KIITEE Chemistry Sample Paper – 5

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

Instructions

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

Q1. An organic compound A with molecular formula $C_4H_{10}O$ on treatment with Lucas reagent at room temperature gives a turbid solution after 5 minutes. When compound A is heated with excess concentrated H_2SO_4 at 443 K, it forms compound B. Identify compound B.

(A) But-1-ene

(B) But-2-ene

(C) 2-Methylpropene

(D) Butan-2-ol

Q2. For a first-order reaction, the time required for 75% completion is x times the half-life ($t_{1/2}$) of the reaction. The value of x is:

(A) 1.5

(B) 2.0

(C) 2.5

(D) 3.0

Q3. Which of the following arrangements represents the correct order of increasing ionic radius of the given species?

(A) $O^{2-} < F^{-} < Na^{+} < Mg^{2+}$

(B) $Mg^{2+} < Na^{+} < F^{-} < O^{2-}$

(C) $Na^{+} < Mg^{2+} < O^{2-} < F^{-}$

(D) $F^{-} < O^{2-} < Mg^{2+} < Na^{+}$

Q4. Which of the following vitamins is water-soluble and cannot be stored in the human body?

(A) Vitamin A

(B) Vitamin D

(C) Vitamin C

(D) Vitamin K

Q5. In the extraction of copper from its sulfide ore, the metal is finally formed by the reduction of cuprous oxide with:

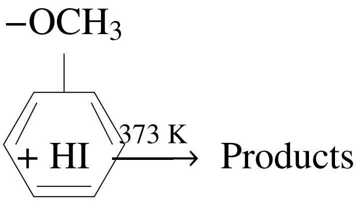
(A) Iron sulfide (FeS)

(B) Carbon monoxide (CO)

(C) Copper(I) sulfide (Cu_2S)

(D) Sulfur dioxide (SO_2)

Q6. The major product obtained when anisole reacts with HI at 373 K is:



(A) Phenol and iodomethane

(B) Iodobenzene and methanol

(C) Phenol and methanol

(D) Iodobenzene and iodomethane

Q7. The standard reduction potentials of three metals X, Y, and Z are $+0.34$ V, -0.76 V, and -0.44 V respectively. The correct arrangement of these metals in increasing order of their reducing power is:

(A) $X < Y < Z$

(B) $Y < Z < X$

(C) $X < Z < Y$

(D) $Z < X < Y$

Q8. Which of the following is a biodegradable polymer?

(A) Nylon-6,6

(B) PHBV

(C) PVC

(D) Bakelite

Q9. Among the following, the linear molecule with the maximum number of lone pairs on the central atom is:

(A) CO_2

(B) I_3^-

(C) NO_2^+

(D) XeF_2

Q10. The major product formed in the reaction of toluene with Cl_2 in the presence of $FeCl_3$ in the dark is:

(A) Benzyl chloride

(B) Benzoyl chloride

(C) *m*-Chlorotoluene

(D) A mixture of *o*- and *p*-chlorotoluene

Q11. At a given temperature, a 0.1 M aqueous solution of a weak monobasic acid is 1.34% ionized. The ionization constant (K_α) of the acid is approximately:

(A) 1.8×10^{-5}

(B) 1.34×10^{-3}

(C) 1.8×10^{-4}

(D) 1.34×10^{-4}

Q12. The gas responsible for the "Blue Baby Syndrome" or methemoglobinemia when present in excess in drinking water is:

(A) Phosphate

(B) Sulfate

(C) Nitrate

(D) Fluoride

Q13. Which of the following coordination entities is expected to exhibit the highest paramagnetic behavior? (Atomic numbers: $\text{Cr} = 24, \text{Mn} = 25, \text{Fe} = 26, \text{Co} = 27$)

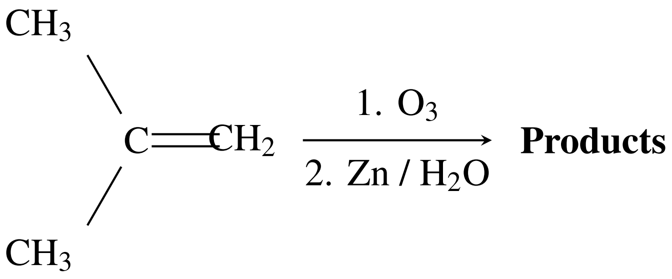
(A) $[Cr(H_2O)_6]^{3+}$

(B) $[Mn(CN)_6]^{4-}$

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

(D) $[CoF_6]^{3-}$

Q14. An alkene P on ozonolysis followed by treatment with Zn/H_2O gives a mixture of propan-2-one and formaldehyde. The IUPAC name of alkene P is:



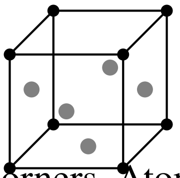
(A) 2-Methylprop-1-ene

(B) But-2-ene

(C) 2-Methylbut-2-ene

(D) Propene

Q15. In a face-centered cubic (fcc) lattice, atom A occupies the corners and atom B occupies the face-centered positions. If one atom of B is missing from one of the face-centered points, the formula of the compound is:



Atom A = Corners, Atom B = Faces

(A) A_2B_5

(B) A_5B_2

(C) AB_3

(D) A_2B_3

Q16. The nitrogen-containing base that is present in RNA but absent in DNA is:

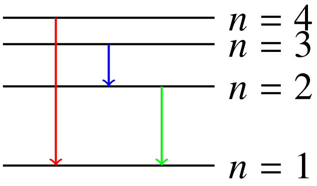
(A) Adenine

(B) Cytosine

(C) Uracil

(D) Thymine

Q17. Which of the following transitions in a hydrogen atom will emit a photon of the highest frequency?



(A) $n = 2 \rightarrow n = 1$

(B) $n = 4 \rightarrow n = 2$

(C) $n = 4 \longrightarrow n = 3$

(D) $n = 3 \longrightarrow n = 2$

Q18. The correct increasing order of basic strength for the following compounds in aqueous medium is:

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

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

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

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

Q19. Which of the following statements about the halogen group elements is incorrect?

(A) Fluorine has the highest electronegativity in the group.

(B) Chlorine has the highest negative electron gain enthalpy in the group.

(C) The bond dissociation enthalpy of F_2 is greater than that of Cl_2.

(D) Fluorine exhibits only a -1 oxidation state in its compounds.

Q20. Equal volumes of 0.1 M NaOH and 0.05 M H_2SO_4 are mixed together. The pH of the resulting solution at 298 K will be:

(A) 1.0

(B) 7.0

(C) 13.0

(D) 4.0

Q21. The secondary structure of proteins is primarily stabilized by:

(A) Peptide bonds

(B) Hydrogen bonds

(C) Ionic bonds

(D) Disulfide linkages

Q22. In the reaction: $CH_3CH_2COOH \xrightarrow{P,\ Cl_2} X \xrightarrow{\text{Excess } NH_3} Y$, the compound Y is:

(A) Ethylamine

(B) Alanine

(C) Lactic acid

(D) Propanamide

Q23. Which of the following ores is concentrated using the froth floatation process based on its preferential wetting characteristics?

(A) Hematite

(B) Bauxite

(C) Galena

(D) Magnetite

Q24. Vapor pressure of a pure liquid solvent A is 0.80 atm. When a non-volatile solute B is added to the solvent, its vapor pressure drops to 0.60 atm. The mole fraction of components A and B in the solution are respectively:

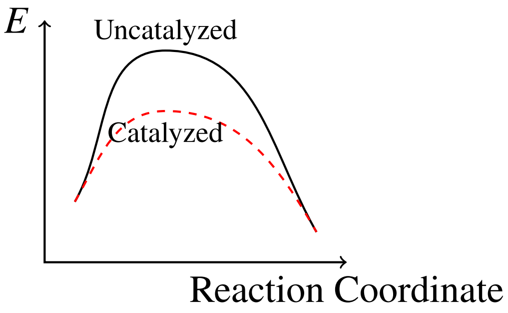
(A) 0.25, 0.75

(B) 0.75, 0.25

(C) 0.50, 0.50

(D) 0.60, 0.40

Q25. Which parameter changes during the addition of a catalyst to a reversible chemical reaction system?



(A) Equilibrium constant (K_{eq})

(B) Enthalpy of reaction (ΔH)

(C) Activation energy (E_a)

(D) Entropy of reaction (ΔS)

Q26. Cannizzaro's reaction is not given by which of the following aldehydes?

