KIITEE Chemistry Sample Paper – 7

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

Instructions

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

Q1. Which of the following aqueous solutions will exhibit the highest boiling point elevation?

(A) 0.05 M $Al_2(SO_4)_3$

(B) 0.10 M $K_4[Fe(CN)_6]$

(C) 0.15 M $BaCl_2$

(D) 0.20 M Urea

Q2. The principal organic product formed in the reaction of 1-bromobutane with excess alcoholic NH_3 under high pressure is:

(A) Butan-1-amine

(B) N-Butylbutan-1-amine

(C) N,N-Dibutylbutan-1-amine

(D) Tetrabutylammonium bromide

Q3. In which of the following pairs of species do both members have identical geometry and hybridization?

(A) XeF_2, CO_2

(B) BF_3, NH_3

(C) ICl_4^-, XeF_4

(D) SO_4^{2-}, XeO_4

Q4. Which of the following polymers is classified as a biodegradable polyester?

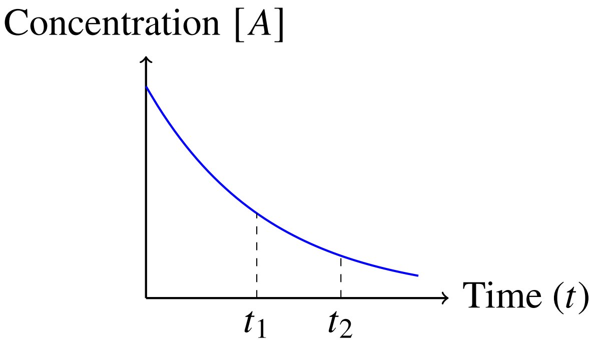
(A) Nylon-6,6

(B) PHBV

(C) Buna-N

(D) Terylene

Q5. For a first-order reaction, if the time required for 60% completion is t_1, and the time required for 80% completion is t_2, the ratio t_2/t_1 is closest to the values shown in the kinetics profile below:



(A) 1.33

(B) 1.75

(C) 2.15

(D) 2.50

Q6. The correct decreasing order of basic strength among the following amines in aqueous medium is:

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

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

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

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

Q7. Which of the following pollutants is primarily responsible for the phenomenon of 'blue baby syndrome' in infants?

(A) Phosphate

(B) Nitrate

(C) Sulfate

(D) Fluoride

Q8. In the extraction of copper from its sulfide ore, the metal is finally formed by the reduction of cuprous oxide with:

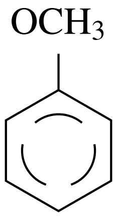
(A) Iron(II) sulfide

(B) Carbon monoxide

(C) Copper(I) sulfide

(D) Sulfur dioxide

Q9. The major product obtained when anisole (shown below) is treated with a mixture of concentrated HNO_3 and concentrated H_2SO_4 is:



(A) 2-Nitroanisole

(B) 4-Nitroanisole

(C) 3-Nitroanisole

(D) 2,4-Dinitroanisole

Q10. How many unpaired electrons are present in the high-spin complex $[CoF_6]^{3-}$?

(A) 0

(B) 2

(C) 4

(D) 5

Q11. The standard reduction potentials of three metals A, B, and C are +0.34 V, −0.76 V, and −0.44 V respectively. The correct order of their reducing power is:

(A) A > C > B

(B) B > C > A

(C) C > B > A

(D) B > A > C

Q12. Which of the following α-amino acids does not possess a chiral center and is optically inactive?

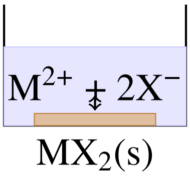
(A) Alanine

(B) Leucine

(C) Glycine

(D) Valine

Q13. The solubility product (K_{sp}) of a sparingly soluble salt MX_2 is 3.2×10^{-11}. Its solubility in pure water can be visualized from saturated solution equilibrium systems:



(A) 2.0×10^{-4} mol L^{-1}

(B) 4.0×10^{-4} mol L^{-1}

(C) 5.6×10^{-6} mol L^{-1}

(D) 3.2×10^{-4} mol L^{-1}

Q14. The standard enthalpy of formation ($\Delta_f H^\circ$) is zero for which of the following substances at 298 K?

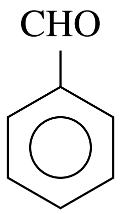
(A) Graphite (s)

(B) Diamond (s)

(C) Bromine (g)

(D) Iodine (l)

Q15. The product formed when benzaldehyde (shown below) reacts with concentrated sodium hydroxide solution is a mixture of:



(A) Benzyl alcohol and Sodium benzoate

(B) Sodium benzoate and Phenol

(C) Benzyl alcohol and Phenol

(D) Benzoic acid and Benzene

Q16. Which of the following oxide elements shows amphoteric behavior?

(A) N_2O_3

(B) Cr_2O_3

(C) N_2O_5

(D) CrO_3

Q17. The monomeric units of Novolac, a linear polymer used in paints, are:

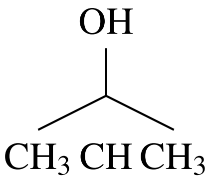
(A) Ethylene glycol and Phthalic acid

(B) Phenol and Formaldehyde

(C) Melamine and Formaldehyde

(D) Urea and Formaldehyde

Q18. An organic compound 'X' with molecular formula C_3H_6O forms a 2,4-DNP derivative but does not reduce Tollen's reagent. Compound 'X' on reduction with $NaBH_4$ gives the following structural outcome:



$CH_3\overset{OH}{\overset{|}{CH}}CH_3$

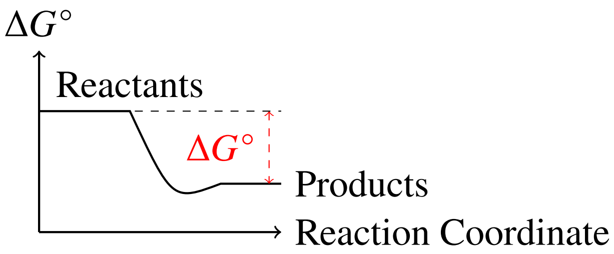
(A) Propan-1-ol

(B) Propan-2-ol

(C) Propanone

(D) Propanoic acid

Q19. For a cell reaction involving a two-electron change, the standard EMF of the cell is found to be 0.295 V at 298 K. The equilibrium constant (K_c) for the reaction plotted along standard free energy coordinates can be evaluated from: (Given: $2.303RT/F = 0.059$ V)



(A) 1.0×10^{10}

(B) 1.0×10^{5}

(C) 2.0×10^{10}

(D) 1.0×10^{-10}

Q20. Which of the following ordered arrangements represents the correct sequence of increasing ozone depleting potential?

(A) $CF_4 < CF_2Cl_2 < CF_3Cl$

(B) $CF_4 < CF_3Cl < CF_2Cl_2$

(C) $CF_2Cl_2 < CF_3Cl < CF_4$

(D) $CF_3Cl < CF_2Cl_2 < CF_4$

Q21. The correct order of acid strength among the following halogen oxoacids is:

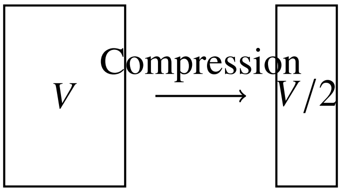
(A) $HClO < HClO_2 < HClO_3 < HClO_4$

(B) $HClO_4 < HClO_3 < HClO_2 < HClO$

(C) $HClO_3 < HClO_4 < HClO_2 < HClO$

(D) $HClO_4 < HClO_2 < HClO_3 < HClO$

Q22. An industrial chemical process reaches equilibrium at a certain temperature. If the volume of the reaction vessel is suddenly halved for the system: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, the equilibrium constant K_p will be affected as shown by the thermodynamic framework below:



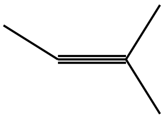
(A) Increase

(B) Decrease

(C) Remain unchanged

(D) Double

Q23. Ozonolysis of an alkene 'M' followed by treatment with Zn/H_2O yields a mixture of ethanal and propanone. The skeletal configuration of alkene 'M' matches which of the following structures?



(A) 2-Methylbut-2-ene

(B) Pent-2-ene

(C) 3-Methylbut-1-ene

(D) 2-Methylbut-1-ene

Q24. Which of the following configurations represents an element with the highest second ionization enthalpy?

(A) $1s^22s^22p^63s^1$

(B) $1s^22s^22p^63s^2$

(C) $1s^22s^22p^63s^23p^1$

(D) $1s^22s^22p^63s^23p^3$

Q25. Which test can be successfully implemented to distinguish between methanol and ethanol?

(A) Lucas test

(B) Iodoform test

(C) Tollen's test

(D) Carbylamine test

Q26. What is the total number of ions produced per formula unit when the coordination complex Pentaamminenitrochromium(III) chloride is dissolved in water?

(A) 2

(B) 3

(C) 4

(D) 5

Q27. According to the molecular orbital theory, which of the following species possesses a fractional bond order and is simultaneously paramagnetic?

(A) O_2^{2-}

(B) N_2^+

(C) C_2

(D) O_2

Q28. The rate constant of a chemical reaction is found to be 3.4×10^{-4} mol^{-1} L s^{-1}. The overall order of this reaction is:

(A) Zero

(B) First

(C) Second

(D) Third

Q29. RNA differs structurally from DNA by containing which specific sugar and nitrogenous base configuration?

