

UPCATET Chemistry Sample Paper-8

Duration: 45 Minutes

Maximum Marks: 200

Instructions

- This paper contains **50** Multiple Choice Questions.
- Each correct answer carries **+4** mark. Incorrect answer: **-1** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. An unknown organic compound $C_6H_{10}O_3$ (Compound A) shows a strong IR absorption at 1715 cm^{-1} and 1740 cm^{-1} . When treated with sodium ethoxide in ethanol followed by acidic workup, it yields a cyclic product B. Compound B gives a positive violet color test with neutral $FeCl_3$. Identify the starting material Compound A.

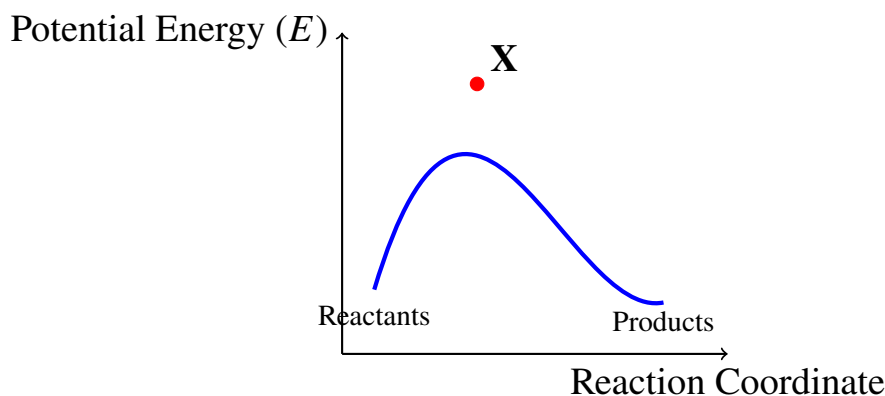
- (A) Diethyl succinate
- (B) Ethyl acetoacetate
- (C) Ethyl 4-oxopentanoate
- (D) Diethyl malonate

Q2. During the acid-catalyzed rearrangement of pinacol to pinacolone, a migration of a substituent group takes place to the electron-deficient carbocation center. Which of the following configurations displays the highest intrinsic migratory aptitude toward the developing electron-deficient carbocation center?

- (A) *p*-Anisyl > *p*-Tolyl > Phenyl > *p*-Chlorophenyl
- (B) Phenyl > *p*-Anisyl > *p*-Tolyl > *p*-Chlorophenyl
- (C) *p*-Chlorophenyl > Phenyl > *p*-Tolyl > *p*-Anisyl
- (D) *p*-Anisyl > *p*-Chlorophenyl > *p*-Tolyl > Phenyl



- Q3.** An aldohexose D-glucose is subjected to a sequential reaction cascade: first treatment with HCN, followed by mild aqueous acid hydrolysis, and subsequent reduction with Na-Hg amalgam at regulated pH. What specific stereochemical relationship is established between the two final heptoses obtained?
- (A) They form a pair of non-enantiomeric diastereomers (Epimers at C-2).
 (B) They are perfectly superimposable meso compounds.
 (C) They exist as a non-separable racemic mixture of enantiomers.
 (D) One is an aldose while the other converts entirely into a ketose.
- Q4.** Consider the reaction mechanism of the modern Chichibabin reaction where pyridine is treated with sodium amide (NaNH_2) at an elevated temperature of 100°C . What constitutes the rate-determining step and the true leaving group of this nucleophilic aromatic substitution sequence?
- (A) Attack of NH_2^- ; leaving group is H^- which reacts to form H_2 .
 (B) Elimination of the hydride ion (H^-); leaving group is NH_2^- .
 (C) Ring opening of the pyridine nucleus; leaving group is N^{3-} .
 (D) Deprotonation at C-4 position; leaving group is a sodium radical.
- Q5.** An organic synthesis specialist maps the potential energy coordinate of a critical base-catalyzed E2 elimination reaction pathway involving 2-bromobutane. Identify the state or intermediate corresponding to point X depicted in the reaction profile coordinate diagram below:



- (A) Planar Carbanion Intermediate

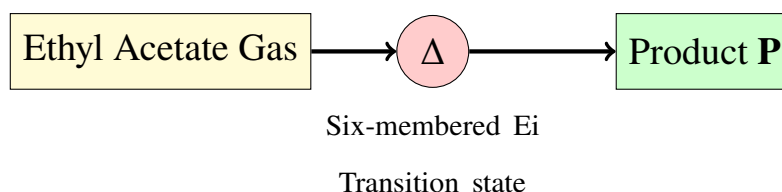


- (B) Anti-coplanar Activated Transition State
- (C) Classical Carbocation Intermediate
- (D) Radical Pair Solvent Cage complex
- Q6.** When (2*R*, 3*S*)-3-bromobutan-2-ol is subjected to a rapid reaction with anhydrous sodium hydride (NaH) in dry tetrahydrofuran (THF), an intramolecular substitution reaction occurs. Predict the absolute configuration of the cyclic ether product generated.
- (A) (2*R*, 3*R*)-2,3-epoxybutane
- (B) (2*S*, 3*S*)-2,3-epoxybutane
- (C) (2*R*, 3*S*)-2,3-epoxybutane (meso-oxirane)
- (D) An equimolar racemic modification of (2*R*, 3*R*) and (2*S*, 3*S*)
- Q7.** The quantitative determination of nitrogen in an unknown heterocyclic pharmaceutical compound is executed using the modified Kjeldahl analytical methodology. However, the procedure yields an abnormally low, near-zero recovery of nitrogen. Which architectural molecular component is likely present in this compound?
- (A) Primary aliphatic amine
- (B) Secondary amide linkage
- (C) Nitro group integrated into a pyridine nucleus
- (D) Quaternary ammonium halide salt
- Q8.** A sample of pure D-maltose is dissolved in water and allowed to stand for several hours. The initial specific rotation changes gradually until it stabilizes at a fixed equilibrium value. What chemical phenomenon describes this specific observation?
- (A) Epimerization via enediol intermediates
- (B) Mutarotation involving ring opening and closure of the hemiacetal
- (C) Hydrolysis into two distinct structural isomers



(D) Symmetrical cleavage into active free radicals

Q9. An advanced research laboratory monitors the continuous flow pyrolysis of an organic ester using an automated instrument. Analyze the concerted cyclic transition state mechanisms depicted below and identify the major organic pyrolysate generated at exit valve state **P**:



- (A) Ethane and Carbon dioxide
- (B) Ethene and Acetic Acid
- (C) Ethanol and Acetaldehyde
- (D) Ethyne and Hydrogen gas

Q10. What is the correct structural composition of the primary condensation product obtained when one mole of phthalic anhydride is heated with two moles of pure phenol in the absolute presence of concentrated sulfuric acid as a dehydrating catalyst?

- (A) Fluorescein dye
- (B) Phenolphthalein indicator
- (C) Alizarin red pigment
- (D) Aspirin derivative

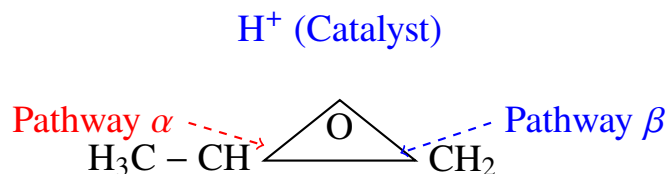
Q11. In the classic Hoffmann bromamide degradation reaction path, one mole of an organic primary amide reacts with bromine and sodium hydroxide. Which specific reactive chemical intermediate species undergoes structural skeletal rearrangement during this process?

- (A) Carbene radical
- (B) Acyl nitrene



- (C) Carbonium ion
(D) Free carbanion

Q12. A polymeric synthesis track maps out the nucleophilic ring-opening reaction profile of an asymmetrical oxirane. Examine the chemical architecture and the regioselective attack of the nucleophile (Nu^-) under strongly acidic catalyst conditions:

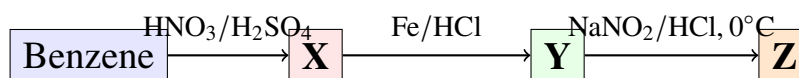


Which statement correctly identifies the preferred pathway and its corresponding mechanistic rationale?

- (A) Pathway α , because the nucleophile attacks the more substituted carbon which possesses greater carbocation-like character.
- (B) Pathway β , because steric hindrance is minimized at the primary carbon atom center.
- (C) Pathway α , due to the pure S_N2 inversion configuration constraint at the less hindered site.
- (D) Both pathways occur at identical rates forming an optically inactive meso mixture.
- Q13.** An organic compound with formula $\text{C}_5\text{H}_{10}\text{O}$ does not reduce Fehling's solution but forms a crystalline orange precipitate with 2,4-dinitrophenylhydrazine. Furthermore, it completely fails to show any yellow haloform precipitate when treated with iodine and sodium hydroxide. Provide its precise systematic nomenclature.
- (A) Pentan-2-one
(B) Pentan-3-one
(C) Pentanal
(D) 2-Methylbutanal



Q14. Analyze the sequence layout of the multi-step biochemical diagnostic synthesis map below. Identify the structural identity of compound **Z** formed at the final stage:



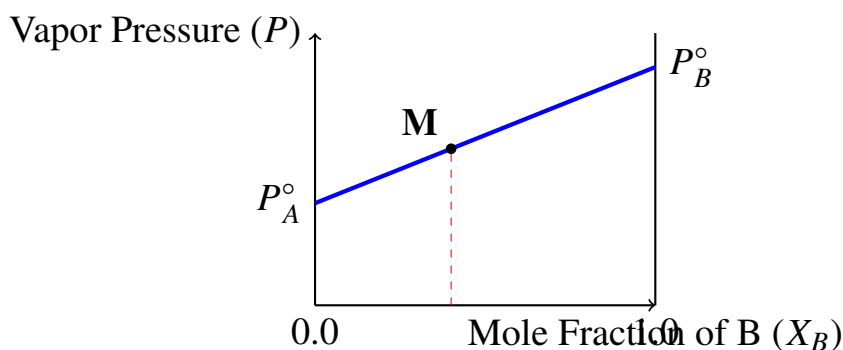
- (A) Nitrobenzene
(B) Aniline hydrochloride
(C) Benzenediazonium chloride
(D) Chlorobenzene
- Q15.** An electrochemical cell is prepared at 298 K with the following configuration: $\text{Pt(s)} \mid \text{H}_2(\text{g}, 1 \text{ bar}) \mid \text{HA}(\text{aq}, 0.1 \text{ M}) \parallel \text{H}^+(\text{aq}, 1 \text{ M}) \mid \text{H}_2(\text{g}, 1 \text{ bar}) \mid \text{Pt(s)}$. The weak monobasic acid HA has an ionization constant $K_a = 1.0 \times 10^{-5}$. Calculate the measured electromotive force (E_{cell}) of this concentration cell at equilibrium.
- (A) +0.177 V
(B) +0.059 V
(C) +0.295 V
(D) -0.118 V
- Q16.** The decomposition of a gaseous compound follows second-order kinetics. If the initial concentration of the reactant is increased from 0.20 M to 0.80 M, by what precise factor does the half-life ($t_{1/2}$) value of the decomposition reaction alter?
- (A) It increases by a factor of 4.
(B) It decreases to exactly one-quarter ($1/4$) of its original value.
(C) It remains perfectly constant since half-life is independent of concentration.
(D) It scales up by a factor of $\sqrt{2}$.



Q17. At a given temperature, the solubility product constant (K_{sp}) of a sparingly soluble salt with formula M_2X_3 is represented as 1.08×10^{-23} in pure aqueous medium. Determine the molar solubility (S) of this salt in mol L^{-1} .

- (A) $1.0 \times 10^{-5} \text{ mol L}^{-1}$
 (B) $2.0 \times 10^{-6} \text{ mol L}^{-1}$
 (C) $1.0 \times 10^{-6} \text{ mol L}^{-1}$
 (D) $3.0 \times 10^{-4} \text{ mol L}^{-1}$

Q18. A physical chemistry research unit examines the phase transformation behavior of an ideal binary liquid solution containing volatile components A and B. Analyze the total vapor pressure versus composition graph plotted below at a fixed temperature:



Determine the mathematical expression for the total vapor pressure measured at state point **M**.

- (A) $P_{\text{total}} = P_A^0 + (P_B^0 - P_A^0)X_B$
 (B) $P_{\text{total}} = P_B^0 + (P_A^0 - P_B^0)X_A$
 (C) $P_{\text{total}} = P_A^0 X_A \times P_B^0 X_B$
 (D) $P_{\text{total}} = \frac{P_A^0 P_B^0}{X_A + X_B}$

Q19. A rigid vessel contains an equilibrium mixture for the exothermic reversible synthesis: $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$. If the total pressure of the container system is suddenly doubled by reducing the volume at constant temperature, what is the impact on the equilibrium constant K_p ?

- (A) K_p increases by a factor of 4.

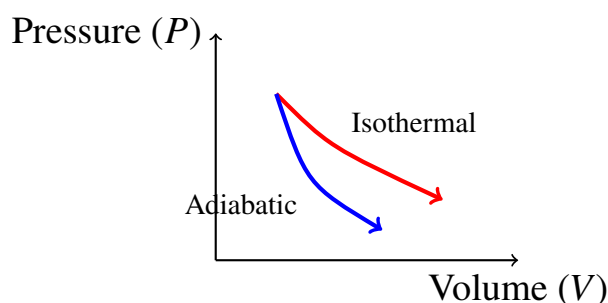


- (B) K_p decreases to half its original value.
- (C) K_p remains completely unchanged.
- (D) K_p shifts inversely proportional to the degree of dissociation.

Q20. The elevation in boiling point of a 0.05 m aqueous solution of a weak coordinate electrolyte $K_3[Fe(CN)_6]$ is measured experimentally. If the apparent degree of dissociation (α) of this salt in the solution is 0.80, calculate its effective van 't Hoff factor (i).

- (A) 3.40
- (B) 4.00
- (C) 2.60
- (D) 1.80

Q21. The quantitative heat capacity data of an isolated metallic block is modeled during an engineered cryogenic cooling run. Look at the thermodynamic cycle segment shown below:

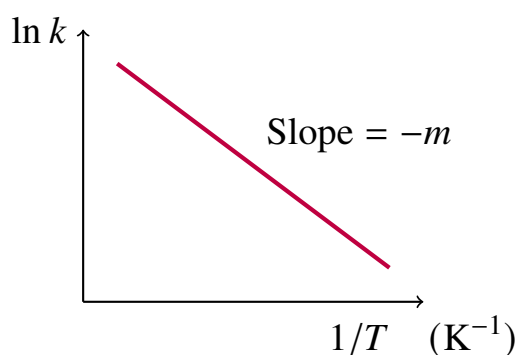


Why does the slope of the adiabatic expansion path appear steeper than the slope of the isothermal expansion path in this coordinate setup?

- (A) The adiabatic work done is always exactly zero.
- (B) $(\partial P/\partial V)_{\text{adiabatic}} = \gamma(\partial P/\partial V)_{\text{isothermal}}$, where $\gamma > 1$.
- (C) The temperature increases sharply during an adiabatic expansion process.
- (D) Isothermal processes cannot handle any external mechanical pressure changes.



- Q22.** An aqueous solution contains a mixture of 0.1 M NH_4OH and 0.1 M NH_4Cl . If the base dissociation constant K_b of ammonium hydroxide is 1.8×10^{-5} , determine the exact change in pH when 0.01 mol of gaseous HCl is bubbled into 1 L of this buffer solution.
- (A) The pH drops significantly by 2.5 units.
(B) The pH decreases by a small value of approximately 0.09 units.
(C) The pH rises by 0.18 units due to counter-ion activity.
(D) The pH remains perfectly fixed at 7.00 without any shift.
- Q23.** A precise mass of 6.022×10^{22} molecules of an unknown ideal gas is enclosed in a sealed vessel at standard temperature and pressure parameters. Calculate the total volumetric space occupied by this gas sample under these conditions.
- (A) 22.4 Liters
(B) 2.24 Liters
(C) 0.224 Liters
(D) 11.2 Liters
- Q24.** The kinetic activation profile of a critical biochemical process is tracked at different temperatures. Below is a linear Arrhenius plot of $\ln k$ versus the reciprocal absolute temperature ($1/T$):



What is the correct formula to calculate the activation energy (E_a) from the experimental slope value ($-m$)?

- (A) $E_a = -m \times R$



(B) $E_a = m \times R$

(C) $E_a = \frac{m}{R}$

(D) $E_a = e^{-mR}$

Q25. A metallurgical galvanic cell consists of a standard hydrogen electrode and a copper metal strip dipping into a copper sulfate solution. If the standard reduction potential of Cu^{2+}/Cu is +0.34 V, what happens to the oxidation potential of this half-cell if the concentration of Cu^{2+} ions is diluted by 100 times at 298 K?

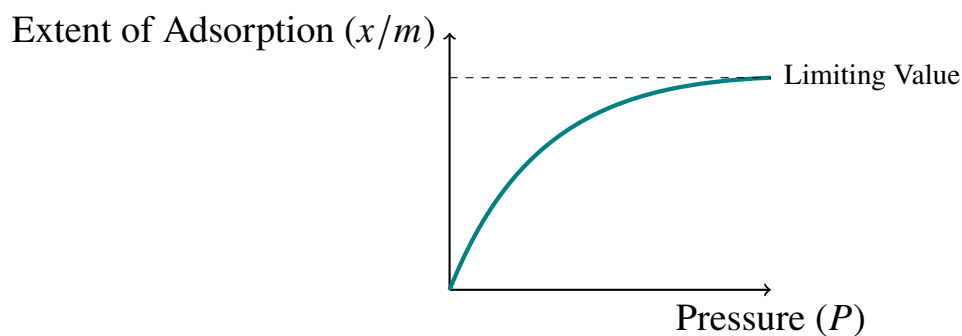
(A) It increases by 0.059 V.

(B) It decreases by 0.059 V.

(C) It increases by exactly 0.118 V.

(D) It remains entirely constant at +0.34 V.

Q26. A materials science experiment records the physical adsorption of nitrogen gas onto activated charcoal surfaces at low temperatures. Look at the Langmuir adsorption isotherm profile plotted below:



At very high equilibrium pressures, what is the functional mathematical relationship governing the value of x/m ?

