bonds. Only those hydrogen atoms attached to highly electronegative oxygen atoms can ionize in aqueous solution to exhibit acidic behavior.

Solution:

(a) The oxoacids in question are hypophosphorous acid (H_3PO_2), phosphorous acid (H_3PO_3), and phosphoric acid (H_3PO_4). In all three molecules, the central phosphorus atom adopts a tetrahedral coordination geometry.

(b) In H_3PO_2, there is one P=O bond, two P-H bonds, and one P-OH bond, making it a monobasic acid. In H_3PO_3, there is one P=O bond, one P-H bond, and two P-OH bonds, making it a dibasic acid. In H_3PO_4, there is one P=O bond and three P-OH bonds, making it a tribasic acid.

(c) Generally, acid strength increases with the oxidation state of the central atom. However, for the oxoacids of phosphorus, the trend reverses due to the unique electronic effects of the non-ionizable P-H bonds and differences in conjugate base solvation.

(d) Hypophosphorous acid (H_3PO_2) exhibits the highest relative acid strength because its conjugate anion is stabilized by the strong electron-withdrawing effect of the central phosphorus atom bound to two hydrides. Phosphoric acid (H_3PO_4) is the weakest among them because its charge is distributed over multiple hydroxyl pathways, giving the sequence $H_3PO_4 < H_3PO_3 < H_3PO_2$.

Final Answer: The correct order of increasing acid strength is $H_3PO_4 < H_3PO_3 < H_3PO_2$.

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:

Solid-state chemistry models the structural arrangement of atoms within crystalline lattices. In a face-centered cubic unit cell, atoms occupy all eight corners of the cube as well as the centers of all six faces. To establish a quantitative relationship between the edge length of the unit cell and the atomic radius, we identify the direction along which the constituent spherical atoms are in direct physical contact.

Solution:

(a) In a face-centered cubic lattice, the atoms located at the corners of the unit cell do not touch each other along the principal cube edge. Instead, they come into direct contact along the diagonal of any given square face of the unit cell.

(b) Let the edge length of the cubic unit cell be represented by the variable a. According to the Pythagorean theorem, the length of the face diagonal across a square face with side dimensions a is equal to the square root of two multiplied by a.

(c) Looking along this face diagonal, the path crosses the atomic radius of one corner atom, the full diameter (two radii) of the face-centered atom, and the atomic radius of the opposite corner atom.

(d) Summing these segments shows that the face diagonal is equal to four times the atomic radius r. Setting these two geometric expressions equal gives the equation where the square root of two times a equals $4r$. Isolating the edge length a yields four divided by the square root of two times r, which simplifies directly to two times the square root of two multiplied by r.

Final Answer: The length of the edge of the unit cell is $2\sqrt{2}r$.

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept:
Stereochemistry explores the spatial arrangement of atoms in chiral molecules. Isomers with the same molecular formula and connectivity can differ in their three-dimensional configurations. Enantiomers are non-superimposable mirror images that rotate plane-polarized light in opposite directions. Diastereomers are stereoisomers that are not mirror images of one another, often possessing multiple chiral centers with differing configurations at some, but not all, positions.
Solution:

(a) The provided structural images illustrate two chemical compounds represented as Fischer projections. Both molecules contain a terminal aldehyde group at the top, a primary alcohol group at the bottom, and two internal chiral carbon centers.

(b) To determine the stereochemical relationship between Structure 1 and Structure 2, we can mentally project a vertical mirror plane between them to see if they display a mirror-image relationship.

(c) Looking at the top chiral center (carbon-2), Structure 1 has its hydrogen atom on the left and hydroxyl group on the right, while Structure 2 has its hydroxyl group on the left and hydrogen atom on the right. This represents a inversion of configuration.

(d) Looking at the bottom chiral center (carbon-3), Structure 1 has its hydroxyl group on the left and hydrogen atom on the right, while Structure 2 has its hydrogen atom on the left and hydroxyl group on the right. This center is also inverted. Because every chiral center is inverted, Structure 1 and Structure 2 are non-superimposable mirror images, classifying them as enantiomers.