(A) Ribose and Thymine

(B) Deoxyribose and Uracil

(C) Ribose and Uracil

(D) Deoxyribose and Thymine

Q30. The major product obtained when 2-bromobutane is treated with potassium tert-butoxide in tert-butyl alcohol is:

(A) but-1-ene

(B) trans-but-2-ene

(C) cis-but-2-ene

(D) 2-butanol

Q31. Which of the following gases is predominantly responsible for the phenomenon of global warming and is targeted heavily under greenhouse tracking?

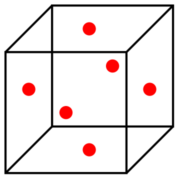
(A) O_3

(B) CO_2

(C) SO_2

(D) N_2O

Q32. In a face-centered cubic (fcc) crystal lattice of an element, what percentage of the total unit cell volume shown below is completely empty space?



(A) 26%

(B) 32%

(C) 48%

(D) 68%

Q33. The spin-only magnetic moment of a divalent transition metal ion (M^{2+}) with atomic number 26 in an aqueous solution is:

(A) 3.87 BM

(B) 4.90 BM

(C) 5.92 BM

(D) 2.84 BM

Q34. The correct decreasing order of reactivity towards nucleophilic acyl substitution for the following carboxylic acid derivatives is:

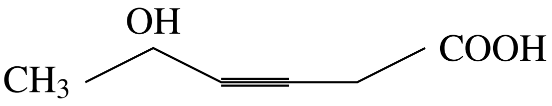
(A) Acid chloride > Acid anhydride > Ester > Amide

(B) Acid chloride > Ester > Acid anhydride > Amide

(C) Amide > Ester > Acid anhydride > Acid chloride

(D) Acid anhydride > Acid chloride > Ester > Amide

Q35. What is the correct IUPAC name of the structural skeleton compound given below?



(A) 5-Hydroxyhex-2-ynoic acid

(B) 2-Hydroxyhex-4-ynoic acid

(C) 5-Hydroxyhex-3-ynoic acid

(D) 1-Hydroxyhex-4-ynoic acid

Q36. The coagulation of a negative sol like As_2S_3 is achieved most effectively by adding a minimum concentration of which of the following electrolytes?

(A) NaCl

(B) $MgSO_4$

(C) $AlCl_3$

(D) $K_3[Fe(CN)_6]$

Q37. Which of the following statement groups correctly identifies the main components of photochemical smog?

(A) SO_2, Nitrogen oxides, and Particulates

(B) O_3, PAN, and Nitrogen oxides

(C) CO_2, CO, and Sulfur oxides

(D) O_3, SO_2, and Hydrocarbons

Q38. When d-glucose is treated with excess phenylhydrazine, it forms an osazone. Which other carbohydrate will yield the exact same osazone structure under identical conditions?

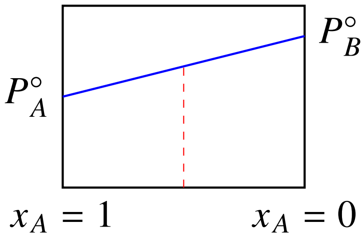
(A) d-Galactose

(B) d-Fructose

(C) d-Sucrose

(D) d-Arabinose

Q39. Vapor pressure of pure liquid A is 400 mm Hg and that of pure liquid B is 600 mm Hg at a given temperature. According to the ideal binary liquid-vapor mixture profile shown below, if an ideal solution is prepared by mixing equal moles of A and B, the mole fraction of component A in the vapor phase at equilibrium will be:



(A) 0.40

(B) 0.50

(C) 0.60

(D) 0.67

Q40. Which of the following compounds will not undergo Friedel-Crafts alkylation reaction due to strong deactivation of the aromatic ring?

(A) Toluene

(B) Chlorobenzene

(C) Nitrobenzene

(D) Bromobenzene

Detailed Solutions

Q1.

Solution

Concept:

The elevation in boiling point (ΔT_b) is a colligative property which depends directly on the concentration of solute particles in the solution. It is mathematically defined by the relation $\Delta T_b = i \cdot K_b \cdot m$, where i is the van 't Hoff factor representing the total number of ions formed upon complete dissociation, K_b is the molal elevation constant of the solvent, and m is the molality of the solution. For dilute aqueous systems, molarity (M) can be used as a close approximation for molality to evaluate the relative order of colligative effects.

Solution:

Step 1: Identify the nature of solute dissociation and determine the van 't Hoff factor (i) for each option.

Step 2: For Option (A), $Al_2(SO_4)_3$ is a strong electrolyte that dissociates into two Al^{3+} ions and three SO_4^{2-} ions. Therefore, $i = 2 + 3 = 5$. The effective particle concentration is calculated as:

$$i \cdot M = 5 \cdot 0.05 \text{ M} = 0.25 \text{ M}$$

Step 3: For Option (B), $K_4[Fe(CN)_6]$ dissociates to yield four K^+ ions and one complex anion $[Fe(CN)_6]^{4-}$. Thus, $i = 4 + 1 = 5$. The effective particle concentration is:

$$i \cdot M = 5 \cdot 0.10 \text{ M} = 0.50 \text{ M}$$

Step 4: For Option (C), $BaCl_2$ dissociates into one Ba^{2+} ion and two Cl^- ions, giving $i = 1 + 2 = 3$. The effective particle concentration is:

$$i \cdot M = 3 \cdot 0.15 \text{ M} = 0.45 \text{ M}$$

Step 5: For Option (D), Urea is an organic non-electrolyte compound. It does not undergo any dissociation or association in water, so $i = 1$. The effective particle concentration is:

$$i \cdot M = 1 \cdot 0.20 \text{ M} = 0.20 \text{ M}$$

Step 6: Compare all the calculated effective particle concentrations ($i \cdot M$ values): 0.25 M, 0.50 M, 0.45 M, and 0.20 M. The highest product value is 0.50 M, corresponding to the potassium ferrocyanide solution. Since boiling point elevation scales linearly with effective particle concentration, this solution will exhibit the greatest elevation.

Final Answer: $\boxed{0.10 \text{ M } K_4[Fe(CN)_6]}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:

The reaction of an alkyl halide with ammonia (NH_3) proceeds via an S_N2 nucleophilic substitution mechanism. This pathway belongs to the classical nucleophilic alkylation scheme. Ammonia acts as a neutral nucleophile, using its lone pair to attack the electrophilic carbon bearing the halogen. When an excess of ammonia is specifically used relative to the alkyl halide, the reaction stops predominantly after the first substitution, effectively preventing further alkylation cycles.

Solution:

Step 1: Analyze the chemical reactants and conditions. We have 1-bromobutane reacting with an excess concentration of alcoholic ammonia under high pressure conditions.

Step 2: Ammonia attacks the primary carbon of 1-bromobutane, displacing the bromide leaving group in a single concerted nucleophilic step.

Step 3: This initial displacement step forms an intermediate butylammonium ion salt:

$$CH_3CH_2CH_2CH_2Br + NH_3 \rightarrow CH_3CH_2CH_2CH_2NH_3^+ + Br^-$$

Step 4: A second molecule of ammonia quickly deprotonates this charged intermediate to yield the neutral primary amine, butan-1-amine:

$$CH_3CH_2CH_2CH_2NH_3^+ + NH_3 \rightleftharpoons CH_3CH_2CH_2CH_2NH_2 + NH_4^+$$

Step 5: Because ammonia is present in large excess, any freshly formed primary amine molecule is statistically heavily outcompeted by the massive amount of ammonia molecules when searching for unreacted 1-bromobutane. This suppresses secondary, tertiary, and quaternary side reactions, ensuring that the primary amine remains the dominant major product.

Final Answer: $\boxed{\text{Butan-1-amine}}$

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

Go Back to Question 2

Q3.

Solution

Concept:
To establish identical geometry and orbital hybridization between two species, one must use Valence Shell Electron Pair Repulsion (VSEPR) theory. The steric number equation determines the hybridization state: Steric Number (SN) = $\frac{1}{2}[V + M - C + A]$, where V is the number of valence electrons on the central atom, M is the number of monovalent atoms, C is the cationic charge, and A is the anionic charge. The spatial arrangement of bonding pairs and lone pairs dictates the final molecular geometry.

Solution:
Step 1: Evaluate the structures of the molecular species listed across the options.
Step 2: For Option (C), look at ICl_4^- and XeF_4. For the central iodine atom in ICl_4^-, the steric number is calculated as:

$$SN = \frac{1}{2}[7 + 4 - 0 + 1] = 6$$

This corresponds to sp^3d^2 hybridization. With 4 bonding pairs and 2 lone pairs, its molecular geometry is square planar.
Step 3: For the central xenon atom in XeF_4, the steric number is computed as:

$$SN = \frac{1}{2}[8 + 4 - 0 + 0] = 6$$

This yields the same sp^3d^2 hybridization state. Containing 4 bonding pairs and 2 lone pairs, it also adopts a square planar molecular geometry.
Step 4: Compare other choices to confirm they mismatch. In Option (A), XeF_2 has a linear geometry (sp^3d, 3 lone pairs) while CO_2 is linear but with sp hybridization. In Option (B), BF_3 is trigonal planar (sp^2) while NH_3 is trigonal pyramidal (sp^3). In Option (D), both share a tetrahedral shape but SO_4^{2-} uses sp^3 while transition metal configurations or expanded states vary in bonding mechanics. Thus, only Option (C) matches perfectly in both properties.

Final Answer: $\boxed{ICl_4^-, XeF_4}$

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept:

Biodegradable polymers undergo environmental breakdown via naturally occurring microbial metabolic processes. A significant group of these materials consists of biopolyesters, which contain repeating ester linkages ($-COO-$) within their backbone that are susceptible to enzymatic hydrolysis. Identifying the correct polymer requires recognizing its functional groups and monomeric components.

Solution:

Step 1: Analyze the chemical classifications of the polymers presented in the choices.