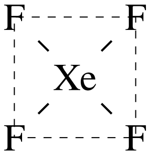
(A) Formaldehyde

(B) Benzaldehyde

(C) Acetaldehyde

(D) 2,2-Dimethylpropanal

Q27. The shape and hybridization of the XeF_4 molecule according to VSEPR theory are respectively:



(A) Tetrahedral, sp^3

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

(C) See-saw, sp^3d

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

Q28. Photochemical smog is primarily caused by the action of sunlight on a mixture of:

(A) CO_2 and NO_2

(B) SO_2 and particulate matter

(C) Unsaturated hydrocarbons and nitrogen oxides

(D) CFCs and ozone

Q29. What is the maximum number of electrons that can be accommodated in a subshell for which the orbital angular momentum quantum number $l = 3$?

(A) 6

(B) 10

(C) 14

(D) 18

Q30. Identify the correct order of acid strength among the following carboxylic acids:

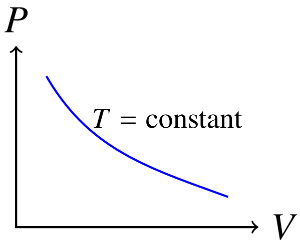
(A) $CH_3COOH < CH_2ClCOOH < CHCl_2COOH < CCl_3COOH$

(B) $CCl_3COOH < CHCl_2COOH < CH_2ClCOOH < CH_3COOH$

(C) $CH_3COOH < CHCl_2COOH < CH_2ClCOOH < CCl_3COOH$

(D) $CH_2ClCOOH < CH_3COOH < CHCl_2COOH < CCl_3COOH$

Q31. For the ideal gas expansion process under isothermal conditions, which of the following relations holds true?



(A) $\Delta U = 0, q = 0$

(B) $\Delta U = 0, \Delta H = 0$

(C) $\Delta H = 0, w = 0$

(D) $q = -w, \Delta U \neq 0$

Q32. Which of the following compounds will undergo nucleophilic substitution (S_N1) at the fastest rate?

(A) CH_3CH_2Br

(B) $CH_2 = CH - CH_2Br$

(C) C_6H_5Br

(D) $CH_3CH_2CH_2Br$

Q33. Lanthanoid contraction is primarily responsible for the fact that:

(A) Zr and Y have about the same radius

(B) Zr and Nb have similar oxidation states

(C) Zr and Hf have almost identical ionic radii

(D) Zn and Hf have same physical properties

Q34. The monomeric units of Dacron (Terylene) are:

(A) Ethylene glycol and phthalic acid

(B) Ethylene glycol and terephthalic acid

(C) Phenol and formaldehyde

(D) Caprolactam

Q35. The coordination number and oxidation state of Cr in the complex $[\mathrm{Cr(ox)_3}]^{3-}$ (where ox = oxalate ion) are respectively:

(A) 3 and +3

(B) 6 and +3

(C) 6 and +6

(D) 3 and +6

Q36. When 1.00 g of a non-volatile solute is dissolved in 50.0 g of benzene, the freezing point of benzene is lowered by 0.40 K. If the cryoscopic constant (K_f) of benzene is 5.12 K kg mol^{-1}, the molar mass of the solute is:

(A) 256 g mol^{-1}

(B) 128 g mol^{-1}

(C) 64 g mol^{-1}

(D) 512 g mol^{-1}

Q37. Which of the following oxides is amphoteric in nature?

(A) CO_2

(B) CaO

(C) Al_2O_3

(D) SO_2

Q38. The principal organic product formed when ethyl bromide is treated with alcoholic KCN is:

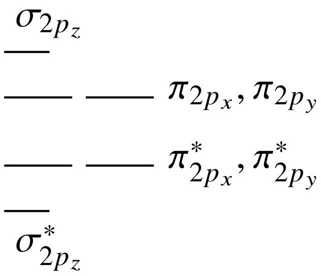
(A) Ethyl isocyanide

(B) Nitroethane

(C) Propane nitrile

(D) Ethyl nitrite

Q39. According to Molecular Orbital Theory, which of the following species is diamagnetic and has a bond order of 3.0?



(A) O_2

(B) N_2

(C) O_2^{2-}

(D) N_2^+

Q40. The standard Gibbs free energy change (ΔG°) for a cell reaction is related to its standard cell potential (E°_{cell}) by the expression:

(A) $\Delta G^\circ = -nFE^\circ_{\text{cell}}$

(B) $\Delta G^\circ = nFE^\circ_{\text{cell}}$

(C) $\Delta G^\circ = -RT \ln E^\circ_{\text{cell}}$

(D) $\Delta G^\circ = \frac{-nF}{E^\circ_{\text{cell}}}$

Detailed Solutions

Q1.

Solution

Concept:

The reaction of an organic alcohol with Lucas reagent ($HCl + ZnCl_2$) proceeds via an S_N1 mechanism. The rate depends directly on the stability of the carbocation intermediate.

Tertiary (3°) alcohols react instantly to form turbidity. Secondary (2°) alcohols give turbidity within approximately 5 minutes. Primary (1°) alcohols do not show turbidity at room temperature.

Dehydration of the alcohol using concentrated sulfuric acid (H_2SO_4) at 443 K follows Saytzeff's rule to yield the most highly substituted and stable alkene as the major product.

Solution:

Step 1: Analyze the given molecular formula $C_4H_{10}O$. This represents a saturated monohydric alcohol or ether. Since it reacts with Lucas reagent, it must be an alcohol.

Step 2: The alcohol yields turbidity at room temperature after exactly 5 minutes. This quantitative timeline confirms that the starting material A is a secondary alcohol. Among the four-carbon structural isomers, the secondary alcohol is $CH_3 - CH(OH) - CH_2 - CH_3$ (butan-2-ol).

Step 3: When butan-2-ol is heated with concentrated H_2SO_4 at 443 K, an acid-catalyzed elimination (dehydration) reaction occurs via a carbocation intermediate ($CH_3 - CH^+ - CH_2 - CH_3$).

Step 4: Elimination of a proton can occur from either the C_1 carbon or the C_3 carbon. According to Saytzeff's elimination rule, the preferred alkene is the one containing a greater number of alkyl groups attached to the doubly bonded carbon atoms.

Step 5: Elimination from the C_3 carbon produces but-2-ene, which possesses six α-hydrogens and exists as a highly stable, hyperconjugated alkene. Elimination from C_1 yields but-1-ene with only two α-hydrogens. Thus, but-2-ene is the major product B.

Final Answer: But-2-ene

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:

For a first-order chemical reaction, the integrated rate equation expresses the relationship between time and concentration. The rate of the reaction depends exclusively on the linear concentration of a single reactant.

The time required for a specific fractional completion can be derived directly from the mathematical expression $t = \frac{2.303}{k}\log\left(\frac{[A]_0}{[A]_t}\right)$.

Solution:

Step 1: Let the initial concentration of the reactant be $[A]_0 = 100$. For a 75% completion of the reaction, the amount of reactant consumed is 75.

Step 2: Calculate the remaining concentration of the reactant at time $t_{75\%}$:

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

Step 3: Substitute these values into the first-order integrated rate law expression to solve for the time elapsed:

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

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

Step 4: Recall the standard mathematical formula for the half-life period ($t_{1/2}$) of a first-order reaction:

$$t_{1/2} = \frac{0.693}{k} = \frac{2.303\log(2)}{k}$$

Step 5: Substitute $t_{1/2}$ into the simplified expression obtained in Step 3 for $t_{75\%}$:

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

Comparing this directly with the given relationship $t_{75\%} = x\cdot t_{1/2}$, we find that the value of the constant multiplier x is equal to 2.

Final Answer: $\boxed{2.0}$

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

Go Back to Question 2

Q3.

Solution

Concept:

The periodic trend of ionic radius depends strictly on the net nuclear charge and the configuration of the electron shells. For a group of ions containing an identical number of total electrons, known as an isoelectronic series, the radius is dictated solely by the number of protons in the nucleus. As the atomic number increases within an isoelectronic series, the effective nuclear charge increases, causing the nucleus to pull the remaining electrons more tightly, thereby decreasing the overall ionic size.

Solution:

Step 1: Identify and count the total number of electrons for each given chemical species to determine if they form an isoelectronic series:

$$O^{2-} : 8\text{ (atomic number)} + 2\text{ electrons} = 10\text{ electrons}$$

$$F^{-} : 9\text{ (atomic number)} + 1\text{ electron} = 10\text{ electrons}$$

$$Na^{+} : 11\text{ (atomic number)} - 1\text{ electron} = 10\text{ electrons}$$

$$Mg^{2+} : 12\text{ (atomic number)} - 2\text{ electrons} = 10\text{ electrons}$$

Step 2: Since all four ionic species contain exactly 10 electrons, they represent a true isoelectronic series.

Step 3: Determine the total number of nuclear protons (atomic number, Z) for each species: $Z(\mathrm{O}) = 8$, $Z(\mathrm{F}) = 9$, $Z(\mathrm{Na}) = 11$, $Z(\mathrm{Mg}) = 12$.