Final Answer: The statement about the given pair of molecules that is true is that they are enantiomers.

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 18

Q19.

Solution

Concept:
The oxidation state of an atom in a polyatomic molecule reflects the hypothetical charge it would carry if all its bonding pairs were assigned to the more electronegative element. For compounds containing peroxide linkages, applying standard oxidation number rules can lead to incorrect results if the specific oxygen-oxygen single bonds are not accounted for. Determining correct values requires evaluating the underlying molecular structure.

Solution:

(a) Peroxodisulfuric acid, commonly known as Marshall's acid, has the chemical formula $H_2S_2O_8$. Applying the standard rule where oxygen is assumed to be exclusively in a -2 state yields an incorrect oxidation state of +7 for sulfur, which exceeds its total number of valence electrons.

(b) To find the true oxidation states, we look at its structural bonding layout: $(HO) - SO_2 - O - O - SO_2 - (OH)$. This reveals a symmetrical molecule with a central peroxide bridge (-O-O-) linking two identical sulfone fragments.

(c) The structural breakdown shows two hydrogen atoms in their normal $+1$ oxidation state and six oxo-type oxygen atoms bound via single or double bonds to sulfur, carrying their typical -2 oxidation state. The remaining two oxygen atoms form the peroxide bridge, where each oxygen has an oxidation state of -1.

(d) Setting up a balanced oxidation equation for the neutral molecule gives two times $(+1)$ plus two times the sulfur oxidation state plus six times (-2) plus two times (-1) equals zero. Simplifying this mathematical expression reduces to two times the sulfur oxidation state minus twelve equals zero, yielding a value of +6 for both sulfur atoms.

Final Answer: The oxidation states of sulfur atoms are +6 and +6.

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept:
Chemistry in everyday life explores the practical application of chemical compounds in consumer products, pharmaceuticals, and hygiene materials. Commercial soaps are manufactured through the saponification of fatty acids with strong alkali bases. To modify their performance or add therapeutic benefits, specialized chemical additives are blended into the soap base to provide specific functions like skin softening, deodorizing, or reducing microbial populations.

Solution:

(a) Commercial soaps are excellent at emulsifying and removing oils and dirt from the skin, but standard soap bases lack the ability to kill or significantly inhibit the growth of microscopic pathogens.

(b) To impart antiseptic properties, a compatible antimicrobial chemical agent must be incorporated into the soap formulation. This additive must remain stable in the alkaline soap matrix and non-toxic to human skin cells upon topical application.

(c) Bithionol is an aromatic chlorinated sulfur compound that functions as a powerful antibacterial and antifungal agent. When added to soap formulations, it adheres slightly to the skin surface, providing a sustained reduction in skin bacteria and minimizing body odor caused by microbial decomposition.

(d) Examining the alternative options, sodium rosinate is added to improve lather formation, glycerol acts as a humectant to retain moisture, and sodium dodecylbenzenesulfonate is a synthetic detergent rather than an antiseptic soap additive. Therefore, bithionol is the correct component.

Final Answer: The chemical agent commonly added to commercial soaps is Bithionol.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:
The formylation of phenols with chloroform in an alkaline medium is an electrophilic aromatic substitution reaction called the Reimer-Tiemann reaction. This reaction sequence introduces a formyl group ortho to the phenolic hydroxyl unit. The pathway relies on generating a highly reactive, neutral, electron-deficient intermediate species via alpha-elimination from chloroform under strongly basic conditions.

Solution:

(a) When chloroform is exposed to aqueous sodium hydroxide, the hydroxide ion acts as a strong base to abstract the acidic proton attached to the carbon center of the chloroform molecule. This initial proton extraction yields a temporary, highly unstable trichloromethyl carbanion intermediate.

(b) The trichloromethyl carbanion spontaneously undergoes a rapid alpha-elimination process by shedding a chloride leaving group. The simultaneous loss of the proton and the chloride ion from the exact same carbon atom generates a neutral, divalent carbon species known as dichlorocarbene ($: CCl_2$).