Step 2: Nylon-6,6 is a synthetic polyamide containing amide linkages, which is non-biodegradable under standard natural conditions.

Step 3: PHBV stands for Poly(β-hydroxybutyrate-co-β-hydroxyvalerate). It is a copolymer synthesized from 3-hydroxybutanoic acid and 3-hydroxypentanoic acid.

Step 4: The condensation reaction between the hydroxyl ($-OH$) and carboxylic acid ($-COOH$) groups of these monomers forms an ester backbone:

$$\text{nMonomers} \longrightarrow [\text{-O-CH(CH}_3\text{)-CH}_2\text{-CO-O-CH(CH}_2\text{CH}_3\text{)-CH}_2\text{-CO-}]_\text{n}$$

Because of these structural ester linkages and its biological origin, PHBV undergoes clean bacterial degradation in the environment, breaking down into carbon dioxide and water.

Step 5: Buna-N is a synthetic elastomer copolymer of 1,3-butadiene and acrylonitrile, while Terylene is a synthetic polyester; however, Terylene is highly resistant to natural environmental degradation. Therefore, PHBV is the correct biodegradable polyester option.

Final Answer: $\boxed{\text{PHBV}}$

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

Go Back to Question 4

Q5.

Solution

Concept:

The integrated rate equation for a first-order chemical reaction is given by the expression:

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

where k is the specific reaction rate constant, $[A]_0$ represents the initial reactant concentration, and $[A]_t$ represents the remaining reactant concentration at any given time t. Colligative properties or percentages can be inserted directly to determine specific time intervals.

Solution:

Step 1: Formulate the equation for t_1, the time required for 60% completion of the first-order reaction. At this point, 60% of the reactant has been consumed, leaving 40% of the initial amount. Thus, $[A]_{t1} = 0.40[A]_0$.

$$t_1 = \frac{2.303}{k}\log\left(\frac{100}{40}\right) = \frac{2.303}{k}\log(2.5)$$

Step 2: Formulate the equation for t_2, the time required for 80% completion. Here, 80% of the starting material is consumed, leaving behind 20%. Thus, $[A]_{t2} = 0.20[A]_0$.

$$t_2 = \frac{2.303}{k}\log\left(\frac{100}{20}\right) = \frac{2.303}{k}\log(5)$$

Step 3: Set up the ratio of t_2 to t_1 by dividing the second equation by the first equation. Notice that the constant factor $\frac{2.303}{k}$ cancels out:

$$\frac{t_2}{t_1} = \frac{\log(5)}{\log(2.5)}$$

Step 4: Substitute the standard base-10 logarithmic values ($\log(5) \approx 0.6990$ and $\log(2.5) \approx 0.3979$) into the ratio:

$$\frac{t_2}{t_1} = \frac{0.6990}{0.3979} \approx 1.756$$

Step 5: Compare this numerical result with the choices provided. The calculated value aligns closely with 1.75.

Final Answer: $\boxed{1.75}$

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

Go Back to Question 5

Q6.

Solution

Concept:

The basic strength of aliphatic amines in an aqueous medium is determined by three competing chemical factors: the inductive effect ($+I$) of the alkyl groups, steric hindrance around the nitrogen atom, and the stabilization of the substituted ammonium cation via hydration (hydrogen bonding with water molecules). For methyl-substituted amines, these counteracting forces result in a non-linear trend that deviates from gas-phase basicity.

Solution:

Step 1: Analyze the three core effects for methyl-substituted amines in water.

Step 2: The inductive effect increases electron density on nitrogen as the number of methyl groups increases, suggesting a basicity order of: tertiary > secondary > primary.

Step 3: Hydration energy stabilizes the conjugate acid through hydrogen bonding. Since smaller cavities with more hydrogen atoms form stronger bonds with water, this effect favors a basicity order of: primary > secondary > tertiary.

Step 4: Steric hindrance disrupts both the approach of a proton and effective hydration, heavily destabilizing the bulky tertiary amine conjugate acid.

Step 5: Combining these trends for the methyl group (CH_3) gives a specific, well-established order of basic strength: secondary amine is the strongest because it balances steric access with inductive enrichment, followed by the primary amine, then the tertiary amine, and lastly ammonia (NH_3).

Step 6: Expressing this sequence using the specific compounds yields:

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

This match corresponds to Option (A).

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

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:

Environmental contamination of water resources by certain chemical runoff ions can lead to severe physiological toxicoses. Infant methemoglobinemia, commonly known as 'blue baby syndrome', is a hematological disorder caused by a specific pollutant in drinking water that interferes with the blood's oxygen transport capacity.

Solution:

Step 1: Examine the biochemical mechanism behind the disease. When infants ingest water containing high levels of nitrate (NO_3^-), standard gastrointestinal bacteria reduce these ions into highly reactive nitrite (NO_2^-) ions.

Step 2: Nitrite ions enter the bloodstream and bind to hemoglobin, oxidizing the normal ferrous iron (Fe^{2+}) state into the ferric iron (Fe^{3+}) state. This altered form of hemoglobin is called methemoglobin.

Step 3: Unlike regular hemoglobin, methemoglobin cannot bind or transport oxygen molecules to body tissues.

Step 4: This systemic oxygen deprivation causes clinical hypoxia, giving the infant's skin a characteristic blue or cyanotic tint.

Step 5: Based on this toxicological pathway, nitrate is identified as the ion responsible for blue baby syndrome. This matches Option (B).

Final Answer: $\boxed{\text{Nitrate}}$

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

Go Back to Question 7

Q8.

Solution

Concept:

The metallurgy of copper using its sulfide ore (such as copper pyrites) involves a process known as self-reduction or auto-reduction. After initial roasting, a portion of the copper(I) sulfide (Cu_2S) is oxidized into copper(I) oxide (Cu_2O). In the final Bessemerization stage, these two species undergo a redox reaction without requiring an external reducing agent like carbon or carbon monoxide.

Solution:

Step 1: Review the chemical changes that occur in the furnace during the final stages of copper extraction.

Step 2: The roasted ore contains a mixture of copper(I) oxide (Cu_2O) and unoxidized copper(I) sulfide (Cu_2S).

Step 3: When the mixture is heated to high temperatures in the converter, the copper(I) oxide reacts directly with the copper(I) sulfide.

Step 4: Write out the balanced chemical equation for this auto-reduction process:

$$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2(g)$$

Step 5: In this reaction, the sulfur atoms in Cu_2S oxidize to form sulfur dioxide gas, while the copper ions in both compounds are reduced to elemental metallic copper. This crude product is called blister copper.

Step 6: Based on this mechanism, the substance acting as the reducing agent for cuprous oxide is copper(I) sulfide. This corresponds to Option (C).

Final Answer: $\boxed{\text{Copper(I) sulfide}}$

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

Go Back to Question 8

Q9.

Solution

Concept:
Electrophilic aromatic substitution on a substituted benzene ring is governed by the electronic and steric properties of the existing substituent group. The methoxy group ($-OCH_3$) on anisole has a lone pair on the oxygen atom adjacent to the ring, which enables it to donate electron density via resonance ($+M$ effect). This donation increases electron density across the ring, activating it toward electrophilic attack specifically at the ortho and para positions.

Solution:
Step 1: Identify the nitrating agent and the electrophile. A mixture of concentrated nitric acid (HNO_3) and concentrated sulfuric acid (H_2SO_4) generates the active nitronium ion electrophile (NO_2^+).
Step 2: Analyze the directing influence of the methoxy group ($-OCH_3$) on anisole. Resonance structures show that negative charges develop at the ortho and para positions:

$$C_6H_5OCH_3 + NO_2^+ \rightarrow \text{ortho- product} + \text{para- product}$$

Step 3: Evaluate steric hindrance for both positions. The ortho position is adjacent to the bulky methoxy group, introducing significant steric strain during the transition state.
Step 4: The para position is far from the methoxy group, allowing the nitronium ion to attack with minimal steric hindrance.
Step 5: Due to this lower steric hindrance, the para-isomer (4-nitroanisole) forms as the major product, while the ortho-isomer forms only as a minor product. This matches Option (B).

Final Answer: $\boxed{\text{4-Nitroanisole}}$

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:

Crystal Field Theory (CFT) explains the electronic configuration of coordination complexes by evaluating the oxidation state of the central metal, its d-electron count, and the field strength of the ligands. Fluoride (F^-) is a weak-field ligand located near the beginning of the spectrochemical series. It produces a small crystal field splitting energy (Δ_o), meaning electrons do not pair up in the lower energy orbitals but instead populate the higher energy orbitals according to Hund's rule.

Solution:

Step 1: Determine the oxidation state of cobalt in the coordination complex $[CoF_6]^{3-}$. Let x be the oxidation state of Co:

$$x + 6(-1) = -3 \implies x = +3$$

Step 2: Write out the ground-state electronic configuration of elemental Cobalt ($Z = 27$), which is $[Ar]3d^7 4s^2$. Removing three electrons yields the configuration for the Co^{3+} ion: $[Ar]3d^6$.

Step 3: Analyze the orbital splitting pattern. In an octahedral crystal field, the five $3d$ orbitals split into three lower-energy t_{2g} orbitals and two higher-energy e_g orbitals.

Step 4: Since fluoride is a weak-field ligand, the pairing energy (P) is greater than the splitting energy ($\Delta_o < P$). The complex adopts a high-spin configuration.

Step 5: Distribute the 6 electrons across the split d-orbitals according to Hund's rule: fill the t_{2g} orbitals singly, then the e_g orbitals singly, and pair the remaining electron in the t_{2g} level. This yields an orbital distribution of $t_{2g}^4 e_g^2$.