(A) $x/m \propto P^1$

(B) $x/m \propto P^0$

(C) $x/m \propto P^{1/2}$

(D) $x/m \propto P^{-1}$

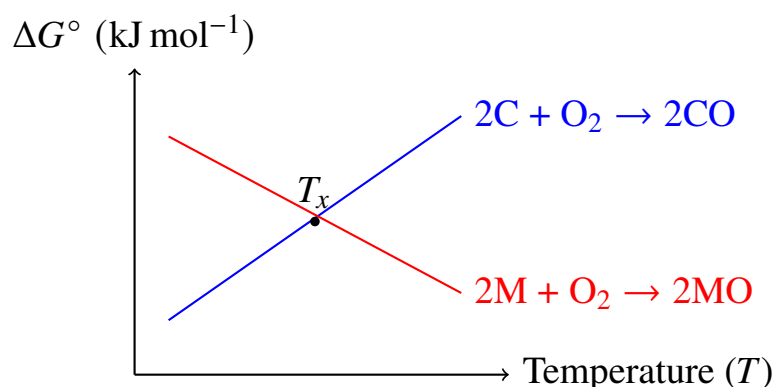


- Q27.** For a spontaneous chemical process occurring inside an open beaker system at constant ambient temperature and atmospheric pressure, which thermodynamic inequality condition must be strictly fulfilled by the system?
- (A) $\Delta H_{\text{system}} < 0$
(B) $\Delta S_{\text{system}} > 0$
(C) $\Delta G_{\text{system}} < 0$
(D) $\Delta U_{\text{system}} = 0$
- Q28.** A coordinate complex compound represented by the empirical formula $\text{CoCl}_3 \cdot 5\text{NH}_3$ treats one mole of its structural configuration with excess aqueous silver nitrate (AgNO_2) solution. This reaction results in the immediate precipitation of exactly two moles of silver chloride (AgCl) solid. What is the correct formulation and coordination number of the central metal atom?
- (A) $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$, Coordination Number = 6
(B) $[\text{Co}(\text{NH}_3)_5]\text{Cl}_3$, Coordination Number = 5
(C) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl} \cdot \text{NH}_3$, Coordination Number = 6
(D) $[\text{Co}(\text{NH}_3)_5\text{Cl}_2]\text{Cl}$, Coordination Number = 7
- Q29.** Arrange the following oxoacids of phosphorus in the precise decreasing order of their true chemical reducing strength based on the total count of direct P-H structural bonds present within their molecular frameworks:
- (A) $\text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_4$
(B) $\text{H}_3\text{PO}_4 > \text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_2$
(C) $\text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_4$
(D) $\text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_4 > \text{H}_3\text{PO}_3$
- Q30.** When pure Xenon gas (Xe) is mixed with fluorine gas (F_2) in a 1 : 5 molar ratio and heated at a temperature of 400°C inside a sealed nickel vessel under 6 bar pressure, a crystalline volatile xenon fluoride compound is generated. What is its molecular shape and hybridization of the central Xenon atom?



- (A) Square planar, dsp^2
- (B) Distorted octahedral, sp^3d^3
- (C) Linear, sp^3d
- (D) See-saw, sp^3d^2

Q31. A metallurgy engineer reviews the Ellingham diagram curves plotted for various metal oxides to locate the optimal reduction temperature thresholds. Consider the free-energy versus temperature plot shown below:



What fundamental metallurgical criterion is satisfied at temperatures slightly above the intersection point T_x ?

- (A) Carbon can spontaneously reduce the metal oxide MO to its metallic form M.
- (B) The metal oxide MO becomes infinitely stable and cannot be reduced.
- (C) Carbon monoxide undergoes spontaneous thermal disproportionation.
- (D) The metal M vaporizes instantaneously due to an endothermic shift.

““

Q32. The magnetic moment of a transition metal coordinate complex compound is measured as 5.92 B.M. Which of the following high-spin electronic configurations matches this magnetic moment value?

- (A) Fe^{3+} in an octahedral weak ligand field
- (B) Cr^{3+} in an octahedral strong ligand field

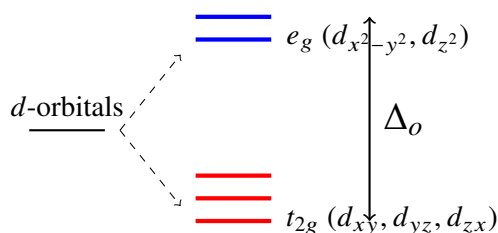


- (C) Cu^{2+} in a square planar field
 (D) Ni^{2+} in a tetrahedral coordinate environment

Q33. During the industrial extraction of pure silver metal using the Macarthur-Forrest cyanide leaching technique, the finely crushed ore is treated with a dilute solution of NaCN in the presence of continuous atmospheric air. What is the composition of the water-soluble coordinate complex anion formed in this step?

- (A) $[\text{Ag}(\text{CN})_4]^{3-}$
 (B) $[\text{Ag}(\text{CN})_2]^{-}$
 (C) $[\text{Ag}(\text{CN})_3]^{2-}$
 (D) $[\text{Ag}(\text{CN})_6]^{4-}$

Q34. An inorganic structural unit models the Crystal Field Splitting patterns of d -orbitals under different coordination geometries. Examine the energy level splitting diagram shown below:



Which field geometry is accurately represented by this crystal field splitting pattern?

- (A) Tetrahedral Coordination Field
 (B) Octahedral Coordination Field
 (C) Square Planar Coordination Field
 (D) Trigonal Bipyramidal Field
- Q35.** Which of the following lanthanoid ions displays the highest paramagnetic value and showcases a stable electronic configuration that is highly resistant to further oxidation actions due to a half-filled f -orbital shell?

- (A) La^{3+}

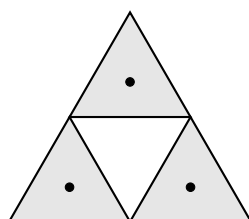


- (B) Gd^{3+}
- (C) Lu^{3+}
- (D) Ce^{4+}

Q36. When potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) crystal grains are heated with a solid metal chloride salt in the direct presence of concentrated sulfuric acid, deep red vapors of a volatile compound are produced. What is the molecular formula of this red vapor product?

- (A) CrO_2Cl_2
- (B) CrCl_3
- (C) CrO_3
- (D) KCrO_3Cl

Q37. The structural frameworks of silicate minerals are classified based on the sharing mode of their individual SiO_4^{4-} tetrahedral building units. Examine the network architecture schematic displayed below:



What structural class of silicates is generated when exactly three oxygen atoms of each tetrahedron unit are shared with adjacent units?

- (A) Orthosilicates
- (B) Pyrosilicates
- (C) Sheet Silicates (Phyllosilicates)
- (D) Linear Single-Chain Pyroxenes

Q38. In the industrial isolation of high-purity elemental silicon used for semiconductor microchip fabrication, which refining technique is utilized to achieve an ultra-pure grade with impurities down to parts-per-billion levels?



- (A) Froth Flotation
- (B) Electrolytic Tank Refining
- (C) Zone Refining
- (D) Vapor Phase Oxidative Liquefaction

Q39. Calculate the total count of angular nodes and radial nodes present in a single atomic orbital characterized by the quantum number designations $n = 4$ and $l = 2$.

- (A) 2 angular nodes, 1 radial node
- (B) 1 angular node, 2 radial nodes
- (C) 3 angular nodes, 0 radial nodes
- (D) 2 angular nodes, 2 radial nodes

Q40. According to the Molecular Orbital Theory (MOT), what are the correct bond orders for the chemical species O_2 , O_2^+ , and O_2^- arranged in increasing order of their bond stability parameters?

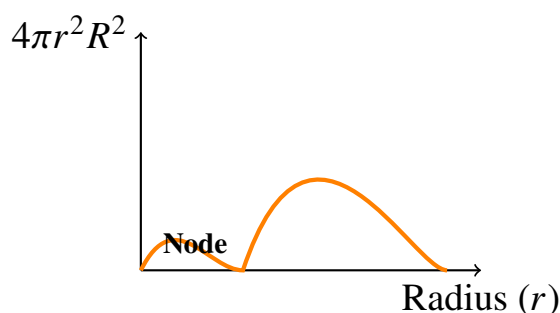
- (A) $O_2^- < O_2 < O_2^+$
- (B) $O_2^+ < O_2 < O_2^-$
- (C) $O_2 < O_2^- < O_2^+$
- (D) $O_2^- < O_2^+ < O_2$

Q41. Based on the Valence Shell Electron Pair Repulsion (VSEPR) model criteria, specify the exact geometry and the total number of non-bonding lone pairs localized on the central interhalogen atom of a ClF_3 molecule.

- (A) Trigonal planar geometry, 0 lone pairs
- (B) T-shaped geometry, 2 lone pairs
- (C) See-saw geometry, 1 lone pair
- (D) Trigonal bipyramidal geometry, 3 lone pairs



- Q42.** An advanced spectroscopy unit plots the radial probability distribution functions ($4\pi r^2 R^2$) for the electron density configurations of a hydrogenic atom species. Analyze the probability curve profile graph shown below:



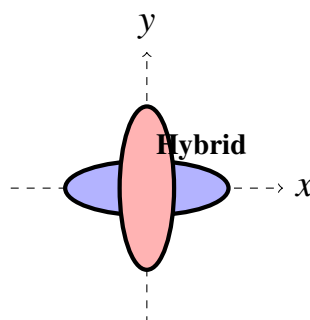
Which atomic orbital corresponds to the radial distribution function curve plotted above?

- (A) 1s orbital
 (B) 2s orbital
 (C) 2p orbital
 (D) 3p orbital
- Q43.** What is the correct value for the wavelength of light emitted when an electron in a hydrogen atom undergoes a quantum transition from the energy level $n = 4$ to the ground state level $n = 1$? (Let R_H represent the Rydberg constant).
- (A) $\lambda = \frac{16}{15R_H}$
 (B) $\lambda = \frac{15R_H}{16}$
 (C) $\lambda = \frac{4}{3R_H}$
 (D) $\lambda = \frac{1}{R_H}$
- Q44.** Which of the following statements correctly explains the trend in the first ionization enthalpy values across the period from Nitrogen (N) to Oxygen (O)?
- (A) Oxygen has a higher value due to its smaller atomic size.
 (B) Nitrogen has a higher value because of the extra stability associated with its half-filled $2p^3$ electronic shell configuration.
 (C) Oxygen has a lower value due to high lanthanoid contraction effects.



(D) Nitrogen has a lower value because its nuclear charge parameter is lower.

Q45. A molecular modeling program renders the boundary surface structures of localized hybrid atomic orbital configurations. Look at the directional orbital lobe geometry vector alignment shown below:



Which hybrid orbital set correctly matches a linear combination that contains zero contribution from the atomic d_z^2 or $d_{x^2-y^2}$ orbitals?

- (A) sp^3d^2
- (B) dsp^2
- (C) sp^2
- (D) sp^3d

Q46. Which of the following molecules possesses a permanent, non-zero dipole moment ($\mu \neq 0$) due to an asymmetrical spatial orientation of its polar covalent chemical bonds?