(c) Dichlorocarbene possesses a vacant p-orbital alongside its non-bonding electron pair, rendering it a highly reactive electrophile. The phenoxide ion, created by deprotonation of phenol by sodium hydroxide, possesses high electron density at its ortho position due to resonance.

(d) The electron-rich ortho position of the phenoxide ring attacks the vacant orbital of the dichlorocarbene electrophile. Subsequent proton shifts and alkaline hydrolysis of the resulting dichloromethyl intermediate lead to the creation of salicylaldehyde. Therefore, dichlorocarbene serves as the driving intermediate.

Final Answer: The intermediate chemical species driving this substitution reaction is Dichlorocarbene.

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept:

The electronic configuration of transition metal elements is determined by filling atomic subshells in accordance with the Aufbau principle, Hund's rule, and the Pauli exclusion principle. When neutral transition metal atoms lose electrons to form positive cations, electrons are removed from the outermost shell before any electrons are extracted from the underlying inner d-orbitals. The number of unpaired spins can then be deduced using orbital diagrams.

Solution:

(a) The given element has an atomic number of 26, which corresponds to iron (Fe) in the periodic table. The ground-state electronic configuration of a neutral gaseous iron atom is represented systematically as $[Ar]3d^6 4s^2$.

(b) To form a divalent transition metal ion (Fe^{2+}), the neutral atom must shed a total of two electrons. According to established ionization rules for d-block elements, the outermost $4s$ electrons possess higher principal quantum numbers and are lost prior to the $3d$ electrons.

(c) Removing both valence electrons from the $4s$ subshell leaves the inner electronic core completely untouched. This ionization step results in a ground-state electronic configuration for the gaseous divalent cation represented precisely as $[Ar]3d^6 4s^0$.

(d) The $3d$ subshell consists of five individual degenerate orbitals. Following Hund's rule of maximum multiplicity, the six available d-electrons are distributed such that each of the five orbitals receives a single electron with parallel spin before any pairing takes place. The sixth electron pairs up in the first orbital, leaving four orbitals with single electrons, giving four unpaired electrons.

Final Answer: The total number of unpaired electrons present is 4.

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 22

Q23.

Solution

Concept:
The temperature dependence of chemical reaction rates is modeled mathematically by the Arrhenius equation. This model links the operational rate constant with absolute temperature, the universal gas constant, a frequency factor, and the experimental activation energy. Plotting the natural logarithm of the rate constant against the reciprocal of absolute temperature yields a straight line whose geometric parameters correspond to specific thermodynamic variables.

Solution:

(a) The Arrhenius relationship can be written in its linear logarithmic format as the natural logarithm of the rate constant k equals the natural logarithm of the pre-exponential factor A minus the quotient of the activation energy E_a and the product of the gas constant R and temperature T.

(b) Comparing this expression to the standard mathematical straight-line equation ($y = mx + c$) allows us to map the variables directly onto the provided graph. The dependent variable along the vertical y-axis is $\ln k$, while the independent variable along the horizontal x-axis is $1/T$.

(c) The vertical y-intercept represents the value where the reciprocal temperature equals zero, which corresponds to the natural logarithm of the pre-exponential frequency factor A. The parameter that describes the steepness or direction of the line is the slope.

(d) The slope of this linear plot is equal to the negative ratio of the activation energy to the universal gas constant ($-E_a/R$). Given that the reaction rate doubles over a specified temperature interval, the activation energy can be calculated directly by measuring the experimental slope of this line, making option A correct.

Final Answer: The parameter that can be derived is Activation energy from the slope.

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept:
Structural isomerism in coordination chemistry arises when compounds share an identical empirical formula but differ in the spatial connectivity of their component ligands or counterions. Ionization isomerism occurs specifically when ligand species bound within the inner coordination sphere exchange places with ionic counterions located in the outer ionization sphere. These isomers generate entirely distinct ionic species when dissolved in water.

Solution:

(a) The two coordination complexes provided in the problem are formulaically represented as $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5(Br)]SO_4$. Both compounds contain an identical ratio of cobalt, ammonia, sulfate, and bromine.