Step 6: Count the unpaired electrons: one paired orbital and four singly occupied orbitals means there are 4 unpaired electrons. This matches Option (C).

Final Answer: $\boxed{4}$

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:
The reducing power of a metal reflects its tendency to lose electrons and undergo oxidation. According to standard electrochemical conventions, a substance's reducing power is inversely related to its standard reduction potential (E°). A more negative or lower standard reduction potential indicates that a metal is easily oxidized, making it a stronger reducing agent.

Solution:
Step 1: Collect the standard reduction potential values provided for the three metals:

$$E^\circ_{\mathrm{A}} = +0.34\ \mathrm{V}, \quad E^\circ_{\mathrm{B}} = -0.76\ \mathrm{V}, \quad E^\circ_{\mathrm{C}} = -0.44\ \mathrm{V}$$

Step 2: Arrange the given values in ascending numerical order:

$$-0.76\ \mathrm{V} < -0.44\ \mathrm{V} < +0.34\ \mathrm{V}$$

Step 3: Map these ordered potentials back to their corresponding metals:

$$E^\circ_{\mathrm{B}} < E^\circ_{\mathrm{C}} < E^\circ_{\mathrm{A}}$$

Step 4: Apply the electrochemical rule: a lower reduction potential corresponds to a stronger reducing power. Therefore, metal B is the strongest reducing agent because it has the most negative potential, followed by metal C, while metal A is the weakest reducing agent due to its positive potential.
Step 5: Write out the final decreasing order of reducing power: B > C > A. This sequence matches Option (B).

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

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:
An organic compound is optically active if it contains a chiral center, which is a tetrahedral carbon atom bonded to four entirely different atom groups. For α-amino acids, the general structure features a central alpha-carbon (C_α) bonded to an amino group ($-NH_2$), a carboxylic acid group ($-COOH$), a hydrogen atom ($-H$), and a variable side-chain substituent ($-R$). If the side chain is a hydrogen atom, the alpha-carbon is bonded to two identical groups, making the molecule achiral and optically inactive.

Solution:
Step 1: Examine the structural configurations of the amino acid choices to evaluate their alpha-carbon environments.
Step 2: Alanine features a methyl side chain ($-R = -CH_3$), creating four unique groups on the alpha-carbon and making it chiral.
Step 3: Leucine features an isobutyl side chain ($-R = -CH_2CH(CH_3)_2$), which also creates a chiral center.
Step 4: Glycine is the simplest amino acid. Its side chain consists of a single hydrogen atom ($-R = -H$). The full chemical structure of glycine can be written as:

$$H_2N - CH_2 - COOH$$

Step 5: Because the central alpha-carbon in glycine is bonded to two identical hydrogen atoms, it lacks an asymmetric chiral center. The molecule possesses a plane of symmetry, rendering it achiral and optically inactive.
Step 6: Valine has an isopropyl side chain and remains chiral. Therefore, glycine is the only optically inactive alpha-amino acid. This aligns with Option (C).

Final Answer: $\boxed{\text{Glycine}}$

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept:

The solubility product constant (K_{sp}) governs the equilibrium established in a saturated solution of a sparingly soluble salt. For a generic ternary salt with the formula MX_2, dissolution yields one metal cation and two non-metal anions per formula unit. Expressing the equilibrium concentrations of these ions in terms of the molar solubility (S) allows for a direct calculation of the salt's overall solubility.

Solution:

Step 1: Write out the balanced chemical equation for the dissolution of the salt MX_2 in water:

$$\mathrm{MX_2(s)} \rightleftharpoons \mathrm{M^{2+}(aq)} + \mathrm{2X^-(aq)}$$

Step 2: Define equilibrium concentrations in terms of the molar solubility, S (in mol L^{-1}):

$$[\mathrm{M^{2+}}] = S, \quad [\mathrm{X^-}] = 2S$$

Step 3: Set up the equilibrium expression for the solubility product constant (K_{sp}):

$$K_{sp} = [\mathrm{M^{2+}}][\mathrm{X^-}]^2 = (S)(2S)^2 = 4S^3$$

Step 4: Substitute the given value of K_{sp} (3.2×10^{-11}) into the algebraic equation:

$$3.2 \times 10^{-11} = 4S^3$$

Step 5: Isolate S^3 by dividing both sides of the equation by 4:

$$S^3 = \frac{3.2 \times 10^{-11}}{4} = 8.0 \times 10^{-12}$$

Step 6: Calculate the cube root of both sides to determine the value of S:

$$S = \sqrt[3]{8.0 \times 10^{-12}} = 2.0 \times 10^{-4} \text{ mol L}^{-1}$$

Step 7: Match this calculated value with the given options. The result corresponds exactly to Option (A).

Final Answer: $\boxed{2.0 \times 10^{-4} \text{ mol L}^{-1}}$

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept:

By thermodynamic convention, the standard enthalpy of formation ($\Delta_f H^\circ$) of an element is assigned a baseline value of zero when it exists in its most stable physical state and allotropic form under standard reference conditions ($T = 298$ K and $P = 1$ bar). Evaluating thermodynamic values requires identifying the primary reference state for each element.

Solution:

Step 1: Review the standard reference states for the elements listed in the options.

Step 2: Carbon exists in multiple allotropic forms, primarily graphite and diamond. Among these, graphite is the thermodynamically most stable form at 298 K and 1 bar. Consequently, $\Delta_f H^\circ$ [Carbon, graphite] = 0, while the value for diamond is non-zero (≈ 1.9 kJ/mol).

Step 3: For Bromine, the standard physical state under reference conditions is a liquid ($Br_2(l)$). Therefore, gaseous bromine ($Br_2(g)$) has a non-zero enthalpy of formation.

Step 4: For Iodine, the standard physical state under reference conditions is a solid ($I_2(s)$), meaning liquid iodine ($I_2(l)$) has a positive enthalpy of formation.

Step 5: Based on these criteria, graphite is the only substance in the choices that represents a standard elemental reference state, making its enthalpy of formation zero. This matches Option (A).

Final Answer: $\boxed{\text{Graphite (s)}}$

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

Go Back to Question 14

Q15.

Solution

Concept:
The Cannizzaro reaction is a base-induced disproportionation reaction of aldehydes that lack an α-hydrogen atom. When treated with a concentrated strong base, one molecule of the aldehyde undergoes nucleophilic oxidation to form a carboxylic acid salt, while a second molecule undergoes reduction to form a primary alcohol.

Solution:
Step 1: Analyze the structure of benzaldehyde (C_6H_5CHO). The formyl carbon is bonded directly to a benzene ring carbon that lacks any hydrogen atoms, meaning benzaldehyde has no α-hydrogens.
Step 2: When benzaldehyde is treated with a concentrated sodium hydroxide (NaOH) solution, it cannot undergo an aldol condensation. Instead, it follows the Cannizzaro reaction pathway.
Step 3: In this mechanism, a hydroxide ion attacks the carbonyl carbon of one benzaldehyde molecule, forming a tetrahedral intermediate. This intermediate transfers a hydride ion (H^-) directly to a second benzaldehyde molecule.
Step 4: The molecule that loses the hydride ion is oxidized to benzoic acid, which immediately reacts with the basic medium to form sodium benzoate:

$$C_6H_5CHO + OH^- \rightarrow C_6H_5COO^- + \text{Co-products}$$

Step 5: The second molecule, which accepts the hydride ion, is reduced to a benzyl oxide intermediate that protonates to form benzyl alcohol:

$$C_6H_5CHO + H^- \rightarrow C_6H_5CH_2O^- \rightarrow C_6H_5CH_2OH$$

Step 6: Combining these steps shows that the reaction produces a mixture of benzyl alcohol and sodium benzoate. This corresponds to Option (A).

Final Answer: Benzyl alcohol and Sodium benzoate

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:
Chemical oxides are classified as acidic, basic, or amphoteric depending on how they react with acids and bases. Most non-metal oxides in high oxidation states are acidic, while metal oxides in low oxidation states are basic. Some transition metal oxides in intermediate oxidation states exhibit amphoteric behavior, meaning they can dissolve in both strong acids and strong bases.

Solution:
Step 1: Analyze the properties of the oxides listed in the options.
Step 2: Nitrogen is a non-metal. Both N_2O_3 and N_2O_5 are covalent non-metal oxides that react with water to form nitrous acid (HNO_2) and nitric acid (HNO_3), respectively. Thus, both are purely acidic oxides.
Step 3: Evaluate the chromium oxides. Chromium can exist in multiple oxidation states. In chromium trioxide (CrO_3), chromium is in its highest oxidation state (+6). This high charge density makes the oxide strongly acidic, and it reacts with water to form chromic acid (H_2CrO_4).
Step 4: In dichromium trioxide (Cr_2O_3), chromium is in the intermediate +3 oxidation state. This oxide is insoluble in water but exhibits amphoteric behavior, reacting with acids to form hydrated Cr^{3+} salts and dissolving in concentrated bases to form chromite complexes:

$$Cr_2O_6^{3-} \text{ complexes or similar species}$$

Step 5: Because Cr_2O_3 displays both acidic and basic chemical properties, it is classified as an amphoteric oxide. This matches Option (B).

Final Answer: $\boxed{Cr_2O_3}$

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept:

Novolac is a linear condensation polymer that serves as a precursor to cross-linked networks like bakelite. It is synthesized via a step-growth condensation polymerization of two primary monomers in the presence of an acid catalyst, using a controlled molar ratio where the aldehyde component is kept as the limiting reactant.

Solution:

Step 1: Identify the chemical components involved in the industrial production of phenol-formaldehyde resins.