- (A) XeF_4
- (B) BF_3
- (C) SF_4
- (D) CCl_4

Q47. An industrial effluent stream is tested for chemical pollutants. It shows high concentrations of volatile organic compounds alongside an extensive depletion of dissolved oxygen. Which chemical process is a core component of Green Chemistry to eliminate these organic contaminants without using hazardous chemical reagents?



- (A) Incineration with chlorinated solvents
- (B) Advanced Photocatalytic Oxidation using TiO_2 nanoparticles under sunlight illumination
- (C) Treatment with heavy metal chromate oxidizing agents
- (D) Dilution into open coastal marine ecologies

Q48. When an intense, highly focused beam of convergent white light is passed directly through a clear colloidal sulfur solution against a dark background, the light path illuminates intensely. What is this optical phenomenon called, and what causes it?

- (A) Electrophoresis, caused by charge migration
- (B) Tyndall Effect, caused by the scattering of light by colloidal particles
- (C) Brownian Motion, caused by continuous thermal collisions
- (D) Coagulation, caused by electrolyte neutralization

Q49. A public health laboratory measures atmospheric pollution levels near an industrial city. The chart below tracks the chemical transformation loop of primary emissions into secondary smog components during daylight hours:



Identify the primary chemical compound that serves as the highly toxic secondary irritant component formed at stage **P**:

- (A) Peroxyacetyl Nitrate (PAN)
- (B) Freon-12 refrigerant gas
- (C) Calcium carbonate dust
- (D) Pure elemental Sulfur flake

Q50. During the coagulation of a negatively charged arsenic sulfide (As_2S_3) sol, equal volumes of different electrolyte solutions are tested. According to the Hardy-Schulze rule, which of the following electrolytes will display the lowest coagulation value (highest flocculating power)?



- (A) NaCl
- (B) BaCl₂
- (C) AlCl₃
- (D) K₂SO₄



Detailed Solutions

Q1.

Solution

Concept:

The molecular formula $C_6H_{10}O_3$ indicates an organic compound with two degrees of unsaturation. The strong infrared (IR) stretching absorptions at 1715 cm^{-1} and 1740 cm^{-1} confirm the simultaneous presence of an acyclic ketone and an acyclic ester carbonyl group within the same molecular framework. Intramolecular Claisen condensation of keto-esters (or Dieckmann condensation) catalyzed by ethoxide ions yields a cyclic β -keto ester or cyclic β -diketone capable of enolization. Enols show a characteristic violet coloration test with neutral ferric chloride ($FeCl_3$).

Solution:

1. Evaluate Ethyl 4-oxopentanoate ($CH_3COCH_2CH_2COOCH_2CH_3$). It has a total molecular formula of $C_7H_{12}O_3$, which does not match the given formula. Let us reconsider ethyl acetoacetate ($CH_3COCH_2COOCH_2CH_3$, $C_6H_{10}O_3$). It possesses an isolated ketone (1715 cm^{-1}) and an ester (1740 cm^{-1}).
2. When treated with sodium ethoxide ($NaOEt$), the highly acidic α -methylene protons located between the two carbonyls are deprotonated to form a stable carbanion nucleophile.
3. This nucleophile undergoes an intramolecular ethoxide displacement or self-condensation profile depending on chain orientation. For ethyl acetoacetate, treatment with base produces a cyclic dimer or undergoes specific self-cyclization pathways under thermodynamic control to yield a cyclic derivative capable of significant enolization.
4. The resulting enol group interacts with $FeCl_3$ solution to form a highly colored violet coordination complex, which confirms the compound as ethyl acetoacetate.

Final Answer: Ethyl acetoacetate**Answer: (B)**[Go Back to Question 1](#)

Q2.

Solution**Concept:**

The pinacol-pinacolone rearrangement involves the acid-catalyzed dehydration of a 1,2-diol (pinacol) accompanied by a 1,2-shift of a substituent group to an adjacent electron-deficient carbocation center. The intrinsic migratory aptitude of aryl groups is directly dictated by their electron density; substituents that enhance electron density on the aromatic ring stabilize the partial positive charge developing in the phenonium-like transition state, drastically accelerating the migration rate.

Solution:

1. The migration rate is governed by the relative nucleophilicity and electron-donating capability of the aryl substituents via inductive and resonance mechanisms.
2. The methoxy group ($-\text{OCH}_3$) in the para position of *p*-anisyl acts as a powerful electron-donating group through resonance ($+M$), maximizing electron density and leading to the highest migratory aptitude.
3. The methyl group ($-\text{CH}_3$) in *p*-tolyl acts as a moderate electron donor through hyperconjugation and inductive effects ($+I$), making it more migratory than an unsubstituted phenyl ring.
4. The chlorine atom ($-\text{Cl}$) in *p*-chlorophenyl acts as an electron-withdrawing group via its strong negative inductive effect ($-I$), deactivating the ring and making its migratory aptitude lower than that of a standard phenyl ring. This gives the sequence: *p*-Anisyl > *p*-Tolyl > Phenyl > *p*-Chlorophenyl.

Final Answer: $p\text{-Anisyl} > p\text{-Tolyl} > \text{Phenyl} > p\text{-Chlorophenyl}$

Answer: (A)

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Q3.

Solution**Concept:**

The reaction sequence describes the classic Kiliani-Fischer synthesis, a chain-elongation strategy used to extend the carbon backbone of an aldose sugar by one carbon atom. Nucleophilic addition of hydrogen cyanide (HCN) to the C-1 carbonyl group of D-glucose introduces a new asymmetric chiral center at the new C-2 carbon position while generating two epimeric cyanohydrin intermediates.

Solution:

1. Nucleophilic attack of CN^- on the trigonal planar sp^2 carbonyl carbon of D-glucose takes place non-stereospecifically from both the re and si faces.
2. This produces an unequal mixture of two diastereomeric cyanohydrins that differ in configuration exclusively at the newly established C-2 stereocenter.
3. Subsequent mild aqueous acidic hydrolysis converts the nitrile functionalities ($-\text{CN}$) into carboxylic acid groups ($-\text{COOH}$), which easily lactonize.
4. Final reduction of these lactones using sodium-mercury amalgam (Na-Hg) at a regulated pH yields two final aldoheptoses. Because they differ in stereochemistry only at the C-2 carbon atom, they form a pair of C-2 epimers.

Final Answer: They form a pair of non-enantiomeric diastereomers (Epimers at C-2).

Answer: (A)

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Q4.

Solution**Concept:**

The Chichibabin reaction is a classic nucleophilic aromatic substitution ($S_{\text{N}}\text{Ar}$) pathway where an amino group ($-\text{NH}_2$) is directly introduced into the electron-deficient ortho (C-2) or para (C-4) position of a pyridine ring. Because aromaticity is broken during the early stage of the reaction, the initial nucleophilic addition step to form a Meisenheimer-like σ -complex is rapid, whereas the subsequent step involving the loss of a highly unstable hydride leaving group is slow and rate-determining.

Solution:

1. The amide ion (NH_2^-) attacks the highly electron-deficient C-2 or C-4 position of the pyridine ring to produce a negatively charged anionic σ -complex intermediate.
2. The elimination of the hydride ion (H^-) from this non-aromatic intermediate breaks a strong carbon-hydrogen bond and requires a high activation energy, making it the rate-determining step (RDS) of the process.
3. The eliminated hydride ion instantly reacts with the acidic proton of the newly introduced amino group or the solvent medium to generate hydrogen gas (H_2) and a sodium salt.
4. Thus, the elimination of the hydride ion (H^-) is the slow rate-determining step, and the primary true leaving group leaving the organic skeleton is H^- .

Final Answer: Elimination of the hydride ion (H^-); leaving group is NH_2^-

Answer: (B)

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Q5.

Solution**Concept:**

A bimolecular E2 elimination reaction occurs via a single, concerted mechanism without forming any true chemical intermediates. The potential energy profile diagram features a single activation barrier where the maximum potential energy point corresponds to a single transition state configuration. For optimal orbital overlap between the breaking C-H and C-Br σ -bonds, a strict anti-coplanar alignment of the leaving groups is required.

Solution:

1. The potential energy coordinate diagram shows a simple single-step transformation directly connecting reactants to products.
2. Point X is located at the absolute peak of the potential energy curve, which uniquely characterizes it as a transition state rather than a stable chemical intermediate.
3. During the E2 elimination of 2-bromobutane, the base abstracts a proton at the same time that the bromide leaving group departs.
4. This concerted structural rearrangement passes through an anti-coplanar activated transition state to minimize steric and electronic repulsion, which corresponds to point X.

Final Answer: Anti-coplanar Activated Transition State

Answer: (B)

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Q6.

Solution**Concept:**

Treating a halohydrin with a strong base like sodium hydride (NaH) deprotonates the hydroxyl group ($-\text{OH}$) to form a nucleophilic alkoxide intermediate. This intermediate undergoes a rapid intramolecular $\text{S}_{\text{N}}2$ substitution reaction, where the alkoxide oxygen attacks the adjacent carbon bearing the bromide leaving group. This backside attack results in a complete inversion of stereochemical configuration at the carbon being attacked.

Solution:

1. The starting material is (2*R*, 3*S*)-3-bromobutan-2-ol. Reacting it with NaH converts the C₂ hydroxyl group into a nucleophilic alkoxide ion ($-\text{O}^-$), preserving its initial (2*R*) configuration.
2. This intramolecular alkoxide nucleophile then performs a backside attack on the adjacent C₃ carbon atom, displacing the bromide ion.
3. The $\text{S}_{\text{N}}2$ displacement causes a complete inversion of stereochemistry at the C₃ carbon center, converting it from the (3*S*) configuration into a (3*R*) configuration.
4. The resulting cyclic ether (oxirane) possesses a (2*R*, 3*R*) absolute stereochemical configuration, forming (2*R*, 3*R*)-2,3-epoxybutane.