(b) In the first compound, the sulfate group is directly coordinated to the central cobalt ion as an anionic ligand inside the brackets, while the bromide ion resides outside the coordination sphere to balance the charge. Dissolving this compound in water yields a bromide ion (Br^-) and a pentaamminesulfatocobalt(III) cation.

(c) In the second compound, the bromide ion is bound directly within the inner coordination sphere, while the sulfate ion balances the charge from the outer sphere. Dissolving this compound in water yields a free sulfate ion (SO_4^{2-}) and a pentaamminebromocobalt(III) cation.

(d) Because these structural isomers are characterized by an exchange of ions between the inner coordination sphere and the outer ionization sphere, they release entirely different ions in aqueous solution. This behavior defines ionization isomerism.

Final Answer: The type of structural isomerism exhibited is Ionization isomerism.

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept:

Thin-layer and paper chromatography are standard laboratory techniques used to separate and analyze the components of a chemical mixture based on their relative affinities for a stationary phase and a moving mobile phase. The migration of each chemical component is quantified by calculating its retardation factor (R_f). This value is a dimensionless ratio that reflects the relative velocity of a substance under specific experimental parameters.

Solution:

(a) The retardation factor (R_f) for any individual component in a chromatographic separation is determined by dividing the distance traveled by that specific spot by the total distance traveled by the solvent front. Both measurements must be taken from the common baseline.

(b) According to the provided schematic diagram, the baseline is clearly marked near the bottom of the analytical matrix. The total distance from this initial baseline to the upper solvent front line is explicitly dimensioned as 10 cm.

(c) Component B is represented by a red circle that has migrated upward along the center of the column. The diagram indicates that the distance traveled by component B from the baseline to its final position is exactly 5 cm.

(d) Substituting these numerical values into the standard equation yields the calculation where R_f equals 5 cm divided by 10 cm. This simplifies to an absolute value of 0.5. Because this factor is a ratio of identical units, it is written without dimensions and always ranges between zero and one.

Final Answer: The retardation factor calculated for component B is 0.5.

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:

The transformation of carboxylic acid amides into primary aliphatic or aromatic amines can be achieved through various rearrangement pathways. A degradation pathway reduces the length of the carbon backbone by shedding the carbonyl carbon atom as a carbonate byproduct. This transformation requires treating an unsubstituted amide with a halogen in the presence of a strong base.

Solution:

(a) Amides contain a carbonyl group directly attached to an amino group. Converting an amide into a primary amine containing one less carbon atom requires a reaction that can selectively clip the carbonyl carbon from the rest of the molecular skeleton.

(b) Treating an amide with bromine in an aqueous or ethanolic solution of sodium hydroxide initiates an original base-mediated nitrogen rearrangement pathway. This reaction sequence begins with the N-bromination of the amide functional group.

(c) The basic environment promotes the elimination of a proton, followed by an alkyl or aryl group migration from the carbonyl carbon to the adjacent electron-deficient nitrogen atom, yielding an isocyanate intermediate.

(d) Subsequent alkaline hydrolysis of the isocyanate intermediate eliminates the carbon atom as a sodium carbonate molecule, leaving behind a primary amine containing one less carbon atom than the starting material. This classic synthetic method is known as the Hoffmann bromamide degradation reaction.

Final Answer: The functional group conversion is called Hoffmann bromamide degradation reaction.

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept:

The electrical properties of electrolyte solutions are governed by relationships linking resistance, conductivity, and ionic concentration. Electrolytic conductivity represents the inverse of resistivity and quantifies the ease with which an electric current flows through a unit volume of solution. Molar conductivity accounts for concentration effects by normalizing this specific conductivity against the molar concentration of the dissolved solute.

Solution:

(a) To compute the molar conductivity, we must first determine the specific conductivity (κ) of the electrolyte solution from the measured resistance (R) and the cell constant (G^*). Conductivity is defined mathematically as the cell constant divided by resistance.

(b) The problem states that the cell constant is 0.5 cm^{-1} and the measured electrical resistance is 25 ohms. Substituting these values gives a specific conductivity equal to 0.5 divided by 25, which evaluates to 0.02 S cm^{-1}.