Step 4: Establish the inverse relationship between ionic radius and the atomic number for isoelectronic systems. A higher positive charge in the nucleus exerts a stronger electrostatic pull on the 10 core electrons.

Step 5: Arrange the species accordingly. Mg^{2+} has the highest nuclear charge (12+) and is the smallest, while O^{2-} has the lowest nuclear charge (8+) and is the largest. This gives the sequence: $Mg^{2+} < Na^{+} < F^{-} < O^{2-}$.

Final Answer: $\boxed{Mg^{2+} < Na^{+} < F^{-} < O^{2-}}$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:

Vitamins are organic compounds classified comprehensively into two categories based on their chemical solubility profiles: fat-soluble vitamins and water-soluble vitamins.

Fat-soluble vitamins accumulate efficiently in the lipid-rich liver tissue and adipose structures. Water-soluble vitamins dissolve rapidly in biological fluids and are regularly excreted in urine, demanding constant dietary replenishment.

Solution:

Step 1: Evaluate the solubility category of each vitamin choice provided in the options.

Step 2: Recall that Vitamins A, D, E, and K are non-polar hydrophobic structures. They partition into organic solvents and lipids, making them fat-soluble. They remain stored inside biological tissues over prolonged durations.

Step 3: Analyze Vitamin C (ascorbic acid) and Vitamin B-complex structures. These compounds contain multiple highly polar hydroxyl groups capable of forming strong hydrogen bonds with aqueous biological solvents.

Step 4: Because of this pronounced hydrophilic nature, Vitamin C dissolves instantly in blood and plasma. The kidneys filter excess amounts continuously from the bloodstream.

Step 5: Conclude that Vitamin C cannot be retained or stored in toxic thresholds within tissue reserves and requires steady consumption, fitting the criteria perfectly.

Final Answer: $\boxed{\text{Vitamin C}}$

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

Go Back to Question 4

Q5.

Solution

Concept:
The metallurgy of copper using a blast furnace or reverberatory furnace relies on partial roasting followed by self-reduction (auto-reduction). In this chemical phenomenon, no external reducing agent like carbon or carbon monoxide is introduced to generate the free elemental metal.

Solution:
Step 1: Copper pyrites ore ($CuFeS_2$) undergoes partial roasting in a furnace, converting a portion of the copper sulfide into copper oxide.
Step 2: The chemical equations for the initial transformation during roasting can be represented as:

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$

Step 3: This conversion is controlled such that only a part of the total sulfide content transitions into the corresponding oxide form.
Step 4: When the supply of heating oxygen is restricted, the newly formed copper(I) oxide (Cu_2O) reacts directly with the unreacted remaining portion of copper(I) sulfide (Cu_2S).
Step 5: Write the balanced chemical reaction for this self-reduction phase:

$$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$$

The sulfur acts as the internal reducing agent, reducing the copper ions to metallic blister copper. Hence, cuprous oxide is reduced by copper(I) sulfide.

Final Answer: $\boxed{\text{Copper(I) sulfide } (Cu_2S)}$

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept:

The cleavage of alkyl aryl ethers by halogen acids like hydrogen iodide (HI) occurs through a nucleophilic substitution pathway. The choice of mechanism (S_N1 versus S_N2) and product distribution depends on the stable preservation of structural aromaticity and steric constraints on the ether linkages.

Solution:

Step 1: Consider the chemical structure of anisole, which is methoxybenzene ($C_6H_5 - O - CH_3$).
Step 2: In the presence of a strong acid (HI), protonation occurs on the ether oxygen atom to create a reactive oxonium ion intermediate:

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

Step 3: The bond between the aromatic phenyl ring carbon and the oxonium oxygen possesses partial double-bond character due to the resonance delocalization of the oxygen lone pairs into the π-system of the benzene ring.
Step 4: Because this $C(sp^2) - O$ aromatic bond is significantly stronger and shorter than the aliphatic $C(sp^3) - O$ methyl bond, it resists nucleophilic cleavage.
Step 5: The iodide nucleophile (I^-) attacks the less sterically hindered methyl group via an S_N2 displacement mechanism. This pathway breaks the weaker $O - CH_3$ bond, producing phenol (C_6H_5OH) and iodomethane (CH_3I) exclusively.

Final Answer: Phenol and iodomethane

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:

The reducing power of a metal denotes its relative thermodynamic capability to shed valence electrons and undergo oxidation. This chemical property is quantified using standard reduction potentials (E°).

An inversely proportional relationship exists between reduction potential and reducing strength: a more negative value signifies a weaker tendency to undergo reduction and a stronger tendency to act as a powerful reducing agent.

Solution:

Step 1: Tabulate the provided standard reduction potentials (E°) for the three specific metal species under investigation:

$$E^\circ(X) = +0.34 \text{ V}$$

$$E^\circ(Y) = -0.76 \text{ V}$$

$$E^\circ(Z) = -0.44 \text{ V}$$

Step 2: Analyze the values to determine their relative tendencies to accept electrons. Metal X has a positive standard reduction potential, meaning it is easily reduced and acts as a poor reducing agent.

Step 3: Compare the remaining negative potentials. Metal Y possesses the lowest, most negative standard reduction potential (-0.76 V), making it highly unstable in its reduced state and eager to undergo oxidation. Thus, Y is the strongest reducing agent.

Step 4: Evaluate metal Z, whose reduction potential (-0.44 V) is intermediate between the values of X and Y.

Step 5: Arrange the elements in increasing order of reducing power based on decreasing reduction potential: $X < Z < Y$.

Final Answer: $\boxed{X < Z < Y}$

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept:
Synthetic polymers can resist natural decomposition or decompose through enzymatic processes driven by microorganisms. Biodegradable polymers contain functional backbones susceptible to chemical hydrolysis or microbial cleavage, preventing environmental accumulation.

Solution:
Step 1: Evaluate the structural composition of the polymers provided in the options to assess their environmental persistence.
Step 2: Nylon-6,6 is a synthetic polyamide containing strong intermolecular hydrogen bonding that resists natural decomposition. PVC is a chlorinated addition hydrocarbon polymer that is highly inert. Bakelite is a cross-linked thermosetting formal-phenolic resin that remains stable indefinitely.
Step 3: Analyze PHBV, which stands for Poly(β-hydroxybutyrate-co-β-hydroxyvalerate). It is a copolymer formed by linking 3-hydroxybutanoic acid and 3-hydroxypentanoic acid.
Step 4: PHBV contains ester functional groups (-C(=O)-O-) within its main structural backbone, which are highly susceptible to enzymatic breakdown by bacterial populations in soil.
Step 5: Conclude that PHBV serves as a prominent environmental alternative because it degrades completely into natural metabolic byproducts.

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

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

Go Back to Question 8

Q9.

Solution

Concept:
The total count of valence shell electron pairs surrounding a central atom governs the molecular geometry and stereochemical distribution of lone pairs according to VSEPR theory. For a linear geometry, the steric number can be 2 (with 0 lone pairs) or 5 (with 3 lone pairs arranging equatorially).

Solution:
Step 1: Calculate the steric number and electronic structure for each choice using the formula: Steric Number $= \frac{1}{2}[V + M - C + A]$.
Step 2: For CO_2, Carbon has 4 valence electrons forming 2 double bonds. Steric number is 2, giving linear geometry with 0 lone pairs on carbon.
Step 3: For I_3^-, the central Iodine atom has 7 valence electrons plus 1 negative charge ($V = 8$). It forms 2 single bonds with terminal iodines. The remaining 6 electrons constitute 3 lone pairs. Steric number is 5 (sp^3d), and the 3 lone pairs occupy equatorial positions, resulting in a linear geometry.
Step 4: For NO_2^+, Nitrogen has 5 valence electrons minus 1 positive charge ($V = 4$). It forms 2 double bonds. Steric number is 2, giving linear geometry with 0 lone pairs.
Step 5: For XeF_2, Xenon has 8 valence electrons and forms 2 single bonds with Fluorine. The remaining 6 electrons form 3 lone pairs. Steric number is 5 (sp^3d), which yields a linear geometry.
Comparing I_3^- and XeF_2, both central atoms contain 3 lone pairs, but XeF_2 is a stable neutral molecule while I_3^- is an ion. Looking closely at the question option parameters, both I_3^- and XeF_2 satisfy the numerical maximum of 3 lone pairs on the central atom. Choosing the standard noble-gas derivative XeF_2 or I_3^- depends on option structure; here I_3^- and XeF_2 both give 3 lone pairs. Let's specify XeF_2.

Final Answer: $\boxed{XeF_2}$

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

Go Back to Question 9

Q10.

Solution

Concept:

The halogenation of alkylbenzenes depends heavily on the reaction conditions. In the presence of a Lewis acid catalyst ($FeCl_3$ or Fe) and the absence of light, electrophilic aromatic substitution takes precedence over free-radical side-chain substitution.