Step 2: Phenol reacts with formaldehyde (HCHO) under acidic conditions to undergo electrophilic aromatic substitution, forming ortho- and para-hydroxymethylphenol derivatives.

Step 3: These hydroxymethyl intermediates then undergo condensation, losing water molecules to link the aromatic rings through methylene ($-CH_2-$) bridges.

Step 4: When the reaction is conducted with an excess of phenol under acidic conditions, it forms a linear polymer chain called Novolac:

$$\text{n } C_6H_5OH + \text{n } HCHO \xrightarrow{H^+} [\text{-}C_6H_3(OH) - CH_2\text{-}]_n$$

Step 5: This linear resin is widely used in industries for making varnishes, protective coatings, and paints.

Step 6: Based on this polymerization pathway, the monomeric units of Novolac are phenol and formaldehyde. This corresponds to Option (B).

Final Answer: $\boxed{\text{Phenol and Formaldehyde}}$

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

Go Back to Question 17

Q18.

Solution

Concept:

The molecular formula C_3H_6O corresponds to a degree of unsaturation of one, indicating the presence of either a double bond or a ring. Because the compound forms a 2,4-dinitrophenylhydrazine (2,4-DNP) derivative, it must contain a carbonyl functional group ($C = O$). Carbonyl compounds can be classified as either aldehydes or ketones. Aldehydes reduce Tollen's reagent to form a silver mirror, whereas ketones do not.

Solution:

Step 1: Identify the structure of compound 'X'. Since 'X' has the formula C_3H_6O, contains a carbonyl group, and does not reduce Tollen's reagent, it must be a ketone rather than an aldehyde.

Step 2: The only three-carbon ketone is propanone (commonly known as acetone), which has the structural formula:

$$CH_3 - CO - CH_3$$

Step 3: Analyze the reduction of propanone with sodium borohydride ($NaBH_4$). Sodium borohydride is a reducing agent that delivers a hydride ion (H_-) to the electrophilic carbonyl carbon.

Step 4: This nucleophilic addition converts the ketone group into a secondary alcohol group.

Step 5: Write out the balanced reduction reaction equation:

$$CH_3 - CO - CH_3 \xrightarrow{NaBH_4} CH_3 - CH(OH) - CH_3$$

Step 6: Name the product according to IUPAC nomenclature. A three-carbon chain with a hydroxyl group at the second position is named propan-2-ol. This corresponds to Option (B).

Final Answer: Propan-2-ol

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:

The standard electromotive force (E°_{cell}) of an electrochemical cell is directly related to the thermodynamic equilibrium constant (K_c) of the cell reaction through the Nernst equation at standard temperature (298 K):

$$E^\circ_{\text{cell}} = \frac{2.303RT}{nF} \log K_c$$

where n represents the number of moles of electrons transferred in the balanced redox equation, and the term $\frac{2.303RT}{F}$ simplifies to a constant value of 0.059 V.

Solution:

Step 1: State the given values from the problem:

$$E^\circ_{\text{cell}} = 0.295 \text{ V}, \quad n = 2, \quad \frac{2.303RT}{F} = 0.059 \text{ V}$$

Step 2: Substitute these values into the simplified Nernst relationship equation:

$$0.295 = \frac{0.059}{2} \log K_c$$

Step 3: Isolate the term $\log K_c$ by multiplying both sides by 2 and dividing by 0.059:

$$\log K_c = \frac{0.295 \cdot 2}{0.059}$$

Step 4: Simplify the numerical expression:

$$\log K_c = \frac{0.590}{0.059} = 10$$

Step 5: Solve for K_c by taking the base-10 inverse logarithm of both sides:

$$K_c = 10^{10} = 1.0 \times 10^{10}$$

Step 6: Match this numerical result with the choices. The value corresponds to Option (A).

Final Answer: $\boxed{1.0 \times 10^{10}}$

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept:

Ozone Depleting Potential (ODP) measures the relative amount of degradation a chemical compound causes to the stratospheric ozone layer, using trichlorofluoromethane (CFC-11) as a baseline reference with an ODP of 1.0. A compound's ODP depends primarily on the number of chlorine or bromine atoms it contains, as well as its atmospheric lifetime. Molecules that lack chlorine or bromine atoms cannot participate in catalytic ozone destruction cycles.

Solution:

Step 1: Analyze the chemical compositions of the three halocarbon compounds: CF_4, CF_3Cl, and CF_2Cl_2.

Step 2: Carbon tetrafluoride (CF_4) is a fluorocarbon that contains only carbon-fluorine bonds. Because it contains no chlorine or bromine atoms, it does not release ozone-destroying radicals in the stratosphere, giving it an ODP of approximately zero.

Step 3: Chlorotrifluoromethane (CF_3Cl) contains a single chlorine atom per molecule, allowing it to release one reactive chlorine radical upon photolysis. This gives it a moderate ODP value.

Step 4: Dichlorodifluoromethane (CF_2Cl_2, commonly known as CFC-12) contains two chlorine atoms per molecule, which increases its capacity to catalytically destroy stratospheric ozone and gives it a higher ODP than CF_3Cl.

Step 5: Arrange these compounds in order of increasing ODP based on their chlorine content:

$$CF_4 < CF_3Cl < CF_2Cl_2$$

Step 6: Compare this sequence with the given options. The trend matches Option (B).

Final Answer: $\boxed{CF_4 < CF_3Cl < CF_2Cl_2}$

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:
The acid strength of a series of oxoacids containing the same central halogen atom is determined by the oxidation state of that central atom. As the oxidation state of the halogen increases, its effective electronegativity increases, drawing electron density away from the −OH bond. This polarizes the O – H bond and weakens it, which facilitates the release of a proton. Additionally, a higher oxidation state increases the number of terminal oxygen atoms, which helps stabilize the resulting conjugate anion through resonance.

Solution:
Step 1: Calculate the oxidation state of chlorine in each oxoacid in the series.
Step 2: For hypochlorous acid (HClO), let x be the oxidation state of Cl:

$$+1 - 2 + x = 0 \implies x = +1$$

Step 3: For chlorous acid ($HClO_2$), let x be the oxidation state of Cl:

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

Step 4: For chloric acid ($HClO_3$), let x be the oxidation state of Cl:

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

Step 5: For perchloric acid ($HClO_4$), let x be the oxidation state of Cl:

$$+1 + x + 4(-2) = 0 \implies x = +7$$

Step 6: Arrange the acids in order of increasing oxidation state of the chlorine atom: $+1 < +3 < +5 < +7$. This trend corresponds directly to an increase in overall acid strength:

$$\mathrm{HClO} < \mathrm{HClO_2} < \mathrm{HClO_3} < \mathrm{HClO_4}$$

Step 7: Match this sequence with the options. The trend corresponds to Option (A).

Final Answer: $\boxed{\mathrm{HClO} < \mathrm{HClO_2} < \mathrm{HClO_3} < \mathrm{HClO_4}}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept:

The equilibrium constant (K_p or K_c) of a chemical reaction is a true thermodynamic constant whose value depends exclusively on temperature for a given reaction. While a change in pressure or volume will shift the equilibrium position of a system according to Le Chatelier's principle, it does not alter the underlying ratio defined by the equilibrium constant.

Solution:

Step 1: Analyze the chemical system and the stress applied to it: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. The volume of the reaction vessel is suddenly halved.

Step 2: According to Boyle's law, halving the volume doubles the total pressure of the gas mixture.

Step 3: Le Chatelier's principle states that the system will respond to minimize this stress by shifting its equilibrium position toward the side with fewer moles of gas. Since the reactant side has 4 moles of gas and the product side has 2 moles, the equilibrium shifts in the forward direction, increasing the yield of ammonia.

Step 4: Evaluate the impact of this change on the equilibrium constant (K_p). Because the temperature of the system is held constant throughout the volume change, the value of K_p remains unchanged.

Step 5: The forward shift in the equilibrium position changes the partial pressures of the gases to ensure that their ratio in the K_p expression remains equal to the original value. Therefore, the equilibrium constant remains unchanged. This corresponds to Option (C).

Final Answer: $\boxed{\text{Remain unchanged}}$

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

Go Back to Question 22

Q23.

Solution

Concept:
Ozonolysis followed by reductive workup with zinc and water (Zn/H_2O) oxidatively cleaves the carbon-carbon double bond ($C = C$) of an alkene. This reaction converts each alkene carbon into a carbonyl group ($C = O$). To deduce the structure of the original alkene, align the carbonyl groups of the products facing each other, remove the oxygen atoms, and connect the two carbonyl carbons with a double bond.

Solution:
Step 1: Identify the chemical structures of the given ozonolysis products. Ethanal is a two-carbon aldehyde:

$$\mathrm{CH_3 - CHO}$$

Propanone is a three-carbon ketone:

$$\mathrm{CH_3 - CO - CH_3}$$

Step 2: Arrange the product molecules so that their carbonyl oxygen atoms face each other to facilitate coupling:

$$\mathrm{CH_3 - CH = \mathbf{O}} \quad \text{and} \quad \mathrm{\mathbf{O} = C(CH_3)_2}$$

Step 3: Remove the two oxygen atoms and connect the remaining fragments with a carbon-carbon double bond:

$$\mathrm{CH_3 - CH = C(CH_3)_2}$$

Step 4: Determine the IUPAC name of this alkene structure. Find the longest continuous carbon chain containing the double bond, which is four carbons long (a butene derivative). Number the chain from right to left to give the double bond and the substituent the lowest possible numbers:

$$\overset{4}{\mathrm{C}}\mathrm{H_3} - \overset{3}{\mathrm{C}}\mathrm{H} = \overset{2}{\mathrm{C}}\mathrm{(CH_3)} - \overset{1}{\mathrm{C}}\mathrm{H_3}$$

Step 5: Identify the substituents and their positions: there is a methyl group at carbon-2, and the double bond begins at carbon-2. This gives the IUPAC name 2-methylbut-2-ene. This matches Option (A).