(c) Molar conductivity (Λ_m) is related to specific conductivity and molarity (M) by the standard conversion equation: $\Lambda_m = (\kappa \times 1000)/M$. This factor of 1000 reconciles the volume discrepancy between cubic centimeters and liters.

(d) The concentration of the organic electrolyte is given as 0.5 M. Substituting the calculated specific conductivity and this molarity into the conversion equation gives $\Lambda_m = (0.02 \times 1000)/0.5$. This simplifies to 20 divided by 0.5, yielding a final value of 40 S cm^2 mol^{-1}.

Final Answer: The molar conductivity of this electrolyte solution is 40 S cm^2 mol^{-1}.

Answer: (A)

Go Back to Question 27

Q28.

Solution

Concept:
The lanthanoids are a series of inner transition elements characterized by the progressive filling of their 4f atomic subshells. While the +3 oxidation state is the most common and chemically stable configuration across the entire series, select lanthanoid elements can access alternative +2 or +4 oxidation states. The stability of these non-standard states is influenced by the thermodynamic advantages of achieving empty, half-filled, or completely filled f-subshells.

Solution:

(a) An oxidizing agent functions by accepting electrons from another chemical species during a redox reaction, causing its own oxidation state to decrease. A lanthanoid ion that acts as an oxidizing agent must be in an oxidation state higher than +3 so that it can undergo reduction.

(b) Cerium has an atomic number of 58, and its neutral ground-state electronic configuration is written as $[Xe]4f^15d^16s^2$. When it loses four electrons, it forms the tetravalent cerium ion (Ce^{4+}), which achieves the highly stable, empty electronic configuration of the inert gas xenon ($4f^0$).

(c) Despite the stability of this empty f-subshell configuration, the +3 state remains the thermodynamically favored state for all lanthanoid elements in aqueous solution. Consequently, the Ce^{4+} ion has a strong tendency to gain a single electron to revert to the highly stable Ce^{3+} state.

(d) Because of this strong affinity for electrons, Ce^{4+} serves as a reliable oxidizing agent in volumetric chemical analysis, such as cerimetry, where it oxidizes analyte species while being cleanly reduced to Ce^{3+}.

Final Answer: The lanthanoid ion used as a powerful oxidizing agent is Ce^{4+}.

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept:

Ribonucleic acid molecules perform diverse structural, coding, and catalytic functions during gene expression inside living cells. While some RNA classes serve as temporary genetic messengers or amino acid transporters, other specialized RNA assemblies fold into intricate three-dimensional conformations capable of accelerating chemical transformations, akin to proteinaceous enzymes. These catalytic RNA structures are known as ribozymes.

Solution:

(a) Messenger RNA (mRNA) acts as a linear transient transcript that carries genetic code sequences directly from nuclear DNA to cellular ribosomes. Transfer RNA (tRNA) functions as an adaptor molecule that matches specific amino acids with corresponding codons along the mRNA template.

(b) Ribosomal RNA (rRNA) constitutes the primary structural mass of both the large and small subunits of cellular ribosomes. It provides the architectural framework necessary for binding mRNA and tRNA correctly during translation.

(c) Beyond this structural role, ribosomal RNA functions as the central catalytic engine of the ribosome. The large ribosomal subunit houses a highly conserved segment of rRNA that acts as a ribozyme to catalyze peptide bond formation.

(d) This active site links the incoming amino acid attached to a tRNA molecule to the growing polypeptide chain via a condensation pathway known as peptidyl transferase activity. Therefore, rRNA provides both structural support and catalytic activity during translation.

Final Answer: The type of RNA molecule described is rRNA.

Answer: (C)

Go Back to Question 29

Q30.

Solution

Concept:
Thermodynamics dictates the inherent directionality and feasibility of chemical transformations through state functions. The second law of thermodynamics establishes that any spontaneous natural process must result in an overall increase in the total entropy of the universe. When tracking reactions occurring under constant temperature and pressure parameters, this universal criterion can be evaluated by monitoring changes in Gibbs free energy.