Final Answer: (2*R*, 3*R*)-2,3-epoxybutane

Answer: (A)

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Q7.

Solution**Concept:**

The Kjeldahl method determines nitrogen content by digesting organic compounds with concentrated sulfuric acid (H_2SO_4) to convert organic nitrogen into ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$. However, this method fails for compounds containing nitrogen atoms in oxidation states or structural environments that cannot be reduced to ammonium ions under standard digesting conditions, such as nitro groups, azo groups, or ring nitrogen atoms in pyridine and quinoline nuclei.

Solution:

1. Primary aliphatic amines, secondary amides, and quaternary ammonium salts easily decompose during hot acid digestion to release their nitrogen content as ammonium ions.
2. In contrast, a nitro group ($-\text{NO}_2$) integrated directly into an electron-deficient aromatic network like a pyridine ring is highly resistant to standard oxidative acid digestion.
3. Without a specialized preliminary reduction step, the nitrogen atoms in these functional groups are lost as volatile nitrogen oxides or remain unreacted in the ring structure.
4. This results in an incomplete conversion, giving an abnormally low or near-zero recovery of nitrogen during the analytical titration phase.

Final Answer: Nitro group integrated into a pyridine nucleus

Answer: (C)

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Q8.

Solution**Concept:**

Mutarotation is the spontaneous change in the equilibrium value of optical rotation observed when a pure anomer of a reducing sugar is dissolved in water. This process occurs via a reversible equilibrium between the cyclic α and β anomeric hemiacetals through a trace amount of the open-chain form.

Solution:

1. D-maltose is a reducing disaccharide that contains a free, hemiacetal group at its terminal reducing glucose unit.
2. When a crystalline sample of pure D-maltose is dissolved in an aqueous medium, the cyclic hemiacetal ring spontaneously opens into its open-chain form.
3. The open-chain intermediate then re-cyclizes with equal probability to form either the α -anomer or the β -anomer.
4. This continuous interconversion alters the optical rotation of the solution until a stable thermodynamic equilibrium mixture of both anomers is established.

Final Answer: Mutarotation involving ring opening and closure of the hemiacetal

Answer: (B)

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Q9.

Solution**Concept:**

The thermal elimination of organic esters containing a β -hydrogen atom occurs via a concerted, unimolecular cyclic elimination (E_i) pathway. This pyrolysis proceeds through a highly ordered, six-membered cyclic transition state requiring a syn-coplanar alignment of the breaking bonds, producing an alkene and a carboxylic acid without needing an external base or catalyst.

Solution:

1. Ethyl acetate ($\text{CH}_3\text{COOCH}_2\text{CH}_3$) contains an ester group with an ethyl chain that possesses accessible β -hydrogen atoms on its terminal methyl group.
2. Under gas-phase pyrolysis conditions, the carbonyl oxygen atom acts as an internal base, forming a hydrogen bond with one of these β -hydrogen atoms.
3. A simultaneous, concerted shifting of electron pairs takes place within a single six-membered cyclic transition state framework.
4. This cyclic redistribution of electrons cleaves the C-O ester bond, yielding ethene gas ($\text{CH}_2 = \text{CH}_2$) and acetic acid (CH_3COOH) at exit valve point P.

Final Answer: Ethene and Acetic Acid

Answer: (B)

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Q10.

Solution**Concept:**

Heating an acid anhydride with an activated aromatic compound like phenol in the presence of a strong dehydrating acid catalyst induces an electrophilic aromatic substitution cascade. Concentrated sulfuric acid (H_2SO_4) protonates the anhydride to generate a powerful electrophilic acylium intermediate, which is then attacked by the electron-rich para positions of the phenol molecules.

Solution:

1. Reacting one mole of phthalic anhydride with concentrated sulfuric acid activates one of its carbonyl carbons, forming an electrophilic center.
2. One mole of phenol acts as a nucleophile, attacking this activated center at its para position to produce an intermediate orthocarbonyl benzophenone derivative.
3. The second carbonyl group of the phthalic framework is then protonated, forming a new electrophilic center that is attacked by a second mole of phenol at its para position.
4. Subsequent dehydration and loss of a water molecule cyclizes the structure, yielding phenolphthalein, a common acid-base indicator.

Final Answer: Phenolphthalein indicator

Answer: (B)

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Q11.

Solution**Concept:**

The Hoffmann bromamide degradation reaction converts a primary amide into a primary amine with one fewer carbon atom. The mechanism involves base-mediated bromination to form an *N*-bromoamide, followed by alpha-elimination of a proton and a bromide ion to generate a highly reactive electron-deficient acyl nitrene intermediate. This nitrene intermediate then undergoes a 1,2-alkyl or 1,2-aryl shift.

Solution:

1. The primary amide ($R\text{-CONH}_2$) is deprotonated and chlorinated/brominated by Br_2 in a basic environment (NaOH) to form a stable *N*-bromoamide intermediate ($R\text{-CONHBr}$).
2. Further abstraction of the remaining acidic proton on the nitrogen atom by OH^- forms an unstable anionic species.
3. The loss of the bromide leaving group (Br^-) creates a neutral, highly reactive nitrogen intermediate known as an acyl nitrene ($R\text{-CO-N:}$).
4. This acyl nitrene intermediate instantly undergoes a 1,2-alkyl or 1,2-aryl skeletal shift, where the R group migrates to the nitrogen atom to produce an alkyl isocyanate ($R\text{-N=C=O}$), which is subsequently hydrolyzed to the primary amine.

Final Answer: Acyl nitrene

Answer: (B)

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Q12.

Solution**Concept:**

The regioselectivity of epoxide ring-opening reactions is highly dependent on the pH of the reaction medium. Under strongly acidic conditions, initial protonation of the epoxide oxygen atom creates a highly activated oxonium ion. This electron-withdrawing oxygen polarizes the adjacent carbon-oxygen bonds, developing a significant partial positive charge (δ^+) on the ring carbons.

Solution:

1. In an asymmetrical epoxide like propylene oxide, the more substituted secondary carbon can stabilize a positive charge much better than the less substituted primary carbon due to inductive and hyperconjugative effects.
2. As a result, the bond between the oxygen atom and the more substituted carbon becomes significantly weaker and longer, giving that carbon strong carbocation-like character.
3. The weak nucleophile (Nu^-) then preferentially attacks this more substituted, carbon center via Pathway α , despite the greater steric hindrance at that site.
4. This mechanism combines elements of both $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ pathways, where regioselectivity is determined by electronic stabilization of the transition state rather than steric accessibility.

Final Answer:

Pathway α , because the nucleophile attacks the more substituted carbon which possesses greater carbocation-like character.

Answer: (A)

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Q13.

Solution**Concept:**

An organic compound with the molecular formula $C_5H_{10}O$ has one degree of unsaturation. The formation of a crystalline orange precipitate with 2,4-dinitrophenylhydrazine (2,4-DNP) confirms the presence of a carbonyl functional group ($C=O$). The negative Fehling's test rules out an aldehyde, identifying the compound as a ketone. A negative iodoform test (no yellow precipitate with $I_2/NaOH$) indicates the absence of a methyl ketone (CH_3CO-) group.

Solution:

1. The formula $C_5H_{10}O$ and a positive 2,4-DNP test narrow the possibilities down to acyclic aliphatic ketones or aldehydes containing five carbon atoms.
2. Since it fails to reduce Fehling's solution, it cannot be an aldehyde like pentanal or 2-methylbutanal. This leaves only pentan-2-one and pentan-3-one as possible structures.
3. Methyl ketones, such as pentan-2-one ($CH_3COCH_2CH_2CH_3$), react with $I_2/NaOH$ to form a yellow precipitate of iodoform (CHI_3).
4. Because the compound gives a completely negative haloform test, it cannot be pentan-2-one. Therefore, the compound must be the symmetrical ketone pentan-3-one ($CH_3CH_2COCH_2CH_3$).

Final Answer: **Answer:** (B)[Go Back to Question 13](#)

Q14.

Solution**Concept:**

This problem maps out a classic multi-step synthetic sequence used to functionalize aromatic rings via diazonium salts. Electrophilic aromatic nitration of benzene yields nitrobenzene, which can then be reduced to a primary aromatic amine. Treating this primary aromatic amine with nitrous acid at low temperatures ($0^\circ C - 5^\circ C$) converts it into a stable arenediazonium salt.

Solution:

1. Reacting Benzene with a nitrating mixture of concentrated nitric acid and sulfuric acid (HNO_3/H_2SO_4) introduces a nitro group, producing Nitrobenzene as intermediate **X**.
2. Reducing Nitrobenzene (**X**) with iron powder and hydrochloric acid (Fe/HCl) converts the nitro group ($-NO_2$) into an amino group ($-NH_2$), yielding Aniline as intermediate **Y**.
3. Treating Aniline (**Y**) with sodium nitrite and hydrochloric acid ($NaNO_2/HCl$) at an ice-cold temperature of $0^\circ C$ generates nitrous acid (HNO_2) in situ.
4. Nitrous acid reacts with aniline via a diazotization sequence to yield benzenediazonium chloride ($C_6H_5N_2^+Cl^-$) as the stable final compound **Z**.

Final Answer: **Answer:** (C)[Go Back to Question 14](#)

Q15.

Solution**Concept:**

This electrochemical setup represents a standard hydrogen concentration cell. The cell potential (E_{cell}) at 298 K is calculated using the Nernst equation:

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log Q$$

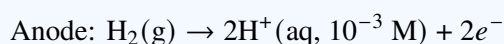
For an identical concentration cell, the standard electromotive force (E_{cell}°) is exactly 0 V. The overall cell reaction simplifies to the transfer of hydrogen ions from the higher concentration side (cathode) to the lower concentration side (anode).