Final Answer: 2-Methylbut-2-ene

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept:
The second ionization enthalpy (IE_2) is the energy required to remove an electron from a univalent gaseous cation. Its magnitude depends primarily on the electronic configuration of the cation. Removing an electron from a stable, filled noble gas shell (ns^2np^6) requires a exceptionally large amount of energy due to the high stability and high effective nuclear charge of the closed-shell configuration.

Solution:
Step 1: Analyze the ground-state electronic configurations presented in the options and determine the configuration of their corresponding +1 cations.
Step 2: For Option (A), the ground-state configuration is $1s^2 2s^2 2p^6 3s^1$ (Sodium, $Z = 11$). Removing one electron yields the univalent cation configuration:

$$M^+ = 1s^2 2s^2 2p^6$$

This configuration matches the stable noble gas shell of neon.
Step 3: For Option (B), the configuration is $1s^2 2s^2 2p^6 3s^2$ (Magnesium, $Z = 12$). The +1 cation configuration is:

$$M^+ = 1s^2 2s^2 2p^6 3s^1$$

Step 4: For Option (C), the configuration is $1s^2 2s^2 2p^6 3s^2 3p^1$ (Aluminum, $Z = 13$). The +1 cation configuration is:

$$M^+ = 1s^2 2s^2 2p^6 3s^2$$

Step 5: For Option (D), the configuration is $1s^2 2s^2 2p^6 3s^2 3p^3$ (Phosphorus, $Z = 15$). The +1 cation configuration is:

$$M^+ = 1s^2 2s^2 2p^6 3s^2 3p^2$$

Step 6: Compare the ease of electron removal among these cations. The cation from Option (A) has a filled $2p^6$ noble gas core. Breaking this stable octet requires significantly more energy than removing an electron from the $3s$ or $3p$ subshells of the other cations. Therefore, the configuration in Option (A) exhibits the highest second ionization enthalpy.

Final Answer: $\boxed{1s^2 2s^2 2p^6 3s^1}$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept:

Distinguishing between two alcohols within the same homologous series requires identifying structural differences that allow them to react differently to specific chemical reagents. Methanol (CH_3OH) is the simplest primary alcohol. Ethanol (CH_3CH_2OH) is a primary alcohol that contains a specific methyl carbinol structural unit ($CH_3CH(OH)-$). This group can undergo oxidation to form a methyl ketone fragment, which reacts with halogens in the presence of a base.

Solution:

Step 1: Evaluate the suitability of the chemical tests listed in the options for distinguishing between methanol and ethanol.

Step 2: The Lucas test distinguishes between primary, secondary, and tertiary alcohols based on their rate of reaction with a solution of anaerobic zinc chloride in concentrated hydrochloric acid. Since both methanol and ethanol are primary alcohols, neither reacts at room temperature, making this test unsuitable.

Step 3: Tollen's test is used to detect aldehydes, and the Carbylamine test is specific for primary amines. Neither reagent reacts with regular aliphatic alcohols.

Step 4: Analyze the Iodoform test. When an alcohol is treated with iodine (I_2) and sodium hydroxide (NaOH), the reagent acts as both an oxidizing agent and a halogenating agent.

Step 5: Ethanol contains the required $CH_3CH(OH)-$ group. It is first oxidized to ethanal (CH_3CHO), which then undergoes tri-iodination and cleavage to form a yellow precipitate of iodoform (CHI_3):

$$CH_3CH_2OH + 4I_2 + 6NaOH \rightarrow CHI_3 \downarrow + HCOONa + 5NaI + 5H_2O$$

Step 6: Methanol (CH_3OH) lacks this methyl group adjacent to the carbinol carbon. It is oxidized to formaldehyde (HCHO), which cannot form iodoform and yields no precipitate. Thus, the iodoform test successfully distinguishes between the two alcohols. This matches Option (B).

Final Answer: Iodoform test

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept:

When an ionic coordination compound dissolves in water, it dissolves completely into its constituent ions. The complex species enclosed within the square coordination brackets ($[\dots]$) behaves as a single structural unit and remains intact, while the counter-ions located outside the brackets dissociate into independent aqueous ions.

Solution:

Step 1: Write out the empirical formula of the complex compound from its systematic IUPAC name: Pentaamminenitrochromium(III) chloride.

Step 2: Identify the components inside the coordination sphere. The central metal ion is chromium (Cr^{3+}). The ligands include five neutral ammine groups (NH_3) and one anionic nitro group (NO_2^-). This forms the complex cation:

$$[Cr(NH_3)_5(NO_2)]^{2+}$$

Step 3: Determine the number of chloride counter-ions required to balance the charge. Since chromium has a +3 charge and the nitro ligand has a -1 charge, the complex cation has a net charge of +2. Balancing this requires two chloride (Cl^-) anions, giving the formula:

$$[Cr(NH_3)_5(NO_2)]Cl_2$$

Step 4: Model the dissolution and dissociation of this compound in an aqueous environment:

$$[Cr(NH_3)_5(NO_2)]Cl_2(s) \xrightarrow{H_2O} [Cr(NH_3)_5(NO_2)]^{2+}(aq) + 2Cl^-(aq)$$

Step 5: Count the total number of ions produced. Dissociation yields one complex coordination cation and two individual chloride anions.

Step 6: Calculate the sum: $1 + 2 = 3$ total ions per formula unit. This result corresponds to Option (B).

Final Answer: $\boxed{3}$

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept:

Molecular Orbital (MO) theory describes the electronic structure of homonuclear diatomic molecules by distributing valence electrons into bonding and antibonding molecular orbitals. The bond order of a species is calculated using the formula:

$$\text{Bond Order} = \frac{\mathrm{N_b} - \mathrm{N_a}}{2}$$

where $\mathrm{N_b}$ is the number of electrons in bonding orbitals and $\mathrm{N_a}$ is the number of electrons in antibonding orbitals. A species is paramagnetic if its molecular orbital diagram contains one or more unpaired electrons.

Solution:

Step 1: Count the total number of valence electrons for each species and determine their molecular orbital configurations.

Step 2: For Option (B), analyze the dinitrogen cation (N_2^+). A neutral N_2 molecule has 14 electrons, so the N_2^+ cation has $14 - 1 = 13$ electrons.

Step 3: Write out the molecular orbital filling sequence for a system with fewer than 14 electrons:

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

Step 4: Calculate the bond order for N_2^+ using the electron counts from the configuration: there are 9 bonding electrons ($\sigma_{1s}, \sigma_{2s}, \pi_{2p_x}, \pi_{2p_y}, \sigma_{2p_z}$) and 4 antibonding electrons ($\sigma_{1s}^*, \sigma_{2s}^*$).

$$\text{Bond Order} = \frac{9-4}{2} = 2.5$$

The resulting bond order of 2.5 is fractional.

Step 5: Determine the magnetic property. The highest occupied molecular orbital (σ_{2p_z}) contains a single, unpaired electron, which makes the N_2^+ cation paramagnetic.

Step 6: Briefly check the other options to confirm they mismatch. O_2^{2-} has an integer bond order of 1 and is diamagnetic; C_2 has an integer bond order of 2 and is diamagnetic; O_2 is paramagnetic but has an integer bond order of 2. Thus, only Option (B) satisfies both criteria.

Final Answer: $\boxed{N_2^+}$

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept:

The overall order of a chemical reaction can be determined directly from the units of its rate constant (k). The general expression for the units of a rate constant as a function of the overall reaction order (n) is given by:

$$\text{Units} = (\text{mol L}^{-1})^{1-n} \cdot \text{s}^{-1} = \text{mol}^{1-n} \cdot \text{L}^{n-1} \cdot \text{s}^{-1}$$

By comparing the given units of a rate constant to this general template, one can solve for the integer value of n.

Solution:

Step 1: Identify the units of the rate constant provided in the problem statement:

$$k = 3.4 \times 10^{-4}\ \text{mol}^{-1}\ \text{L s}^{-1}$$

Step 2: Write out the units to emphasize the exponents for each term:

$$\text{mol}^{-1} \cdot \text{L}^{1} \cdot \text{s}^{-1}$$

Step 3: Equate the exponent of the mole term from the given units to the exponent from the general template equation:

$$1 - n = -1$$

Step 4: Solve the algebraic equation for the reaction order n:

$$1 + 1 = n \implies n = 2$$

Step 5: Verify this result by checking the exponent of the liter term:

$$n - 1 = 2 - 1 = 1$$

This matches the exponent of L^1 in the given units. Therefore, the reaction follows second-order kinetics. This corresponds to Option (C).

Final Answer: $\boxed{\text{Second}}$

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

Go Back to Question 28

Q29.

Solution

Concept:

Nucleic acids are biopolymers composed of repeating nucleotide units, where each nucleotide consists of a pentose sugar, a phosphate group, and a nitrogenous base. DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) exhibit distinct structural differences in both the chemical nature of their pentose sugar ring and the composition of their heterocyclic nitrogenous bases.

Solution:

Step 1: Identify the structural components of a DNA molecule. DNA contains a β-D-2-deoxyribose sugar backbone. Its set of four nitrogenous bases includes the purines adenine (A) and guanine (G), and the pyrimidines cytosine (C) and thymine (T).

Step 2: Identify the structural components of an RNA molecule. RNA contains a modified pentose sugar where the carbon-2 position bears a hydroxyl group, known as β-D-ribose.