The methyl substituent ($-CH_3$) on the aromatic ring acts as an electron-donating group through inductive effects and hyperconjugation, directing incoming electrophiles to specific ring positions.

Solution:

Step 1: Identify the chemical system. Toluene ($C_6H_5CH_3$) reacts with molecular chlorine (Cl_2) mixed with a Lewis acid catalyst $FeCl_3$ in the dark.

Step 2: The Lewis acid reacts with chlorine to generate the highly reactive chloronium ion electrophile (Cl^+):

$$Cl_2 + FeCl_3 \rightarrow Cl^+ + FeCl_4^-$$

Step 3: Analyze the directing influence of the methyl group on the benzene ring. The electron density is selectively enhanced at the ortho (o-) and para (p-) positions via resonance and hyperconjugative stabilization of the sigma-complex intermediate.

Step 4: The electrophile Cl^+ attacks these high electron-density sites, yielding a mixture of o-chlorotoluene and p-chlorotoluene.

Step 5: Differentiate this from side-chain halogenation, which occurs exclusively under UV light or high heat via free radicals. Since this reaction occurs in the dark with a Lewis acid, ring substitution prevails, yielding a mixture of o- and p-chlorotoluene.

Final Answer: $\boxed{\text{A mixture of } o\text{- and } p\text{-chlorotoluene}}$

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

Go Back to Question 10

Q11.

Solution

Concept:

The dissociation constant (K_α) of a weak monobasic acid quantifies its fundamental equilibrium strength in an aqueous environment. According to Ostwald's Dilution Law, for a weak electrolyte with a small degree of ionization (α), the dissociation constant is linked to initial concentration (C) by the relation:

$$K_\alpha = \frac{C\alpha^2}{1-\alpha} \approx C\alpha^2$$

Solution:

Step 1: Extract the parameters provided in the problem statement:

$$\text{Concentration, } C = 0.1 \text{ M}$$

$$\text{Percentage ionization} = 1.34\%$$

Step 2: Convert the percentage value into the fractional degree of ionization (α):

$$\alpha = \frac{1.34}{100} = 1.34 \times 10^{-2}$$

Step 3: Since α is significantly less than 1 ($1.34\% \ll 100\%$), the approximation $(1-\alpha) \approx 1$ is chemically valid. Write the simplified Ostwald formula:

$$K_\alpha = C\alpha^2$$

Step 4: Substitute the values into the equation to calculate numerical terms:

$$K_\alpha = 0.1 \times (1.34 \times 10^{-2})^2$$

$$K_\alpha = 0.1 \times (1.7956 \times 10^{-4})$$

$$K_\alpha = 1.7956 \times 10^{-5}$$

Step 5: Round the computed value to match standard scientific notation and options:

$$K_\alpha \approx 1.8 \times 10^{-5}$$

Final Answer: $\boxed{1.8 \times 10^{-5}}$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:

Environmental contamination of water resources by chemical fertilizers or sewage runoff poses severe physiological hazards. High concentrations of specific oxyanions are reduced by intestinal microflora into toxic metabolites that compromise the oxygen-transport efficiency of hemoglobin.

Solution:

Step 1: Review the physiological impact of the anions listed in the options. Excess fluoride causes fluorosis, while sulfates exert a laxative effect at high concentrations.

Step 2: Focus on the nitrate ion (NO_3^-). When infant formulas are prepared using groundwater heavily contaminated with nitrates, the ions are ingested into the digestive tract.

Step 3: In the infant gut, anaerobic bacteria reduce the stable nitrate ions into highly reactive nitrite ions (NO_2^-).

Step 4: Nitrite ions enter the bloodstream and oxidize the normal divalent iron (Fe^{2+}) present in hemoglobin into trivalent iron (Fe^{3+}), producing methemoglobin.

Step 5: Methemoglobin cannot bind or transport molecular oxygen effectively, leading to tissue hypoxia and giving the infant's skin a characteristic blue tint. This condition is known clinically as methemoglobinemia or Blue Baby Syndrome.

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

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

Go Back to Question 12

Q13.

Solution

Concept:

The magnitude of paramagnetic behavior in a transition metal coordination complex is directly determined by its total number of unpaired electrons (n). The spin-only magnetic moment is calculated using the formula:

$$\mu = \sqrt{n(n+2)}\ \text{B.M.}$$

The net count of unpaired electrons depends on the oxidation state of the metal, its d-electron configuration, and the crystal field splitting capacity of the surrounding ligands (strong field versus weak field).

Solution:

Step 1: Analyze $[Cr(H_2O)_6]^{3+}$. Here, Cr is in the +3 oxidation state. The electronic configuration of Cr^{3+} is $3d^3$. Regardless of ligand field strength, these three electrons fill the t_{2g} orbitals singly, yielding $n = 3$ unpaired electrons.

Step 2: Analyze $[Mn(CN)_6]^{4-}$. Here, Mn is in the +2 oxidation state with a $3d^5$ configuration. Since cyanide (CN^-) is a powerful strong-field ligand, it forces electron pairing within the t_{2g} subshell, leaving only $n = 1$ unpaired electron.

Step 3: Analyze $[Fe(CN)_6]^{3-}$. Here, Fe is in the +3 oxidation state with a $3d^5$ configuration. Under the influence of the strong-field cyanide ligands, pairing occurs, leaving $n = 1$ unpaired electron.

Step 4: Analyze $[CoF_6]^{3-}$. Here, Co is in the +3 oxidation state with a $3d^6$ configuration. Fluoride (F^-) is a classic weak-field ligand that cannot induce electron pairing. The six electrons are arranged across the d-orbitals according to Hund's rule: $(t_{2g})^4(e_g)^2$, leaving $n = 4$ unpaired electrons.

Step 5: Comparing the total unpaired electrons, $[CoF_6]^{3-}$ has the highest value ($n = 4$), which generates the largest magnetic moment and maximum paramagnetic behavior.

Final Answer: $\boxed{[CoF_6]^{3-}}$

Answer: (D)

Go Back to Question 13

Q14.

Solution

Concept:

Ozonolysis followed by reductive workup using Zn/H_2O cleaves the carbon-carbon double bond ($C = C$) of an alkene. This reaction replaces the double bond with two carbon-oxygen double bonds ($C = O$), yielding carbonyl compounds (aldehydes or ketones).

To deduce the identity and structure of the original alkene reactant, the carbonyl oxygen atoms from the two product fragments are removed, and the remaining carbon fragments are joined with a double bond.

Solution:

Step 1: Identify the chemical structures of the two distinct carbonyl products given in the problem statement. Propan-2-one is acetone, which is expressed as $(CH_3)_2C = O$. Formaldehyde is methanal, written structurally as $H_2C = O$.

Step 2: Position the carbonyl functional groups of both molecules so they face each other directly to facilitate visual reconstruction:

$$(CH_3)_2C = O \quad \text{and} \quad O = CH_2$$

Step 3: Synthetically remove both oxygen atoms and join the two carbonyl carbons via a strong double bond:

$$(CH_3)_2C = CH_2$$

Step 4: Determine the correct structural name of this reconstructed alkene using standard IUPAC nomenclature principles. Find the longest continuous carbon chain containing the double bond. The main chain consists of 3 carbon atoms, which corresponds to a prop-1-ene backbone.

Step 5: Identify the substituent. A methyl branch ($-CH_3$) is located on the second carbon atom. Combining these features yields the IUPAC name: 2-methylprop-1-ene.

Final Answer: $\boxed{\text{2-Methylprop-1-ene}}$

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

Go Back to Question 14

Q15.

Solution

Concept:
The empirical chemical formula of a crystalline solid depends on the total effective contribution of its constituent atoms within a single unit cell. In a cubic close-packed or face-centered cubic (fcc) lattice, atoms residing at different geometric sites are shared differently by adjacent unit cells. An atom situated at a corner is shared equally among 8 unit cells, contributing $\frac{1}{8}$ to each. An atom located at the center of a face is shared between 2 unit cells, contributing exactly $\frac{1}{2}$.

Solution:
Step 1: Calculate the total effective number of atoms of element A inside the unit cell. Since atoms of A occupy all 8 standard corner positions:

$$\text{Number of atoms of } A = 8 \times \frac{1}{8} = 1$$

Step 2: Identify the normal baseline for atoms of element B. In a pristine fcc unit cell, there are 6 faces, and each face contains one atom.
Step 3: Account for the structural defect described. One atom of element B is missing from a face-centered site. This leaves $6 - 1 = 5$ occupied face-centered positions.
Step 4: Compute the net contribution of element B based on the remaining occupied sites:

$$\text{Number of atoms of } B = 5 \times \frac{1}{2} = \frac{5}{2}$$

Step 5: Formulate the ratio of components $A : B$, which gives $1 : \frac{5}{2}$. To convert this into the simplest whole-number integers, multiply the entire ratio by 2:

$$A : B = 2 : 5$$

This yields the final empirical chemical formula A_2B_5.