Solution:

(a) The change in Gibbs free energy (ΔG) serves as a chemical potential indicator that incorporates changes in both system enthalpy (ΔH) and system entropy (ΔS) at a specific absolute temperature (T), expressed through the relation $\Delta G = \Delta H - T\Delta S$.

(b) For a chemical system operating at constant temperature and pressure, the condition for thermodynamic spontaneity requires that the total entropy change of the universe (the sum of the system and its surroundings) must be strictly positive.

(c) Mathematically, an increase in the total entropy of the universe corresponds to a net decrease in the Gibbs free energy of the system. Therefore, any spontaneous chemical process must be accompanied by a negative free energy change, written as $\Delta G < 0$.

(d) If ΔG is greater than zero, the process is non-spontaneous under those conditions and requires an input of external work to proceed. When ΔG equals zero, the system has reached a state of dynamic chemical equilibrium. Enthalpy and system entropy changes alone cannot definitively determine spontaneity without considering temperature.

Final Answer: The condition corresponding to a spontaneous process is $\Delta G < 0$.

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept:

The solubility of a gaseous solute in a liquid solvent depends heavily on the pressure exerted by the gas above the liquid surface. As pressure increases, the concentration of gas molecules in the solution increases to establish a new equilibrium. This physical relationship is quantified by a fundamental gas law named after William Henry, which describes ideal behavior in dilute solutions.

Solution:

(a) The solubility of a gas in a liquid medium at a specific temperature is directly proportional to the partial pressure of that gas in equilibrium with the liquid surface.

(b) When expressed in terms of mole fraction, the law states that the partial pressure of the gas in the vapor phase is proportional to the mole fraction of the dissolved gas in the solution phase.

(c) Mathematically, this relationship is expressed as $p = K_H \times x$, where p represents the partial pressure of the gas, x is the mole fraction of the gas in solution, and K_H is the proportionality constant.

(d) This principle explains various natural and industrial phenomena, including the carbonation of soft drinks, where high pressure forces carbon dioxide to dissolve, and decompression sickness in deep-sea divers.

Final Answer: The quantitative relationship is governed by Henry Law.

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept:
Aromatic diazonium salts are highly versatile synthetic intermediates prepared by treating primary aromatic amines with nitrous acid at cold temperatures. The diazonium group is an exceptional leaving group because it departs as stable nitrogen gas. Replacing this group with a hydroxyl group allows for a straightforward synthesis of phenolic compounds from aniline derivatives.
Solution:

(a) The starting material shown in the chemical pathway is benzenediazonium chloride, which is stable only at low temperatures between 0 and 5 degrees Celsius.

(b) When an aqueous solution of this diazonium salt is allowed to warm or is gently heated with water, the diazonium group becomes highly unstable and undergoes nucleophilic substitution.

(c) The carbon-nitrogen bond cleaves heterolytically, releasing a molecule of nitrogen gas and leaving behind a highly reactive phenyl carbocation intermediate.

(d) Water acts as a nucleophile, attacking the phenyl cation. Subsequent loss of a proton from the oxonium intermediate restores aromaticity and produces phenol as the principal organic product.

Final Answer: The organic molecule generated as the principal product is Phenol.

Answer: (C)

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Q33.

Solution

Concept:

Nucleophilic substitution reactions follow different mechanistic pathways depending on the structure of the substrate. The unimolecular nucleophilic substitution mechanism proceeds in two separate stages: the slow, rate-determining departure of a leaving group to form a carbocation intermediate, followed by the rapid attack of a nucleophile. Therefore, any structural feature that stabilizes the carbocation enhances the overall reaction rate.

Solution:

(a) The rate of a unimolecular substitution process depends entirely on the stability of the intermediate carbocation formed during the initial cleavage step.

(b) Comparing the given alkyl halides, methyl chloride and ethyl chloride form highly unstable methyl and primary carbocations, making them unreactive via this pathway.

(c) Isopropyl chloride forms a secondary carbocation, which possesses intermediate stability due to inductive effects and hyperconjugation from two adjacent methyl groups.