Step 3: Compare the heterocyclic bases of RNA to those of DNA. RNA shares the same adenine, guanine, and cytosine bases, but replaces thymine with the pyrimidine base uracil (U).

Step 4: Summarize the structural differences: RNA contains a ribose sugar and the base uracil, whereas DNA contains a deoxyribose sugar and the base thymine.

Step 5: Match this structural configuration with the given options. This combination corresponds to Option (C).

Final Answer: $\boxed{\text{Ribose and Uracil}}$

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

Go Back to Question 29

Q30.

Solution

Concept:

The elimination reaction of an alkyl halide with a strong base proceeds via an E2 (Elimination Bimolecular) mechanism. The regiochemical outcome of this reaction is governed by the steric bulk of the base used. A small, unhindered base (such as sodium ethoxide) selectively removes a proton from the more substituted β-carbon to yield the more stable, highly substituted alkene as the major product (Zaitsev's rule). Conversely, a bulky, sterically hindered base cannot easily access the more crowded internal positions and instead removes a proton from the less hindered, terminal β-carbon, yielding the less substituted alkene as the major product (Hofmann's rule).

Solution:

Step 1: Analyze the structure of the substrate, 2-bromobutane:

$$CH_3 - CH(Br) - CH_2 - CH_3$$

This molecule has two distinct sets of β-hydrogens: three terminal hydrogens on carbon-1 and two internal hydrogens on carbon-3.

Step 2: Identify the nature of the base. Potassium tert-butoxide, $K^+[-O\text{-}C(CH_3)_3]$, is a strong, sterically hindered base due to the bulky methyl groups surrounding its anionic oxygen center.

Step 3: Because of its steric bulk, the tert-butoxide ion encounters significant steric hindrance when approaching the internal secondary β-hydrogens on carbon-3.

Step 4: The base instead removes a proton from the less hindered, primary terminal β-hydrogens on carbon-1.

Step 5: Write out the elimination pathway: removal of a terminal proton followed by the loss of the bromide leaving group forms a double bond between carbon-1 and carbon-2:

$$CH_3 - CH(Br) - CH_2 - CH_3 \xrightarrow{\text{t-BuOK}} CH_2 = CH - CH_2 - CH_3$$

Step 6: The major product of this elimination reaction is but-1-ene. This aligns with Option (A).

Final Answer: $\boxed{\text{but-1-ene}}$

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

Go Back to Question 30

Q31.

Solution

Concept:
The greenhouse effect occurs when atmospheric gases absorb long-wave infrared radiation emitted from the Earth's surface and re-radiate it back down, trapping heat within the troposphere. While several trace gases contribute to global warming on a per-molecule basis, a gas's total impact depends heavily on its atmospheric concentration and total emissions volume.

Solution:
Step 1: Review the main atmospheric gases that contribute to the greenhouse effect: water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).
Step 2: Evaluate the relative contribution of human activities to each gas. While gases like methane have a higher global warming potential per molecule, carbon dioxide is released in massive quantities through the combustion of fossil fuels, industrial processes, and deforestation.
Step 3: Because of its high atmospheric concentration and long residence time, carbon dioxide contributes roughly 60% of the total anthropogenic radiative forcing driving global climate change.
Step 4: Consequently, international environmental frameworks focus primarily on tracking and reducing carbon dioxide emissions to mitigate global warming.
Step 5: Based on these criteria, carbon dioxide is identified as the gas predominantly responsible for global warming among the choices provided. This matches Option (B).

Final Answer: $\boxed{CO_2}$

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept:
The packing efficiency of a crystal lattice is the percentage of the total unit cell volume that is occupied by constituent spherical atoms. It is calculated using the formula:

$$\text{Packing Efficiency} = \frac{Z \cdot \left(\frac{4}{3}\pi r^3\right)}{V_{\text{cell}}} \times 100\%$$

where Z is the effective number of atoms per unit cell, r is the atomic radius, and V_{cell} is the total volume of the cubic unit cell (a^3). The percentage of empty space, or void fraction, is the remaining volume after subtracting the packing efficiency from 100%.

Solution:
Step 1: Identify the structural parameters of a face-centered cubic (fcc) lattice. An fcc unit cell contains atoms at all eight corners and at the centers of all six faces.
Step 2: Calculate the effective number of atoms (Z) in the unit cell:

$$Z = \left(8 \times \frac{1}{8}\right) + \left(6 \times \frac{1}{2}\right) = 1 + 3 = 4$$

Step 3: Determine the relationship between the cube edge length (a) and the atomic radius (r). In an fcc lattice, atoms touch along the face diagonal:

$$4r = a\sqrt{2} \implies a = \frac{4r}{\sqrt{2}} = 2\sqrt{2}r$$

Step 4: Calculate the total volume of the unit cell in terms of r:

$$V_{\text{cell}} = a^3 = (2\sqrt{2}r)^3 = 16\sqrt{2}r^3$$

Step 5: Substitute Z and V_{cell} into the packing efficiency formula:

$$\text{Packing Efficiency} = \frac{4 \cdot \left(\frac{4}{3}\pi r^3\right)}{16\sqrt{2}r^3} \times 100\% = \frac{\pi}{3\sqrt{2}} \times 100\% \approx 74\%$$

Step 6: Calculate the percentage of empty space in the unit cell by subtracting the occupied volume from the total volume:

$$\text{Empty Space} = 100\% - 74\% = 26\%$$

Step 7: Match this result with the given options. The value corresponds to Option (A).

Final Answer: $\boxed{26\%}$

Answer: (A)

Go Back to Question 32

Q33.

Solution

Concept:
The magnetic properties of transition metal complexes are largely determined by the number of unpaired electrons in their d-orbitals. The spin-only magnetic moment (μ) can be calculated using the formula:

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

where n represents the total number of unpaired electrons and BM stands for Bohr Magnetons, the standard unit of magnetic moment.

Solution:
Step 1: Identify the transition metal ion from its atomic number. Atomic number 26 corresponds to Iron (Fe). A divalent ion (M^{2+}) signifies an oxidation state of +2, which corresponds to the Fe^{2+} cation.
Step 2: Write out the electronic configuration of elemental iron: $[Ar]3d^6 4s^2$. Removing the two outer $4s$ electrons yields the electronic configuration for the Fe^{2+} ion: $[Ar]3d^6$.
Step 3: Determine the orbital distribution of these six d-electrons in an aqueous solution. In an aqueous medium, water acts as a weak-field aqua ligand (H_2O), forming a high-spin octahedral complex $[Fe(H_2O)_6]^{2+}$.
Step 4: Distribute the 6 electrons across the five $3d$ orbitals according to Hund's rule: fill all five orbitals with single electrons first, then pair the sixth electron in the first orbital. This leaves four orbitals containing a single, unpaired electron each ($n = 4$).
Step 5: Substitute $n = 4$ into the spin-only magnetic moment equation:

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

Step 6: Calculate the numerical value of $\sqrt{24}$:

$$\mu \approx 4.8989\ \text{BM} \approx 4.90\ \text{BM}$$

Step 7: Compare this result with the choices provided. The value aligns with Option (B).

Final Answer: $\boxed{4.90\ \text{BM}}$

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:
The reactivity of carboxylic acid derivatives toward nucleophilic acyl substitution reactions depends on the leaving ability of their respective functional groups (–L). The reaction proceeds via nucleophilic attack at the carbonyl carbon to form a tetrahedral intermediate, followed by elimination of the leaving group. A weaker base makes a better leaving group because it can more effectively stabilize its negative charge.

Solution:
Step 1: Identify the leaving groups for each carboxylic acid derivative category listed:

$$\text{Acid chloride} \rightarrow \text{Cl}^-, \quad \text{Acid anhydride} \rightarrow \text{RCOO}^-, \quad \text{Ester} \rightarrow \text{RO}^-, \quad \text{Amide} \rightarrow \text{NH}_2^-$$

Step 2: Evaluate the basic strength of these leaving groups by analyzing the strength of their conjugate acids (HCl, RCOOH, ROH, and NH_3).
Step 3: Hydrochloric acid (HCl) is a strong mineral acid, meaning its conjugate base (Cl^-) is an exceptionally weak base and an excellent leaving group. This makes acid chlorides highly reactive.
Step 4: Carboxylic acids (RCOOH) are moderately acidic, so the carboxylate ion ($RCOO^-$) is a moderate leaving group stabilized by resonance, making acid anhydrides the second most reactive derivative.
Step 5: Alkoxides (RO^-) are strong bases and poor leaving groups, while the amide ion (NH_2^-) is an extremely strong base and a very poor leaving group. This makes amides the least reactive toward nucleophilic attack.
Step 6: Arrange the derivatives in order of decreasing reactivity based on leaving group ability:

$$\text{Acid chloride} > \text{Acid anhydride} > \text{Ester} > \text{Amide}$$

This sequence matches Option (A).

Final Answer: $\boxed{\text{Acid chloride > Acid anhydride > Ester > Amide}}$

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

Go Back to Question 34

Q35.

Solution

Concept:
The systematic IUPAC name of an organic molecule is determined by identifying its principal functional group, finding the longest continuous carbon chain containing that group, and numbering the chain to give the principal group the lowest possible locant. When a molecule contains multiple functional groups, their priority determines which group serves as the suffix, while remaining groups are treated as prefixes. Carboxylic acids ($-COOH$) outrank alkynes ($-C \equiv C-$) and alcohols ($-OH$) in nomenclature priority.