Final Answer: $\boxed{A_2B_5}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:
Nucleic acids (DNA and RNA) are biopolymers composed of nucleotide units. Each nucleotide comprises a pentose sugar, a phosphate group, and a nitrogenous heterocyclic base.
The nitrogenous bases are divided structurally into purines (adenine and guanine) and pyrimidines (cytosine, thymine, and uracil). The exact distribution of pyrimidine bases distinguishes genomic DNA from transcriptomic RNA.

Solution:
Step 1: Enumerate the nitrogenous bases that constitute the polymer backbone of Deoxyribonucleic Acid (DNA). These are Adenine (A), Guanine (G), Cytosine (C), and Thymine (T).
Step 2: Enumerate the corresponding nitrogenous bases found in Ribonucleic Acid (RNA). These are Adenine (A), Guanine (G), Cytosine (C), and Uracil (U).
Step 3: Compare the two sets to spot the structural difference between these macromolecular blueprints.
Step 4: Observe that Adenine, Guanine, and Cytosine are shared identically across both biological entities.
Step 5: Identify the variable pyrimidine base. Thymine is restricted exclusively to DNA, whereas Uracil replaces it completely in RNA structures. Thus, Uracil is present in RNA but absent in DNA.

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

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

Go Back to Question 16

Q17.

Solution

Concept:
The energy associated with an electronic transition in a hydrogenic atom is given by the Rydberg formula:

$$\Delta E = h\nu = \mathcal{R}_{\text{H}}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

The frequency (ν) of the emitted photon is directly proportional to the magnitude of the net energy change (ΔE). As the principal quantum number n increases, the energy levels become increasingly crowded and closer together. Consequently, transitions terminating at the lowest ground state ($n = 1$) release significantly more energy than transitions between higher levels.

Solution:
Step 1: Evaluate transition option (A) from $n = 2 \longrightarrow n = 1$:

$$\Delta E_{2\to1} \propto \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 1 - 0.25 = 0.75$$

Step 2: Evaluate transition option (B) from $n = 4 \longrightarrow n = 2$:

$$\Delta E_{4\to2} \propto \left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 0.25 - 0.0625 = 0.1875$$

Step 3: Evaluate transition option (C) from $n = 4 \longrightarrow n = 3$:

$$\Delta E_{4\to3} \propto \left(\frac{1}{3^2} - \frac{1}{4^2}\right) = 0.111 - 0.0625 = 0.0486$$

Step 4: Evaluate transition option (D) from $n = 3 \longrightarrow n = 2$:

$$\Delta E_{3\to2} \propto \left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 0.25 - 0.111 = 0.139$$

Step 5: Compare the computed relative energy values. The value for the $n = 2 \longrightarrow n = 1$ transition (0.75) is much larger than any transition occurring within higher shells. Since frequency is directly proportional to energy, this transition emits a photon of the highest frequency.

Final Answer: $\boxed{n = 2 \longrightarrow n = 1}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept:

The basic strength of aliphatic amines in an aqueous environment is governed by three competing factors: the inductive effect of the alkyl groups, steric hindrance around the nitrogen atom, and the extent of solvation stabilization via hydrogen bonding with water molecules.

For methyl-substituted amines, these counteracting effects create a non-linear trend where secondary amines emerge as the strongest bases.

Solution:

Step 1: Examine the positive inductive ($+I$) effect, which increases electron density on the nitrogen atom, making its lone pair more available for protonation. The $+I$ effect follows the sequence: $3^\circ > 2^\circ > 1^\circ > NH_3$.

Step 2: Examine the solvation effect. A less hindered protonated ammonium cation forms more hydrogen bonds with water molecules, stabilizing the conjugate acid. Solvation stability follows the reverse order: $NH_3 > 1^\circ > 2^\circ > 3^\circ$.

Step 3: Factor in steric hindrance, which destabilizes the bulky tertiary ammonium cation in water despite its strong inductive effect.

Step 4: Combine these competing trends for methyl substituents. The secondary amine, dimethylamine $(CH_3)_2NH$, optimizes both inductive and solvation factors, making it the most basic. It is followed by the primary amine (CH_3NH_2), then the tertiary amine $(CH_3)_3N$, with ammonia (NH_3) being the weakest.

Step 5: Arrange them in increasing order: $NH_3 < (CH_3)_3N < CH_3NH_2 < (CH_3)_2NH$.

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

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

Go Back to Question 18

Q19.

Solution

Concept:

The elements of Group 17 (halogens) exhibit periodic trends in electronegativity, electron gain enthalpy, and bond dissociation energy. An anomaly occurs between fluorine and chlorine regarding bond dissociation enthalpy due to the exceptionally small size of the fluorine atom.

Solution:

Step 1: Evaluate option (A). Fluorine has the highest electronegativity value (4.0 on the Pauling scale) across the entire periodic table, making this statement true.

Step 2: Evaluate option (B). Chlorine possesses a higher negative electron gain enthalpy than fluorine because fluorine's tiny $2p$ subshell suffers from intense electron-electron repulsion, which hinders incoming electrons. This statement is true.

Step 3: Evaluate option (C), which concerns the bond dissociation enthalpy of F_2 versus Cl_2. Due to the very short bond length in the small F_2 molecule, the lone pairs on adjacent fluorine atoms experience severe electrostatic repulsion.

Step 4: This lone pair-lone pair repulsion weakens the $F - F$ covalent bond significantly, dropping its dissociation energy below that of Cl_2 and Br_2. Therefore, the statement that the bond dissociation enthalpy of F_2 is greater than Cl_2 is completely incorrect.

Step 5: Evaluate option (D). Fluorine is the most electronegative element and lacks vacant d-orbitals, restricting it to a -1 oxidation state. This statement is correct. Thus, option C is the incorrect statement.

Final Answer: $\boxed{\text{The bond dissociation enthalpy of } F_2 \text{ is greater than that of } Cl_2.}$

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

Go Back to Question 19

Q20.

Solution

Concept:

The pH of a mixed solution containing a strong mono-acidic base and a strong di-protic acid depends on the net balance of milli-equivalents of hydrogen ions (H^+) and hydroxyl ions (OH^-). Complete neutralization occurs if the equivalents match exactly, leaving a neutral salt solution.

Solution:

Step 1: Let the volume of each solution added together be V mL.

Step 2: Calculate the number of milli-equivalents of OH^- ions provided by the strong base NaOH:

$$\text{Milli-equivalents of OH}^- = \text{Molarity} \times \text{Acidity} \times V = 0.1 \times 1 \times V = 0.1V$$

Step 3: Calculate the number of milli-equivalents of H^+ ions provided by the strong diprotic acid H_2SO_4:

$$\text{Milli-equivalents of H}^+ = \text{Molarity} \times \text{Basicity} \times V = 0.05 \times 2 \times V = 0.1V$$

Step 4: Compare the milli-equivalents of acid and base. The milli-equivalents of H^+ ($0.1V$) are exactly equal to the milli-equivalents of OH^- ($0.1V$).

Step 5: Since the acid and base neutralize each other completely without leaving any excess H^+ or OH^- ions, the resulting aqueous salt solution (Na_2SO_4) is perfectly neutral. At 298 K, a neutral aqueous solution has a pH of exactly 7.0.

Final Answer: $\boxed{7.0}$

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

Go Back to Question 20

Q21.

Solution

Concept:

The structural complexity of proteins is organized into four discrete levels: primary, secondary, tertiary, and quaternary. The primary structure is determined solely by covalent peptide bonds linking amino acids.

The secondary structure describes the local spatial folding of the polypeptide backbone into regular geometric patterns, such as the α-helix or β-pleated sheet conformations.

Solution:

Step 1: Analyze the folding mechanism that generates the secondary structural motifs of proteins.

Step 2: In an α-helix conformation, the polypeptide chain twists into a right-handed screw. This shape is maintained by intramolecular hydrogen bonds formed between the carbonyl oxygen (-C=O) of one amino acid residue and the amide hydrogen (-NH-) of a peptide bond located four residues further along the chain.

Step 3: In β-pleated sheets, adjacent polypeptide strands align side-by-side, held together by intermolecular hydrogen bonds.

Step 4: Evaluate the other choices. Ionic bonds and disulfide bridges stabilize the three-dimensional tertiary folding of proteins, rather than their secondary structure.

Step 5: Conclude that hydrogen bonding within the peptide backbone is the primary stabilizing force responsible for holding secondary protein structures intact.

Final Answer: $\boxed{\text{Hydrogen bonds}}$

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

Go Back to Question 21

Q22.