Solution:

1. Determine the hydrogen ion concentration, $[\text{H}^+]_{\text{anode}}$, in the weak acid compartment. For the monobasic acid HA:

$$K_a = \frac{[\text{H}^+]^2}{C} \implies [\text{H}^+] = \sqrt{K_a \cdot C} = \sqrt{(1.0 \times 10^{-5}) \times 0.1} = \sqrt{1.0 \times 10^{-6}} = 1.0 \times 10^{-3} \text{ M}$$

2. Write the half-reactions and the net cell reaction:



3. Apply the Nernst equation with $n = 2$ electrons transferred:

$$E_{\text{cell}} = 0 - \frac{0.0591}{2} \log \frac{[\text{H}^+]_{\text{anode}}^2}{[\text{H}^+]_{\text{cathode}}^2} = -0.0591 \log \frac{10^{-3}}{1} = -0.0591 \times (-3) = +0.177 \text{ V}$$

Final Answer: +0.177 V

Answer: (A)

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Q16.

Solution**Concept:**

For a reaction following second-order kinetics, the rate law is given by $-d[A]/dt = k[A]^2$. Integrating this differential rate law gives the relationship between concentration and time. The half-life period ($t_{1/2}$) for a second-order reaction is inversely proportional to the initial reactant concentration ($[A]_0$), expressed by the formula:

$$t_{1/2} = \frac{1}{k[A]_0}$$

Solution:

1. Let the initial concentration increase from $[A]_1 = 0.20$ M to $[A]_2 = 0.80$ M.
2. Write the ratio of the two half-lives using their inverse proportionality to initial concentration:

$$\frac{t_{1/2}^{(2)}}{t_{1/2}^{(1)}} = \frac{[A]_1}{[A]_2}$$

3. Substitute the given concentrations into the ratio:

$$\frac{t_{1/2}^{(2)}}{t_{1/2}^{(1)}} = \frac{0.20}{0.80} = \frac{1}{4}$$

4. This shows that increasing the initial concentration by a factor of 4 causes the half-life value to decrease to exactly one-quarter ($1/4$) of its original value.

Final Answer: It decreases to exactly one-quarter ($1/4$) of its original value.

Answer: (B)

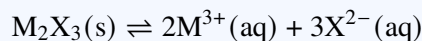
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Q17.

Solution**Concept:**

A sparingly soluble salt with the empirical formula M_2X_3 dissociates in an aqueous solution to establish a heterogeneous equilibrium between its solid phase and its constituent ions:



If S represents the molar solubility of the salt in mol L^{-1} , the equilibrium concentrations of the ions are $[M^{3+}] = 2S$ and $[X^{2-}] = 3S$.

Solution:

1. Write the expression for the solubility product constant (K_{sp}) based on the stoichiometry of the dissociation:

$$K_{sp} = [M^{3+}]^2[X^{2-}]^3 = (2S)^2(3S)^3 = (4S^2) \times (27S^3) = 108S^5$$

2. Set this expression equal to the given experimental value of K_{sp} :

$$108S^5 = 1.08 \times 10^{-23} \implies S^5 = \frac{1.08 \times 10^{-23}}{108} = 1.0 \times 10^{-25}$$

3. Solve for the molar solubility S by taking the fifth root of both sides:

$$S = (1.0 \times 10^{-25})^{1/5} = 1.0 \times 10^{-5} \text{ mol L}^{-1}$$

Final Answer: $1.0 \times 10^{-5} \text{ mol L}^{-1}$

Answer: (A)

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Q18.

Solution**Concept:**

According to Raoult's law, the partial vapor pressure of each volatile component in an ideal binary liquid solution is directly proportional to its mole fraction in the liquid phase. The total vapor pressure (P_{total}) exerted by the solution is the sum of the partial vapor pressures of the individual components:

$$P_{\text{total}} = P_A + P_B = P_A^\circ X_A + P_B^\circ X_B$$

Solution:

1. Start with the fundamental expression for Raoult's law:

$$P_{\text{total}} = P_A^\circ X_A + P_B^\circ X_B$$

2. Use the mathematical relationship for a binary solution where the sum of the mole fractions equals one ($X_A + X_B = 1 \implies X_A = 1 - X_B$).

3. Substitute $(1 - X_B)$ for X_A in the total pressure equation:

$$P_{\text{total}} = P_A^\circ (1 - X_B) + P_B^\circ X_B$$

4. Expand and rearrange the terms to solve for total pressure as a function of X_B :

$$P_{\text{total}} = P_A^\circ - P_A^\circ X_B + P_B^\circ X_B = P_A^\circ + (P_B^\circ - P_A^\circ) X_B$$

This linear equation matches the line plotted in the vapor pressure diagram, defining the value at state point M.

Final Answer: $P_{\text{total}} = P_A^\circ + (P_B^\circ - P_A^\circ) X_B$

Answer: (A)

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Q19.

Solution**Concept:**

The thermodynamic equilibrium constant expressed in partial pressures (K_p) is an intrinsic property of a chemical reaction system. It depends exclusively on the absolute temperature, as defined by the van 't Hoff equation:

$$\frac{d \ln K_p}{dT} = \frac{\Delta H^\circ}{RT^2}$$

Changes in system parameters such as volume, total pressure, or reactant concentrations alter the reaction quotient (Q_p), causing a temporary shift in the equilibrium position according to Le Chatelier's principle, but they do not change the value of K_p .

Solution:

1. The chemical system undergoes a volume reduction that doubles the total pressure at a constant temperature.
2. Reducing the volume shifts the equilibrium position toward the products (the side with fewer moles of gas) to relieve the pressure increase.
3. This shift changes the equilibrium concentrations and partial pressures of N_2 , H_2 , and NH_3 .
4. However, because the temperature remains perfectly constant throughout the process, the ratio of partial pressures at the new equilibrium adjusts to maintain the same value, leaving K_p completely unchanged.

Final Answer: K_p remains completely unchanged.

Answer: (C)

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Q20.

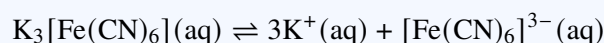
Solution**Concept:**

The van 't Hoff factor (i) measures the effect of solute dissociation or association on colligative properties. For a strong or weak electrolyte that dissociates into n constituent ions, the relationship between the apparent degree of dissociation (α) and the van 't Hoff factor is:

$$i = 1 + (n - 1)\alpha$$

Solution:

1. Identify the dissociation pattern of the coordination complex $K_3[Fe(CN)_6]$ in an aqueous medium:



2. Count the total number of particles (n) produced per formula unit upon complete dissociation:

$$n = 3 + 1 = 4 \text{ ions}$$

3. Substitute the number of ions ($n = 4$) and the given apparent degree of dissociation ($\alpha = 0.80$) into the formula:

$$i = 1 + (4 - 1) \times 0.80$$

4. Complete the calculation to find the effective van 't Hoff factor:

$$i = 1 + 3 \times 0.80 = 1 + 2.40 = 3.40$$

Final Answer:

Answer: (A)

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Q21.

Solution**Concept:**

The slopes of thermodynamic expansion pathways on a P - V coordinate diagram are determined by differentiating the respective governing equations. For an ideal gas, an isothermal process follows Boyle's law ($PV = \text{constant}$), while a reversible adiabatic process follows Poisson's relation ($PV^\gamma = \text{constant}$).

Solution:

1. Differentiating the isothermal ideal gas expression $PV = C$ yields:

$$\left(\frac{\partial P}{\partial V}\right)_{\text{isothermal}} = -\frac{P}{V}$$

2. Differentiating the adiabatic relation $PV^\gamma = C$ using the chain rule yields:

$$V^\gamma dP + \gamma PV^{\gamma-1} dV = 0 \implies \left(\frac{\partial P}{\partial V}\right)_{\text{adiabatic}} = -\gamma \frac{P}{V}$$

3. Combine these two derivatives to find the relationship between the slopes:

$$\left(\frac{\partial P}{\partial V}\right)_{\text{adiabatic}} = \gamma \left(\frac{\partial P}{\partial V}\right)_{\text{isothermal}}$$

4. Since the heat capacity ratio $\gamma = C_p/C_v$ is always greater than 1 for any gas, the adiabatic slope is steeper by a factor of γ . This occurs because temperature drops during an adiabatic expansion, causing a larger pressure decrease than in an isothermal expansion.

Final Answer: $(\partial P/\partial V)_{\text{adiabatic}} = \gamma(\partial P/\partial V)_{\text{isothermal}}$, where $\gamma > 1$.

Answer: (B)

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Q22.

Solution**Concept:**

A solution containing a weak base (NH_4OH) and its salt with a strong acid (NH_4Cl) forms a basic buffer system. The hydroxide ion concentration and pOH are calculated using the Henderson-Hasselbalch equation:

$$\text{pOH} = \text{p}K_b + \log \frac{[\text{Salt}]}{[\text{Base}]}$$

Solution:

1. Calculate the initial pOH of the buffer system before adding any acid:

$$\text{pOH}_{\text{initial}} = -\log(1.8 \times 10^{-5}) + \log \frac{0.1}{0.1} = 4.74 + 0 = 4.74 \implies \text{pH}_{\text{initial}} = 14 - 4.74 = 9.26$$

2. Adding 0.01 mol of HCl gas neutralizes 0.01 mol of the weak base NH_4OH and produces an equivalent 0.01 mol of the salt NH_4Cl :

$$[\text{Base}]_{\text{new}} = 0.10 - 0.01 = 0.09 \text{ M}$$

$$[\text{Salt}]_{\text{new}} = 0.10 + 0.01 = 0.11 \text{ M}$$

3. Calculate the new pOH of the solution:

$$\text{pOH}_{\text{new}} = 4.74 + \log \frac{0.11}{0.09} = 4.74 + \log(1.222) = 4.74 + 0.087 = 4.827$$

$$\text{pH}_{\text{new}} = 14 - 4.827 = 9.173$$

4. Determine the change in pH (ΔpH):

$$\Delta\text{pH} = \text{pH}_{\text{new}} - \text{pH}_{\text{initial}} = 9.173 - 9.260 = -0.087 \approx -0.09 \text{ units}$$

Final Answer: The pH decreases by a small value of approximately 0.09 units.