Solution:
Step 1: Identify the principal functional group in the given compound:

$$CH_3 - CH(OH) - CH_2 - C \equiv C - COOH$$

The carboxylic acid group ($-COOH$) has the highest priority and determines the suffix "-oic acid".
Step 2: Number the continuous carbon chain starting from the carboxylic acid carbon to give it the lowest possible locant:

$$\overset{6}{C}H_3 - \overset{5}{C}H(OH) - \overset{4}{C}H_2 - \overset{3}{C} \equiv \overset{2}{C} - \overset{1}{C}OOH$$

The principal chain contains six carbon atoms, establishing the root name "hex".
Step 3: Locate the unsaturation and substituents along the numbered chain. The carbon-carbon triple bond begins at carbon-2, which adds the infix "-2-yn-".
Step 4: Identify the remaining functional group at carbon-5. The hydroxyl group ($-OH$) is designated by the prefix "5-hydroxy".
Step 5: Assemble the full IUPAC name by combining the prefix, root, infix, and suffix: 5-hydroxyhex-2-ynoic acid.
Step 6: Match this name with the options. The name corresponds to Option (A).

Final Answer: $\boxed{\text{5-Hydroxyhex-2-ynoic acid}}$

Answer: (A)

Go Back to Question 35

Q36.

Solution

Concept:

The coagulation or precipitation of a colloidal sol by an electrolyte is governed by the Hardy-Schulze rule. This rule states that the ions responsible for causing coagulation are those carrying a charge opposite to that of the colloidal particles. Furthermore, the coagulating power of an ion increases rapidly with its valence state.

Solution:

Step 1: Identify the charge of the colloidal sol mentioned in the problem statement. An antimony sulfide sol (As_2S_3) is a classical lyophobic negative sol.

Step 2: Apply the Hardy-Schulze rule. Since the sol carries a negative charge, its coagulation requires the addition of an electrolyte that supplies positive cations.

Step 3: Analyze the cations produced by each electrolyte choice:

$$\mathrm{NaCl} \rightarrow \mathrm{Na}^+, \quad \mathrm{MgSO_4} \rightarrow \mathrm{Mg}^{2+}, \quad \mathrm{AlCl_3} \rightarrow \mathrm{Al}^{3+}, \quad \mathrm{K_3[Fe(CN)_6]} \rightarrow \mathrm{K}^+$$

Step 4: Evaluate the valence states of these cations: Na^+ is monovalent (+1), Mg^{2+} is divalent (+2), and Al^{3+} is trivalent (+3).

Step 5: According to the Hardy-Schulze rule, higher-valent ions have significantly greater coagulating power. The relative order of coagulating efficiency for these cations is:

$$\mathrm{Al}^{3+} > \mathrm{Mg}^{2+} > \mathrm{Na}^+$$

Step 6: Because the trivalent aluminum ion (Al^{3+}) has the highest coagulating power, it requires the minimum concentration to achieve effective coagulation of the negative sol. This corresponds to Option (C).

Final Answer: $\boxed{\mathrm{AlCl_3}}$

Answer: (C)

Go Back to Question 36

Q37.

Solution

Concept:
Photochemical smog is a type of air pollution that develops in warm, sunny urban environments. It is formed through light-induced chemical reactions involving primary pollutants emitted by internal combustion engines, such as unburned hydrocarbons and nitrogen oxides (NO_x). These compounds react in the presence of sunlight to produce secondary pollutants that characterize the smog.

Solution:
Step 1: Understand the chemical formation mechanism of photochemical smog. Solar ultraviolet radiation cleaves nitrogen dioxide (NO_2), releasing highly reactive oxygen atoms that combine with molecular oxygen to generate ozone (O_3):

$$NO_2 + h\nu \rightarrow NO + O, \quad O + O_2 \rightarrow O_3$$

Step 2: Identify the interactions with organic pollutants. Ozone and nitrogen oxides react with unburned hydrocarbons in the atmosphere to form toxic secondary lacrymators, including peroxyacetyl nitrate (PAN) and acrolein.
Step 3: Summarize the primary chemical components that define photochemical smog. It is an oxidizing mixture composed chiefly of ozone (O_3), peroxyacetyl nitrate (PAN), and various oxides of nitrogen (NO_x).
Step 4: Evaluate the choices. Classical smog contains sulfur dioxide, whereas photochemical smog is characterized by the presence of ozone, PAN, and nitrogen oxides. This matches Option (B).

Final Answer: $\boxed{\text{O}_3\text{, PAN, and Nitrogen oxides}}$

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

Go Back to Question 37

Q38.

Solution

Concept:

The reaction of a reducing carbohydrate with excess phenylhydrazine yields a crystalline derivative called an osazone. This reaction involves the functional groups at the carbon-1 and carbon-2 positions of the sugar molecule. During osazone formation, the stereochemical configurations at these first two carbons are altered, while the configurations of all remaining chiral centers (carbon-3, carbon-4, and carbon-5) remain unchanged. Consequently, any carbohydrates that share identical stereochemistry from carbon-3 through carbon-6 will yield the exact same osazone structure.

Solution:

Step 1: Analyze the stereochemical structure of d-glucose. It is an aldohexose with specific configurations at its chiral centers: 2R, 3S, 4R, 5R.

Step 2: Examine how phenylhydrazine reacts with d-glucose. The reagent condenses with the carbon-1 aldehyde group and oxidizes the carbon-2 hydroxyl group into a ketone, which then reacts with a second equivalent of phenylhydrazine. This forms the osazone structure, losing the stereochemical identity of carbon-2.

Step 3: Identify sugars that share the same configuration as d-glucose at carbon-3, carbon-4, and carbon-5.

Step 4: d-fructose is a ketohexose with the carbonyl group located at carbon-2. Its remaining chiral centers at carbon-3, carbon-4, and carbon-5 have the exact same stereochemical configurations as d-glucose.

Step 5: When d-fructose reacts with excess phenylhydrazine, the carbon-1 primary alcohol is oxidized to an aldehyde while the carbon-2 ketone is converted to a hydrazone. This produces a structural derivative that is identical to the osazone derived from d-glucose.

Step 6: Based on this shared stereochemistry, d-fructose yields the same osazone as d-glucose. This matches Option (B).

Final Answer: $\boxed{\text{d-Fructose}}$

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

Go Back to Question 38

Q39.

Solution

Concept:

The total and partial vapor pressures of an ideal binary liquid solution are governed by Raoult's law: $P_A = x_A \cdot P_A^\circ$, where x_A is the mole fraction of component A in the liquid phase and P_A° is its pure vapor pressure. The composition of the vapor phase in equilibrium with the liquid solution can be calculated using Dalton's law of partial pressures:

$$y_A = \frac{P_A}{P_{\text{total}}}$$

where y_A represents the mole fraction of component A in the vapor phase.

Solution:

Step 1: State the given values from the problem description:

$$P_A^\circ = 400 \text{ mm Hg}, \quad P_B^\circ = 600 \text{ mm Hg}$$

Step 2: Determine the liquid-phase mole fractions. The solution is prepared by mixing equal moles of components A and B, which means:

$$x_A = 0.5, \quad x_B = 0.5$$

Step 3: Calculate the partial vapor pressures of each component using Raoult's law:

$$P_A = x_A \cdot P_A^\circ = 0.5 \cdot 400 \text{ mm Hg} = 200 \text{ mm Hg}$$

$$P_B = x_B \cdot P_B^\circ = 0.5 \cdot 600 \text{ mm Hg} = 300 \text{ mm Hg}$$

Step 4: Calculate the total vapor pressure of the ideal solution (P_{total}):

$$P_{\text{total}} = P_A + P_B = 200 + 300 = 500 \text{ mm Hg}$$

Step 5: Apply Dalton's law to find the mole fraction of component A in the vapor phase (y_A):

$$y_A = \frac{P_A}{P_{\text{total}}} = \frac{200 \text{ mm Hg}}{500 \text{ mm Hg}} = 0.40$$

Step 6: Match this numerical result with the choices. The value corresponds to Option (A).

Final Answer: $\boxed{0.40}$

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

Go Back to Question 39

Q40.

Solution

Concept:
The Friedel-Crafts alkylation reaction is an electrophilic aromatic substitution pathway where an alkyl group is attached to a benzene ring. This reaction requires a sufficiently nucleophilic aromatic ring to attack the carbocation intermediate. Benzene rings that are bonded to strongly deactivating, electron-withdrawing groups (via inductive or resonance effects) are poor nucleophiles and generally fail to undergo Friedel-Crafts reactions.

Solution:
Step 1: Evaluate the electronic effects of the substituent groups on the aromatic rings across the options.
Step 2: Toluene contains a methyl substituent ($-CH_3$), which donates electron density to the ring via hyperconjugation and inductive effects, activating it toward electrophilic attack.
Step 3: Chlorobenzene and bromobenzene contain halogen substituents ($-Cl$ and $-Br$). Halogens withdraw electron density inductively but donate electron density through resonance. Although they are weakly deactivating, their rings retain sufficient nucleophilicity to undergo Friedel-Crafts alkylation under appropriate conditions.
Step 4: Nitrobenzene contains a nitro functional group ($-NO_2$). The nitrogen atom bears a positive formal charge and is bonded to electronegative oxygen atoms, making the nitro group a powerful electron-withdrawing group via both resonance and inductive mechanisms ($-M$ and $-I$ effects).
Step 5: This strong electron withdrawal significantly depletes electron density across the aromatic ring, making it highly electrophilic and unreactive toward carbocation intermediates. Consequently, nitrobenzene does not undergo Friedel-Crafts alkylation and is frequently used as an inert solvent for these reactions. This matches Option (C).

Final Answer: $\boxed{\text{Nitrobenzene}}$

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

Go Back to Question 40

Answer Key

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