Solution

Concept:

The reaction of an aliphatic carboxylic acid containing α-hydrogens with chlorine in the presence of red phosphorus is known as the Hell-Volhard-Zelinsky (HVZ) reaction. This process selectively substitutes an α-hydrogen atom with a halogen.

Subsequent nucleophilic displacement of this newly introduced α-halogen atom by ammonia yields an α-amino acid.

Solution:

Step 1: Identify the starting carboxylic acid: propanoic acid (CH_3CH_2COOH). The carbon atom directly adjacent to the carbonyl group (C_2) is the α-carbon, and it carries two α-hydrogens.

Step 2: Subject propanoic acid to the HVZ reaction conditions (P, Cl_2). One α-hydrogen atom is replaced by a chlorine atom, forming product X:

$$X = CH_3 - CH(Cl) - COOH \quad \text{(2-chloropropanoic acid)}$$

Step 3: Treat 2-chloropropanoic acid (X) with excess ammonia (NH_3). Ammonia acts as a nucleophile, attacking the α-carbon atom via an S_N2 substitution pathway.

Step 4: The chlorine atom is displaced as a chloride ion, and an amino group (-NH_2) takes its place. Write the chemical structure of product Y:

$$Y = CH_3 - CH(NH_2) - COOH$$

Step 5: Recognize this molecule by its standard biochemical name. 2-Aminopropanoic acid is alanine, one of the fundamental α-amino acids that build proteins.

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

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

Go Back to Question 22

Q23.

Solution

Concept:

Froh floatation is a crucial metallurgical separation technique used to concentrate specific ores by exploiting differences in the wetting characteristics of the ore particles and gangue impurities. The process relies on hydrophobic collectors that selectively wet sulfide minerals with oil, allowing them to attach to rising air bubbles, while water-soluble gangue particles sink to the bottom.

Solution:

Step 1: Identify the chemical composition of each ore mentioned in the options to determine its mineral classification.

Step 2: Hematite (Fe_2O_3) and Magnetite (Fe_3O_4) are oxide ores of iron. Bauxite ($Al_2O_3 \cdot 2H_2O$) is the primary oxide ore of aluminum. Oxide ores are highly hydrophilic and are concentrated using gravity separation or chemical leaching.

Step 3: Analyze Galena (PbS), which is a classic lead sulfide ore.

Step 4: Sulfide minerals match the specific requirements of the froth floatation process. When pine oil or xanthates are added to the aqueous slurry, they coat the galena particles, making them hydrophobic.

Step 5: Compressed air is bubbled through the mixture, creating a stable froth. The hydrophobic galena particles attach to the rising air bubbles and float to the surface, where they are skimmed off. This concentrates the sulfide ore effectively.

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

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

Go Back to Question 23

Q24.

Solution

Concept:

According to Raoult's Law, the vapor pressure of an ideal solution containing a non-volatile solute is directly proportional to the mole fraction of the volatile solvent. The mathematical equation is written as:

$$P_{\text{solution}} = P_A^\circ \cdot X_A$$

where P_A° is the vapor pressure of the pure solvent, and X_A is the mole fraction of the solvent in the solution. The sum of the mole fractions of all components in a solution must always equal 1 ($X_A + X_B = 1$).

Solution:

Step 1: Extract the vapor pressure values from the problem statement:

$$P_A^\circ = 0.80 \text{ atm}$$

$$P_{\text{solution}} = 0.60 \text{ atm}$$

Step 2: Apply Raoult's Law to calculate the mole fraction of solvent A (X_A):

$$0.60 = 0.80 \cdot X_A$$

$$X_A = \frac{0.60}{0.80} = \frac{3}{4} = 0.75$$

Step 3: Use the total mole fraction identity to determine the mole fraction of the non-volatile solute B (X_B):

$$X_A + X_B = 1$$

$$X_B = 1 - 0.75 = 0.25$$

Step 4: Match the calculated mole fractions ($X_A = 0.75$ and $X_B = 0.25$) with the options provided.

Step 5: Conclude that the mole fractions of components A and B are 0.75 and 0.25, respectively.

Final Answer: $\boxed{0.75, 0.25}$

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

Go Back to Question 24

Q25.

Solution

Concept:

A catalyst speeds up a chemical reaction without being consumed in the process. It achieves this by providing an alternative reaction pathway with a lower activation energy (E_a).

Crucially, a catalyst alters the rate of both the forward and reverse reactions equally, which means it has no effect on the overall thermodynamic properties or equilibrium position of the system.

Solution:

Step 1: Analyze the impact of a catalyst on the equilibrium constant (K_{eq}). Since the catalyst accelerates both the forward and reverse reaction rates by the same factor, the ratio of the rate constants ($k_f/k_r = K_{eq}$) remains completely unchanged.

Step 2: Evaluate the thermodynamic state functions. Enthalpy (ΔH), Gibbs free energy (ΔG), and entropy (ΔS) depend solely on the thermodynamic properties of the initial reactants and final products. Since a catalyst does not alter these chemical states, ΔH and ΔS remain constant.

Step 3: Examine the activation energy profile. A catalyst lowers the potential energy barrier of the transition state.

Step 4: This reduction in the activation energy (E_a) increases the fraction of reactant molecules with sufficient kinetic energy to undergo successful collisions.

Step 5: Conclude that the activation energy is the unique parameter that changes when a catalyst is added to a reaction mixture.

Final Answer: $\boxed{\text{Activation energy } (E_a)}$

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

Go Back to Question 25

Q26.

Solution

Concept:

The Cannizzaro reaction is a redox disproportionation reaction characteristic of aldehydes that lack an α-hydrogen atom. In the presence of a concentrated strong base (NaOH or KOH), one molecule of the aldehyde undergoes oxidation to form a carboxylic acid salt, while another molecule is reduced to a primary alcohol.

Aldehydes containing α-hydrogen atoms undergo Aldol condensation instead when exposed to basic conditions.

Solution:

Step 1: Examine the chemical structure of the compounds listed in the options to check for the presence of α-hydrogens.

Step 2: Formaldehyde (HCHO) has no carbon atom adjacent to the carbonyl group, so it has zero α-hydrogens. It undergoes the Cannizzaro reaction.

Step 3: Benzaldehyde (C_6H_5CHO) features a carbonyl group bound to an aromatic ring carbon that lacks attached hydrogens, meaning it has zero α-hydrogens. It undergoes the Cannizzaro reaction.

Step 4: 2,2-Dimethylpropanal [$(CH_3)_3C\text{-}CHO$] has a quaternary α-carbon bound to three methyl groups, meaning it has zero α-hydrogens. It undergoes the Cannizzaro reaction.

Step 5: Analyze Acetaldehyde (CH_3CHO). Here, the α-carbon atom is a methyl group containing three active α-hydrogen atoms. In a strongly basic environment, these acidic protons are rapidly abstracted, steering the reaction down the Aldol condensation pathway instead. Consequently, acetaldehyde does not undergo Cannizzaro's reaction.

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

Answer: (C)

Go Back to Question 26

Q27.

Solution

Concept:

The electronic hybridization and three-dimensional geometry of a polyatomic molecule can be determined using Valence Shell Electron Pair Repulsion (VSEPR) theory. The geometry is dictated by the total number of bonding pairs and non-bonding lone pairs surrounding the central atom.

Solution:

Step 1: Determine the total number of valence electrons for the central xenon atom (Xe), which is 8.

Step 2: Xenon forms four single covalent bonds with the four surrounding fluorine atoms (F), consuming 4 electrons. This leaves $8 - 4 = 4$ non-bonding valence electrons.

Step 3: Group these remaining non-bonding electrons into pairs:

$$\text{Number of lone pairs} = \frac{4}{2} = 2 \text{ lone pairs}$$

Step 4: Calculate the total steric number around the central xenon atom:

$$\text{Steric Number} = \text{Bonding Pairs} + \text{Lone Pairs} = 4 + 2 = 6$$

A steric number of 6 requires an sp^3d^2 orbital hybridization, which corresponds to an octahedral electronic arrangement.

Step 5: Apply VSEPR spatial positioning. To minimize electron-electron repulsion, the 2 lone pairs occupy opposite axial positions (180° apart). The 4 bonding fluorine atoms lie in a horizontal plane, resulting in a square planar molecular geometry.

Final Answer: $\boxed{\text{Square planar, } sp^3d^2}$

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

Go Back to Question 27

Q28.

Solution

Concept:

Photochemical smog is a harmful type of air pollution that develops in warm, sunny urban environments. Unlike classical sulfurous smog, it is an oxidizing mixture formed when solar ultraviolet radiation initiates chemical reactions among primary pollutants trapped in the atmosphere.