(d) Tert-butyl chloride, or $(CH_3)_3CCl$, undergoes rapid ionization to yield a tertiary carbocation. This intermediate is highly stabilized by the electron-donating inductive effects and nine hyperconjugative hydrogen atoms provided by the three surrounding methyl groups, resulting in the fastest relative rate.

Final Answer: The compound that will readily undergo substitution at the fastest rate is (CH3)3CCl.

Answer: (C)

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Q34.

Solution

Concept:
Qualitative inorganic analysis utilizes specific chemical precipitation reactions to identify the presence of metal cations in an unknown sample. Zinc ions react with coordination complexes to form distinctive insoluble salts. The chemical composition and color of these complex precipitates serve as diagnostic indicators in analytical chemistry schemes.

Solution:

(a) When a soluble zinc salt, such as zinc sulfate, is treated with a potassium ferrocyanide reagent in solution, a double displacement coordination reaction takes place.

(b) The zinc cations interact directly with the potassium ions and the hexacyanoferrate(II) complex anions present in the reaction mixture.

(c) This interaction results in the formation of a characteristic white or grayish-white precipitate, which is insoluble in dilute mineral acids but dissolves in excess alkali.

(d) The correct chemical formula for this complex white precipitate is a mixed metal salt containing both potassium and zinc, written as $K_2Zn_3[Fe(CN)_6]_2$.

Final Answer: The chemical formula of the white precipitate is $K_2Zn_3[Fe(CN)_6]_2$.

Answer: (B)

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Q35.

Solution

Concept:

Environmental chemistry monitors specific chemical indicators to evaluate the health and ecological balance of natural water systems. Dissolved oxygen refers to the amount of free, non-compound oxygen gas present in water. This parameter is essential for sustaining aquatic life, and its concentration reflects the balance between atmospheric aeration, photosynthesis, and organic decomposition.

Solution:

(a) Dissolved oxygen is vital for the respiration of fish and other aquatic organisms in natural ecosystems like rivers, lakes, and streams.

(b) In a healthy, unpolluted natural water body, the concentration of dissolved oxygen must be maintained within a specific optimal range to support diverse aquatic populations.

(c) If the oxygen concentration drops below 6 ppm, the growth of fish is inhibited, and severe depletion can lead to mass mortality of aquatic life.

(d) For a healthy water system at standard temperature, the ideal dissolved oxygen level ranges from 6 to 10 ppm, indicating minimal organic pollution and a balanced ecosystem.

Final Answer: The concentration of dissolved oxygen should ideally be around 6-10 ppm.

Answer: (B)

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Q36.

Solution

Concept:
The bimolecular nucleophilic substitution mechanism occurs in a single concerted step without any intermediates. The incoming nucleophile attacks the chiral carbon center from the side directly opposite to the leaving group to minimize electrostatic repulsion. This backside attack leads to a stereochemical consequence where the spatial configuration around the carbon atom is inverted, much like an umbrella turning inside out in a strong wind.

Solution:

(a) In a bimolecular substitution reaction, the bond-breaking and bond-forming processes take place simultaneously through a single transition state.

(b) Because the nucleophile attacks exclusively from the backside, the groups attached to the asymmetric carbon atom are forced to shift their spatial orientation.

(c) When the reaction is complete, the relative spatial arrangement of the substituents around the chiral center becomes inverted compared to the original starting material.

(d) This stereochemical phenomenon of complete configuration inversion during a bimolecular substitution process is historically named the Walden inversion, after the chemist Paul Walden.

Final Answer: This stereochemical phenomenon is termed as Walden inversion.

Answer: (B)

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Q37.

Solution

Concept:
The periodic trends of atomic dimensions are governed by changes in the principal quantum number and the effective nuclear charge. Moving across a specific period from left to right, electrons are added to the same outermost energy level, while protons are added to the nucleus. This increase in nuclear charge pulls the electron cloud closer to the nucleus, causing a systematic change in atomic size.

Solution:

(a) The elements sodium, magnesium, aluminum, and silicon all belong to the third period of the periodic table, meaning their valence electrons occupy the same principal shell.