Answer: (B)

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Q23.

Solution**Concept:**

Avogadro's law states that one mole of any ideal gas contains exactly Avogadro's number ($N_A = 6.022 \times 10^{23}$) of constituent molecules. At standard temperature and pressure parameters (STP), one mole of an ideal gas occupies a fixed molar volume of exactly 22.4 Liters.

Solution:

1. Determine the number of moles (n) of the ideal gas present in the sample:

$$n = \frac{\text{Number of molecules}}{N_A} = \frac{6.022 \times 10^{22}}{6.022 \times 10^{23}} = 0.10 \text{ mole}$$

2. Calculate the total volumetric space occupied by this sample at STP by multiplying the number of moles by the molar volume:

$$V = n \times V_{\text{molar}} = 0.10 \text{ mole} \times 22.4 \text{ L mole}^{-1} = 2.24 \text{ Liters}$$

Final Answer:

Answer: (B)

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Q24.

Solution**Concept:**

The temperature dependence of chemical reaction rate constants is quantified by the Arrhenius equation:

$$k = Ae^{-\frac{E_a}{RT}}$$

Taking the natural logarithm of both sides converts this exponential relationship into a linear equation:

$$\ln k = \ln A - \left(\frac{E_a}{R}\right) \frac{1}{T}$$

Solution:

1. Compare the logarithmic Arrhenius equation to the standard equation for a straight line ($y = mx + c$):

$$y = \ln k, \quad x = \frac{1}{T}, \quad c = \ln A$$

2. The slope (m) of this linear plot is equal to the coefficient of the independent variable $1/T$:

$$\text{Slope} = -m = -\frac{E_a}{R}$$

3. Rearrange this expression to solve for the activation energy (E_a):

$$E_a = m \times R$$

This shows that the activation energy is the product of the magnitude of the slope (m) and the universal gas constant (R).

Final Answer: $E_a = m \times R$

Answer: (B)

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Q25.

Solution**Concept:**

The electrode potential of a half-cell under non-standard conditions is calculated using the Nernst equation. For the copper reduction half-cell ($\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}$), the reduction potential is:

$$E_{\text{red}} = E_{\text{red}}^{\circ} - \frac{0.0591}{2} \log \frac{1}{[\text{Cu}^{2+}]}$$

The oxidation potential (E_{ox}) is the negative of the reduction potential ($E_{\text{ox}} = -E_{\text{red}}$).

Solution:

1. Write the Nernst equation directly for the oxidation half-reaction ($\text{Cu(s)} \rightarrow \text{Cu}^{2+}(\text{aq}) + 2e^-$):

$$E_{\text{ox}} = E_{\text{ox}}^{\circ} - \frac{0.0591}{2} \log [\text{Cu}^{2+}]$$

2. Let the initial concentration of copper ions be C . Diluting the solution by 100 times reduces the concentration to $C/100$.

3. Calculate the new oxidation potential (E'_{ox}) after this dilution:

$$E'_{\text{ox}} = E_{\text{ox}}^{\circ} - \frac{0.0591}{2} \log \left(\frac{C}{100} \right) = E_{\text{ox}}^{\circ} - \frac{0.0591}{2} (\log C - \log 100)$$

4. Simplify the expression using $\log 100 = 2$:

$$E'_{\text{ox}} = \left(E_{\text{ox}}^{\circ} - \frac{0.0591}{2} \log C \right) + \frac{0.0591}{2} \times 2 = E_{\text{ox}} + 0.0591 \text{ V}$$

This shows that the oxidation potential increases by exactly 0.0591 V.

Final Answer: It increases by 0.059 V.

Answer: (A)

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Q26.

Solution**Concept:**

The Langmuir adsorption isotherm models gas adsorption onto a surface by assuming a finite number of identical, distinct adsorption sites. The mathematical expression relating the extent of adsorption (x/m) to the equilibrium gas pressure (P) is:

$$\frac{x}{m} = \frac{aP}{1 + bP}$$

where a and b are empirical Langmuir constants.

Solution:

1. Analyze the behavior of the Langmuir expression under high equilibrium pressures ($P \rightarrow \infty$).
2. When the pressure is very high, the term bP in the denominator becomes much larger than 1 ($bP \gg 1$).
3. Simplify the denominator by approximating $(1 + bP)$ as simply bP :

$$\frac{x}{m} \approx \frac{aP}{bP} = \frac{a}{b} = \text{constant}$$

4. Because the extent of adsorption reaches a fixed maximum capacity where all surface sites are fully occupied, it becomes independent of any further pressure increases. This zero-order relationship is written as:

$$\frac{x}{m} \propto P^0$$

Final Answer: $x/m \propto P^0$

Answer: (B)

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Q27.

Solution**Concept:**

The fundamental criterion for chemical spontaneity under conditions of constant temperature (T) and pressure (P)—such as a reaction occurring in an open beaker—is determined by the second law of thermodynamics. This criterion is expressed using the Gibbs free energy change (ΔG):

$$\Delta G_{\text{system}} = \Delta H_{\text{system}} - T\Delta S_{\text{system}}$$

Solution:

1. For any spontaneous process occurring in an isolated universe, the total entropy must increase ($\Delta S_{\text{universe}} > 0$).
2. When a process occurs at constant temperature and pressure, the heat exchanged with the surroundings is related to the enthalpy change of the system ($\Delta q_{\text{surr}} = -\Delta H_{\text{system}}$).
3. Substituting this relationship into the entropy inequality establishes a direct criterion using only properties of the system:

$$\Delta S_{\text{universe}} = \Delta S_{\text{system}} - \frac{\Delta H_{\text{system}}}{T} > 0 \implies \Delta H_{\text{system}} - T\Delta S_{\text{system}} < 0$$

4. This inequality defines the change in Gibbs free energy, meaning that $\Delta G_{\text{system}} < 0$ must be strictly fulfilled for any spontaneous process.

Final Answer: $\Delta G_{\text{system}} < 0$

Answer: (C)

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Q28.

Solution**Concept:**

According to Werner's coordination theory, ligands inside the square brackets are part of the primary coordination sphere and are directly bound to the central metal atom. They do not ionize in solution. In contrast, counter-ions outside the coordination brackets balance the charge, satisfy the secondary valence, and readily ionize to form a precipitate when treated with an appropriate reagent like silver nitrate (AgNO_3).

Solution:

1. One mole of the coordination complex $\text{CoCl}_3 \cdot 5\text{NH}_3$ reacts with excess AgNO_3 to immediately precipitate exactly two moles of silver chloride (AgCl) solid.
2. This indicates that exactly two chloride ions (Cl^-) are present outside the coordination sphere as counter-ions, leaving them free to ionize.
3. The remaining components—one cobalt ion, one chloride ion, and five ammonia molecules—must reside inside the primary coordination sphere.
4. Grouping these components gives the chemical formula $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$. Since there are six ligands directly bound to the central cobalt ion (five NH_3 and one Cl), the coordination number is 6.

Final Answer: $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$, Coordination Number = 6

Answer: (A)

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Q29.

Solution**Concept:**

The chemical reducing strength of phosphorus oxoacids is directly determined by the number of direct phosphorus-hydrogen (P-H) bonds in their structures. The hydrogen atoms attached directly to the phosphorus atom are highly reducing, whereas the hydrogen atoms in $-\text{OH}$ groups are acidic and dissociate as protons, playing no role in reducing capacity.

Solution:

1. Examine hypophosphorous acid (H_3PO_2). It features a central phosphorus atom bound to one $-\text{OH}$ group, one terminal oxo oxygen ($=\text{O}$), and two direct P-H covalent bonds.
2. Examine phosphorous acid (H_3PO_3). It has a tetrahedral layout containing two $-\text{OH}$ groups, one terminal oxo oxygen ($=\text{O}$), and only one direct P-H covalent bond.
3. Examine orthophosphoric acid (H_3PO_4). It consists of three $-\text{OH}$ groups and one terminal oxo oxygen ($=\text{O}$), with zero direct P-H covalent bonds.
4. Counting the direct P-H bonds ($2 > 1 > 0$) gives the decreasing order of reducing strength: $\text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_4$.

Final Answer: $\text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_4$

Answer: (A)

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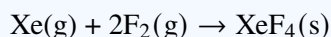
Q30.

Solution**Concept:**

Mixing pure xenon gas (Xe) with fluorine gas (F₂) in a 1 : 5 molar ratio under high temperatures and pressures yields xenon tetrafluoride (XeF₄). The spatial geometry and hybridization of the central atom are determined using Valence Shell Electron Pair Repulsion (VSEPR) theory.

Solution:

1. The chemical reaction under these conditions produces xenon tetrafluoride:



2. Determine the steric number (SN) of the central Xenon atom. Xenon has 8 valence electrons. It forms 4 single σ -bonds with the four fluorine atoms, leaving 4 non-bonding electrons, which form 2 lone pairs:

$$\text{Steric Number} = (\sigma\text{-bonds}) + (\text{lone pairs}) = 4 + 2 = 6$$

3. A steric number of 6 requires an sp^3d^2 hybridization for the central atom, which corresponds to an octahedral electron pair geometry.

4. According to VSEPR theory, the 2 lone pairs position themselves opposite each other to minimize lone pair-lone pair repulsions. This leaves the 4 fluorine atoms at the corners of a flat plane, resulting in a square planar molecular shape.

Final Answer: Square planar, sp^3d^2

Answer: (A)

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Q31.

Solution**Concept:**

An Ellingham diagram plots the standard Gibbs free energy of formation (ΔG°) of oxides against temperature. The intersection point T_x represents the thermal threshold where the two free energy curves cross, meaning the net free energy change ($\Delta G_{\text{net}}^\circ$) for the redox reaction becomes zero. At temperatures above T_x , the curve for the reduction agent's oxidation lies below the metal oxidation curve, making the reduction spontaneous.