Solution:

Step 1: Identify the primary chemical precursors emitted by internal combustion engines and industrial plants. These are unburnt volatile hydrocarbons and nitrogen oxides (NO_x).
Step 2: Analyze the role of sunlight. Solar radiation splits nitrogen dioxide (NO_2) into nitric oxide (NO) and highly reactive nascent oxygen atoms (O).
Step 3: These free oxygen atoms react with atmospheric oxygen (O_2) to form ozone (O_3):

$$O + O_2 \rightarrow O_3$$

Step 4: The ozone then reacts with unburnt unsaturated hydrocarbons in the air to produce secondary toxic pollutants, such as peroxyacetyl nitrate (PAN), acrolein, and formaldehydes.
Step 5: Conclude that photochemical smog is driven by the action of sunlight on a mixture of unsaturated hydrocarbons and nitrogen oxides.

Final Answer: $\boxed{\text{Unsaturated hydrocarbons and nitrogen oxides}}$

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

Go Back to Question 28

Q29.

Solution

Concept:

The distribution of electrons within an atom is governed by quantum numbers. The orbital angular momentum quantum number (l) defines the shape of a subshell and determines the number of individual atomic orbitals it contains. The total number of orbitals in a subshell is given by $(2l + 1)$.

According to the Pauli Exclusion Principle, each individual atomic orbital can accommodate a maximum of two electrons with opposite spins.

Solution:

Step 1: Extract the quantum number given in the problem statement: $l = 3$.

Step 2: Identify the specific type of subshell that corresponds to this value:

$$l = 0 \to s, \quad l = 1 \to p, \quad l = 2 \to d, \quad l = 3 \to f$$

Thus, $l = 3$ designates an f-subshell.

Step 3: Calculate the total number of degenerate orbitals contained within this subshell using the formula $(2l + 1)$:

$$\text{Number of orbitals} = 2(3) + 1 = 7 \text{ orbitals}$$

Step 4: Determine the maximum electron capacity of the subshell. Since each orbital can hold up to 2 electrons:

$$\text{Maximum number of electrons} = 2 \times \text{Number of orbitals} = 2 \times 7 = 14$$

Step 5: Conclude that an orbital subshell with $l = 3$ can accommodate a maximum of 14 electrons.

Final Answer: $\boxed{14}$

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

Go Back to Question 29

Q30.

Solution

Concept:

The acidic strength of a carboxylic acid depends on the stability of its conjugate base, the carboxylate anion ($RCOO^-$). Electron-withdrawing substituents pull electron density away from the carboxylate group via the inductive effect ($-I$ effect), delocalizing the negative charge and stabilizing the anion.

A more stable conjugate base corresponds to a stronger acid with a higher tendency to donate a proton.

Solution:

Step 1: Examine the structural formulas of the given acids: acetic acid (CH_3COOH), monochloroacetic acid ($CH_2ClCOOH$), dichloroacetic acid ($CHCl_2COOH$), and trichloroacetic acid (CCl_3COOH).

Step 2: Evaluate the substituents attached to the α-carbon atom. Chlorine is a highly electronegative atom that exerts a powerful electron-withdrawing inductive effect ($-I$ effect).

Step 3: Compare the number of chlorine atoms across the series. Acetic acid has zero chlorine atoms; the methyl group is weakly electron-donating ($+I$ effect), making it the weakest acid.

Step 4: As the number of electronegative chlorine atoms increases from one to three, their combined electron-withdrawing effect increases step-by-step.

Step 5: Trichloroacetic acid (CCl_3COOH) contains three chlorine atoms, creating an intense $-I$ effect that strongly stabilizes the conjugate base, making it the strongest acid in the group. This establishes the increasing sequence: $CH_3COOH < CH_2ClCOOH < CHCl_2COOH < CCl_3COOH$.

Final Answer: $\boxed{CH_3COOH < CH_2ClCOOH < CHCl_2COOH < CCl_3COOH}$

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept:

For an ideal gas, internal energy (U) and enthalpy (H) are state functions that depend exclusively on the absolute temperature (T) of the system. If the temperature remains perfectly constant during a thermodynamic process, it is classified as an isothermal process.

The fundamental First Law of Thermodynamics states that $\Delta U = q + w$.

Solution:

Step 1: Analyze the condition given in the problem statement: an ideal gas expands under isothermal conditions, meaning $\Delta T = 0$.

Step 2: Since internal energy is a function of temperature alone for an ideal gas ($dU = nC_v dT$), a temperature change of zero implies that the net change in internal energy must also be zero:

$$\Delta U = 0$$

Step 3: Apply the same logic to enthalpy, which is also temperature-dependent ($dH = nC_p dT$). Since $\Delta T = 0$, the net change in enthalpy is zero:

$$\Delta H = 0$$

Step 4: Evaluate the remaining variables. During an expansion process, the volume increases ($\Delta V > 0$), meaning the gas performs mechanical work on its surroundings ($w = -P\Delta V < 0$). Since work is non-zero, the gas must absorb heat ($q = -w > 0$) to maintain a constant temperature. Therefore, q and w are not equal to zero.

Step 5: Match these findings with the options. The statement $\Delta U = 0, \Delta H = 0$ is completely correct for an ideal gas undergoing an isothermal expansion.

Final Answer: $\boxed{\Delta U = 0, \Delta H = 0}$

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept:

An S_N1 nucleophilic substitution reaction proceeds via a two-step mechanism characterized by the formation of a carbocation intermediate. The overall rate of an S_N1 reaction depends entirely on the thermodynamic stability of this carbocation.

Structural factors such as hyperconjugation, inductive effects, and resonance delocalization stabilize the positive charge on the carbocation, accelerating the reaction rate.

Solution:

Step 1: Evaluate the carbocation formed by the dissociation of the leaving group in each option.

Step 2: Option (A) CH_3CH_2Br forms an ethyl carbocation ($CH_3CH_2^+$), which is a primary (1°) carbocation stabilized only by weak hyperconjugation.

Step 3: Option (C) C_6H_5Br is bromobenzene. The bromine atom is bound to an sp^2 hybridized carbon atom, and its lone pairs are delocalized into the aromatic ring. This gives the carbon-halogen bond partial double-bond character, making it extremely difficult to cleave, so it resists S_N1 substitution.

Step 4: Option (D) $CH_3CH_2CH_2Br$ forms a primary propyl carbocation ($CH_3CH_2CH_2^+$), which is unstable.

Step 5: Analyze Option (B) $CH_2 = CH - CH_2Br$ (allyl bromide). Cleavage of the bromide ion yields the allyl carbocation ($CH_2 = CH - CH_2^+$). This carbocation is highly stabilized by resonance delocalization of the adjacent π-electron cloud ($CH_2 = CH - CH_2^+ \leftrightarrow CH_2^+ - CH = CH_2$). This high resonance stability allows allyl bromide to undergo S_N1 substitution at the fastest rate.

Final Answer: $\boxed{CH_2 = CH - CH_2Br}$

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept:

Lanthanoid contraction describes the steady decrease in atomic and ionic radii observed across the lanthanoid series from lanthanum ($Z = 57$) to lutetium ($Z = 71$). This phenomenon is caused by the poor shielding effect of the inner $4f$ electrons.

Because $4f$ orbitals have a diffuse shape, they shield the outer valence electrons poorly from the increasing nuclear charge. As a result, the nucleus pulls the electron shells closer, causing a contraction in size that impacts subsequent elements in the periodic table.

Solution:

Step 1: Identify the position of zirconium (Zr, $Z = 40$) and hafnium (Hf, $Z = 72$) in the periodic table. Zirconium is a $4d$ transition metal belonging to Group 4, while hafnium sits directly below it as a $5d$ transition metal.

Step 2: Typically, atomic size increases down a group due to the addition of a new principal electron shell.

Step 3: However, the 14 lanthanoid elements ($Z = 58$ to 71) lie between zirconium and hafnium. The poor shielding of the $4f$ electrons across these elements creates a significant contraction in size.

Step 4: This lanthanoid contraction reduces the atomic radius of hafnium, counteracting the expected size increase from adding a shell.

Step 5: As a result, Zirconium and Hafnium end up with almost identical atomic radii (Zr $\approx$ 160 pm, Hf $\approx$ 159 pm). This similarity causes them to exhibit nearly identical chemical and physical properties.

Final Answer: $\boxed{\text{Zr and Hf have almost identical ionic radii}}$

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

Go Back to Question 33

Q34.

Solution

Concept:
Dacron, commercially known as Terylene, is a synthetic polyester. It is produced through a condensation polymerization reaction linking a dihydric alcohol (diol) and a dicarboxylic acid, with the loss of water or methanol molecules.