(b) Moving from left to right across this period, the atomic number increases sequentially from eleven for sodium to fourteen for silicon.

(c) This increase in nuclear charge exerts a stronger electrostatic pull on the outer valence electrons, drawing them closer to the nucleus and reducing the atomic radius.

(d) Consequently, sodium has the largest atomic radius in this sequence, while silicon has the smallest. The accurate order of decreasing atomic radii is sodium followed by magnesium, aluminum, and silicon.

Final Answer: The arrangement that lists the elements in order of decreasing atomic radii size is $Na > Mg > Al > Si$.

Answer: (A)

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Q38.

Solution

Concept:
The electrical conductivity of an electrolyte solution increases as it is diluted because interionic interferences decrease. At infinite dilution, the ions are separated by infinite distances, meaning interionic attractions become completely negligible. Under these conditions, each ion moves independently of its co-ions and counter-ions, contributing a fixed value to the total molar conductivity of the electrolyte.

Solution:

(a) At infinite dilution, an electrolyte undergoes complete dissociation into its constituent cations and anions, and all interionic forces disappear.

(b) Friedrich Kohlrausch formulated a law stating that the limiting molar conductivity of an electrolyte can be expressed as the sum of the individual contributions of its anions and cations.

(c) Mathematically, this law is written as the limiting molar conductivity of the electrolyte equals the stoichiometric coefficient of the cation multiplied by its limiting ionic conductivity plus the stoichiometric coefficient of the anion multiplied by its limiting ionic conductivity.

(d) This independent migration principle allows for the determination of limiting molar conductivities for weak electrolytes, which cannot be measured directly by extrapolation.

Final Answer: The quantitative relationship is formulated by Kohlrausch Law.

Answer: (B)

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Q39.

Solution

Concept:
The structural architecture of proteins is classified into four distinct levels of organization. The primary sequence of amino acids folds into specific local conformations, known as the secondary structure, which includes patterns like alpha-helices and beta-pleated sheets. These regular geometric repeating units are stabilized by non-covalent interactions between atoms along the polypeptide backbone.

Solution:

(a) The secondary structure of a protein refers to the localized folding patterns of the polypeptide chain caused by interactions between the amino acid backbones.

(b) In an alpha-helix conformation, the polypeptide backbone curls into a right-handed spiral loop where the amino acid side chains extend outward from the helical axis.

(c) This coiled structure is stabilized by non-covalent hydrogen bonds that form between the carbonyl oxygen atom of one amino acid residue and the amide hydrogen atom of another residue located four positions further along the linear chain.

(d) These repetitive hydrogen bonds run parallel to the helical axis, providing the thermodynamic stability and structural rigidity necessary to maintain the shape of the protein.

Final Answer: The type of intermolecular attractive forces responsible are Hydrogen bonds.

Answer: (B)

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Q40.

Solution

Concept:
The industrial manufacture of sulfuric acid via the Contact process involves the catalytic oxidation of sulfur dioxide gas. The geometry and molecular shape of the resulting sulfur oxide product can be deduced using the Valence Shell Electron Pair Repulsion theory, which models the spatial arrangement that minimizes electrostatic repulsion between valence electron pairs around the central atom.

Solution:

(a) When sulfur dioxide gas reacts with atmospheric oxygen over a vanadium pentoxide catalyst at high temperatures, it undergoes clean oxidation to produce sulfur trioxide (SO_3).

(b) In a molecule of sulfur trioxide, the central sulfur atom has six valence electrons and forms covalent bonds with three surrounding oxygen atoms, leaving no non-bonding lone pairs on the sulfur center.

(c) The three electron domains arrange themselves as far apart as possible in three-dimensional space to minimize steric and electronic repulsion.

(d) According to VSEPR theory, three bonding domains and zero lone pairs around a central atom dictate a symmetric arrangement with bond angles of 120 degrees, producing a trigonal planar molecular geometry.

Final Answer: The correct molecular formula and shape designation is SO_3, Trigonal planar.

Answer: (A)

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Answer Key

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