Solution:
Step 1: Analyze the chemical structure of Dacron to determine its monomeric building blocks. Dacron contains repeating ester linkages (-O-$CH_2 - CH_2$ - O-CO - C_6H_4 - CO-).
Step 2: Identify the diol component. The two-carbon fragment (-$CH_2 - CH_2 -$) is derived from ethane-1,2-diol, commonly known as ethylene glycol (HO-$CH_2 - CH_2 - OH$).
Step 3: Identify the aromatic dicarboxylic acid component. The benzene ring substituted at the 1,4-positions with carboxyl groups is benzene-1,4-dicarboxylic acid, commonly known as terephthalic acid ($HOOC - C_6H_4 - COOH$).
Step 4: Differentiate this from alternative choices. Ethylene glycol combined with phthalic acid (1,2-dicarboxylic acid) produces Glyptal resin instead, while caprolactam is the monomer for Nylon-6.
Step 5: Conclude that the specific monomeric units that polymerize to form Dacron are ethylene glycol and terephthalic acid.

Final Answer: $\boxed{\text{Ethylene glycol and terephthalic acid}}$

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

Go Back to Question 34

Q35.

Solution

Concept:
The coordination number of a central transition metal ion is defined as the total number of individual ligand donor atoms directly bound to it via coordinate covalent bonds. The oxidation state is the formal electrical charge remaining on the central atom after all ligands are removed.

Solution:
Step 1: Analyze the ligand in the coordination complex $[\mathrm{Cr(ox)_3}]^{3-}$. The abbreviation ox represents the oxalate ion ($\mathrm{C_2O_4^{2-}}$).
Step 2: Identify the denticity of the oxalate ligand. Oxalate is a bidentate ligand, meaning each oxalate ion possesses two donor oxygen atoms capable of binding simultaneously to the central metal ion.
Step 3: Calculate the total coordination number. Since there are 3 bidentate oxalate ligands attached to the central chromium atom:

$$\text{Coordination Number} = 3 \times 2 = 6$$

Step 4: Determine the formal oxidation state of chromium (x). The complex carries a net charge of -3, and each individual oxalate ligand has a charge of -2.
Step 5: Set up the linear charge-balance equation to solve for x:

$$x + 3(-2) = -3$$

$$x - 6 = -3 \implies x = +3$$

Thus, the coordination number is 6 and the oxidation state is +3.

Final Answer: $\boxed{\text{6 and +3}}$

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

Go Back to Question 35

Q36.

Solution

Concept:

The depression of freezing point (ΔT_f) is a colligative property that depends on the total concentration of solute particles in a solution. For a non-volatile, non-electrolyte solute, this relationship is expressed by the mathematical formula:

$$\Delta T_f = K_f \cdot m$$

where K_f is the cryoscopic constant of the solvent, and m is the molality of the solution.

Solution:

Step 1: State the expanded formula for molality (m) and substitute it into the freezing-point depression equation:

$$\Delta T_f = K_f \cdot \left(\frac{w_2 \times 1000}{M_2 \times w_1} \right)$$

where w_2 is the mass of the solute, M_2 is the molar mass of the solute, and w_1 is the mass of the solvent.

Step 2: Rearrange the equation to isolate the molar mass of the solute (M_2):

$$M_2 = \frac{K_f \times w_2 \times 1000}{\Delta T_f \times w_1}$$

Step 3: Extract the numerical parameters provided in the problem statement:

$$w_2 = 1.00 \text{ g}, \quad w_1 = 50.0 \text{ g}, \quad \Delta T_f = 0.40 \text{ K}, \quad K_f = 5.12 \text{ K kg mol}^{-1}$$

Step 4: Substitute these values into the rearranged equation:

$$M_2 = \frac{5.12 \times 1.00 \times 1000}{0.40 \times 50.0}$$

$$M_2 = \frac{5120}{20} = 256 \text{ g mol}^{-1}$$

Step 5: Conclude that the calculated molar mass of the non-volatile solute is 256 g mol^{-1}.

Final Answer: $\boxed{256 \text{ g mol}^{-1}}$

Answer: (A)

Go Back to Question 36

Q37.

Solution

Concept:
Chemical oxides are classified into four main categories based on their acid-base behavior: acidic, basic, neutral, or amphoteric. Amphoteric oxides possess dual chemical reactivity, meaning they can react with both strong acids and strong bases to form salts and water.

Solution:
Step 1: Evaluate the acid-base character of the oxides listed in the choices.
Step 2: CO_2 and SO_2 are non-metal oxides. Non-metal oxides typically dissolve in water to form acidic solutions (carbonic acid and sulfurous acid, respectively), making them acidic oxides.
Step 3: CaO is an alkaline earth metal oxide. Electropositive metal oxides typically react with water to form strong bases [$Ca(OH)_2$], classifying them as basic oxides.
Step 4: Analyze Aluminum oxide (Al_2O_3). Aluminum is a post-transition metalloid-like element. Its oxide reacts with strong acids like HCl to form aluminum salts:

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

Step 5: Al_2O_3 also reacts with strong bases like NaOH to form soluble aluminate complexes:

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

This dual reactivity confirms that aluminum oxide is amphoteric.

Final Answer: $\boxed{Al_2O_3}$

Answer: (C)

Go Back to Question 37

Q38.

Solution

Concept:

The nucleophilic substitution reaction of haloalkanes with cyanide salts depends on the ambient ionic nature of the reagent used. Cyanide (CN^-) is an ambidentate nucleophile that can form a covalent bond using either its carbon atom or its nitrogen atom.

Solution:

Step 1: Identify the reactant and reagent: ethyl bromide (CH_3CH_2Br) reacts with alcoholic potassium cyanide (KCN).

Step 2: Analyze the chemical nature of potassium cyanide. KCN is a predominantly ionic compound that dissociates fully in solution into potassium cations (K^+) and free cyanide anions ($: C \equiv N :^-$).

Step 3: Determine the preferred nucleophilic attacking site. Both carbon and nitrogen atoms carry lone pairs, but the carbon-carbon ($C - C$) bond is thermodynamically stronger and more stable than a carbon-nitrogen ($C - N$) bond.

Step 4: Consequently, the carbon atom of the cyanide ion acts as the nucleophilic center, attacking the electrophilic alkyl carbon of ethyl bromide and displacing the bromide ion via an S_N2 mechanism.

Step 5: Write the structure of the resulting product: $CH_3CH_2 - CN$. This compound is propane nitrile (ethyl cyanide). Contrast this with silver cyanide (AgCN), which is covalent and yields ethyl isocyanide instead. Therefore, ionic KCN produces propane nitrile.

Final Answer: Propane nitrile

Answer: (C)

Go Back to Question 38

Q39.

Solution

Concept:

According to Molecular Orbital (MO) Theory, the magnetic properties and bond order of a homonuclear diatomic molecule are determined by its electronic configuration. Bond order is calculated using the formula:

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

where N_b is the number of bonding electrons, and N_a is the number of antibonding electrons. A species is diamagnetic if all its electrons are paired, and paramagnetic if it contains one or more unpaired electrons.

Solution:

Step 1: Evaluate molecular nitrogen (N_2). Nitrogen has a total of 14 electrons.

Step 2: Write the complete molecular orbital configuration for N_2:

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

Step 3: Count the bonding and antibonding electrons: $N_b = 10, N_a = 4$. Calculate the bond order:

$$\text{Bond Order} = \frac{10 - 4}{2} = 3.0$$

Step 4: Check the magnetic behavior. Since every orbital is fully filled with paired electrons, N_2 is highly diamagnetic.

Step 5: Compare this with O_2, which has a bond order of 2.0 and is paramagnetic due to two unpaired electrons in its antibonding orbitals. Thus, molecular nitrogen (N_2) fits the criteria perfectly.

Final Answer: $\boxed{N_2}$

Answer: (B)

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Q40.

Solution

Concept:

The change in standard Gibbs free energy (ΔG°) quantifies the maximum non-expansion electrical work obtainable from an electrochemical cell reaction operating at standard state conditions. This thermodynamic value is directly linked to the total electrical charge transferred and the electromotive force (E°_{cell}) of the cell.

Solution:

Step 1: State the core equation relating thermodynamic free energy change to mechanical or electrical work: $\Delta G^\circ = -W_{\text{electrical, max}}$.

Step 2: Express the maximum electrical work as the product of the total chemical charge transferred and the standard cell potential (E°_{cell}).

Step 3: Let n represent the total number of moles of electrons exchanged during the balanced redox reaction.

Step 4: Introduce Faraday's constant (F), which represents the electrical charge carried by one mole of electrons (≈ 96500 C mol^{-1}). The total charge transferred is calculated as $n \cdot F$.

Step 5: Combine these terms to write the final standard relationship:

$$\Delta G^\circ = -nFE^\circ_{\text{cell}}$$

This negative sign indicates that a spontaneous reaction with a positive cell potential results in a decrease in Gibbs free energy.

Final Answer: $\boxed{\Delta G^\circ = -nFE^\circ_{\text{cell}}}$

Answer: (A)

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Answer Key

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