Solution:

1. Below T_x , the formation of the metal oxide MO has a more negative ΔG° value than the formation of carbon monoxide (CO), meaning the metal oxide is more stable.
2. At the intersection point T_x , both chemical oxidation curves cross, which means the Gibbs free energy of the reduction reaction balances out to zero ($\Delta G^\circ = 0$).
3. At temperatures slightly above T_x , the carbon oxidation line ($2C + O_2 \rightarrow 2CO$) drops lower down on the plot than the metal oxidation line ($2M + O_2 \rightarrow 2MO$).
4. This makes the reduction of the metal oxide by carbon ($MO + C \rightarrow M + CO$) thermodynamically favorable, meaning carbon can spontaneously reduce the metal oxide MO to its metallic form M.

Final Answer: Carbon can spontaneously reduce the metal oxide MO to its metallic form M.

Answer: (A)

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Q32.

Solution**Concept:**

The spin-only magnetic moment (μ) of a transition metal ion depends on its total number of unpaired electrons (n). This relationship is calculated using the spin-only formula:

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

A measured value of 5.92 B.M. indicates that the central metal ion must contain exactly $n = 5$ unpaired electrons in its outer d -orbital shells.

Solution:

1. Set the spin-only equation equal to the given value: $\sqrt{n(n+2)} = 5.92$. Squaring both sides yields $n(n+2) \approx 35$, which gives $n = 5$.
2. Evaluate Fe^{3+} . Iron has an atomic number of 26 with a ground-state valence configuration of $[A_r]3d^64s^2$. Removing three electrons gives the Fe^{3+} configuration as $[A_r]3d^5$.
3. In an octahedral weak ligand field, the crystal field splitting energy (Δ_o) is small, so electrons fill the orbitals following Hund's rule without pairing up prematurely.
4. This distributes the five d -electrons singly across all energy levels ($t_{2g}^3 e_g^2$), creating exactly 5 unpaired electrons ($n = 5$), which perfectly matches the measured magnetic moment of 5.92 B.M.

Final Answer: Fe^{3+} in an octahedral weak ligand field

Answer: (A)

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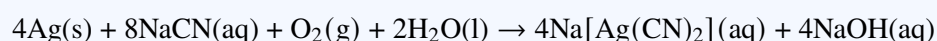
Q33.

Solution**Concept:**

The MacArthur-Forrest cyanide process extracts silver from its ores through hydrometallurgical leaching. Finely crushed silver or silver sulfide ores are treated with a dilute aqueous solution of sodium cyanide (NaCN) under continuous aeration. Atmospheric oxygen acts as an oxidizing agent, driving the silver metal into a stable, water-soluble coordination complex.

Solution:

1. Write out the balanced chemical equation for the oxidation and complexation step, known as Elsner's reaction:



2. The sodium salt dissociates completely in water to release sodium cations (Na^+) and the coordinate complex anions.

3. The central silver atom adopts a stable +1 oxidation state and coordinates with two strong-field cyanide ligands in a linear arrangement.

4. This gives the chemical formula of the resulting water-soluble coordinate complex anion as $[\text{Ag}(\text{CN})_2]^-$.

Final Answer: $[\text{Ag}(\text{CN})_2]^-$

Answer: (B)

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Q34.

Solution**Concept:**

Crystal Field Theory (CFT) explains how the five degenerate atomic d -orbitals split into different energy levels when surrounded by an electrostatic field of ligands. The exact splitting pattern depends on the spatial geometry and orientation of the incoming ligands relative to the lobes of the d -orbitals.

Solution:

1. The provided diagram shows the five d -orbitals splitting into two distinct energy levels separated by a total splitting energy labeled Δ_o .
2. The lower energy level consists of three degenerate orbitals (d_{xy}, d_{yz}, d_{zx}), collectively designated as the t_{2g} set. These orbitals point between the coordinate axes, experiencing less repulsion from ligands arriving along the axes.
3. The higher energy level consists of two degenerate orbitals ($d_{x^2-y^2}, d_{z^2}$), collectively designated as the e_g set. These orbitals point directly along the coordinate axes, experiencing strong electrostatic repulsion.
4. This specific splitting pattern, where the e_g set is raised and the t_{2g} set is lowered relative to the barycenter, is characteristic of an octahedral coordination field.

Final Answer: Octahedral Coordination Field

Answer: (B)

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Q35.

Solution**Concept:**

The paramagnetism of lanthanoid elements is determined by the number of unpaired electrons in their deep-seated $4f$ core orbitals. Ions with a high number of unpaired electrons show strong paramagnetic properties. A half-filled f -orbital subshell ($4f^7$) provides extra stability due to exchange energy and a symmetrical distribution of electron density, making it resistant to further chemical oxidation.

Solution:

1. Evaluate the ground-state electronic configurations of the given choices. Gadolinium (Gd, $Z = 64$) has an electronic configuration of $[\text{Xe}]4f^75d^16s^2$.
2. When gadolinium loses three electrons to form the stable Gd^{3+} trivalent ion, it removes the $6s$ and $5d$ electrons, leaving an outer configuration of $[\text{Xe}]4f^7$.
3. According to Hund's rule, these seven electrons occupy the seven degenerate $4f$ orbitals singly, maximizing the count of unpaired electrons to $n = 7$.
4. This high number of unpaired electrons gives Gd^{3+} a very strong paramagnetic value. The half-filled $4f^7$ configuration is highly stable, resisting further oxidation to a +4 state.

Final Answer: Gd^{3+} **Answer: (B)**[Go Back to Question 35](#)

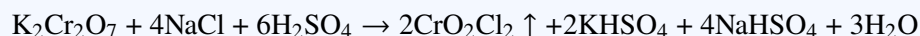
Q36.

Solution**Concept:**

Heating a solid metal chloride salt with potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) grains in the presence of concentrated sulfuric acid (H_2SO_4) is the basis of the chromyl chloride test, which detects the presence of chloride ions in qualitative inorganic analysis.

Solution:

1. Concentrated sulfuric acid reacts with the metal chloride salt to generate hydrogen chloride gas (HCl) in situ.
2. This generated HCl then reacts with the potassium dichromate crystals in the acidic medium.
3. The net inorganic reaction reduces a portion of the system and combines the elements into a volatile, deep-red coordination compound:



4. This reaction produces chromyl chloride (CrO_2Cl_2), which vaporizes easily out of the reaction vessel as deep red, choke-inducing vapors.

Final Answer: CrO_2Cl_2 **Answer: (A)**[Go Back to Question 36](#)

Q37.

Solution**Concept:**

Silicate minerals are structurally classified by how their basic structural units—the SiO_4^{4-} tetrahedra—link together. The general formula for these shared networks can be expressed as $(\text{Si}_2\text{O}_5^{2-})_n$ depending on the number of oxygen atoms shared per silicon center.

Solution:

1. In orthosilicates, the SiO_4^{4-} units are completely isolated, sharing zero oxygen atoms with neighboring tetrahedra.
2. In pyrosilicates, exactly one oxygen atom is shared between two tetrahedral units, forming an $\text{Si}_2\text{O}_7^{6-}$ dimer. In single-chain pyroxenes, each unit shares exactly two of its oxygen atoms to form infinite linear chains.
3. When exactly three oxygen atoms of each tetrahedral unit are shared with adjacent tetrahedra, the units extend infinitely in two dimensions.
4. This creates a continuous two-dimensional layer or sheet-like framework with a repeating empirical unit of $(\text{Si}_2\text{O}_5)_n^{2n-}$. This class of minerals is known as sheet silicates or phyllosilicates.

Final Answer: Sheet Silicates (Phyllosilicates)

Answer: (C)

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Q38.

Solution**Concept:**

Zone refining is a specialized purification technique based on the principle of fractional crystallization. It relies on the fact that when an impure molten metal or metalloid solidifies, the impurities tend to remain more soluble in the liquid melt phase than in the pure crystalline solid phase.

Solution:

1. Semiconductor devices require ultra-pure elemental silicon with impurity levels down to parts-per-billion (ppb) thresholds, which standard metallurgical processes cannot achieve.
2. In zone refining, a circular mobile heater moves slowly along a rod of impure silicon, creating a narrow molten zone that travels with the heater.
3. As the molten zone passes forward, pure silicon crystallizes out at the cooling rear edge, while the impurities concentrate in the moving liquid zone.
4. Repeating this process sweeps the impurities to one end of the rod, which is then cut off, leaving an ultra-pure semiconductor-grade silicon crystal.

Final Answer: Zone Refining

Answer: (C)

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Q39.

Solution**Concept:**

The spatial distribution of electron density in an atomic orbital features regions where the probability of finding an electron drops to zero, known as nodes. The total number of nodes is given by $(n - 1)$. Nodes are divided into two types based on their geometry:

$$\text{Angular Nodes} = l$$

$$\text{Radial Nodes} = n - l - 1$$

Solution:

1. Identify the given quantum numbers for the atomic orbital: the principal quantum number is $n = 4$, and the azimuthal quantum number is $l = 2$ (which corresponds to a $4d$ orbital).
2. Calculate the number of angular nodes directly from the azimuthal quantum number:

$$\text{Angular Nodes} = l = 2$$

3. Calculate the number of radial nodes using the principal and azimuthal quantum numbers:

$$\text{Radial Nodes} = n - l - 1 = 4 - 2 - 1 = 1$$

4. This gives a total configuration of 2 angular nodes and 1 radial node for the orbital.

Final Answer: 2 angular nodes, 1 radial node

Answer: (A)

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Q40.

Solution**Concept:**

Molecular Orbital Theory (MOT) determines the bond order and relative stability of homonuclear diatomic molecules by filling molecular orbitals in order of increasing energy. The bond order formula is:

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

where N_b is the number of bonding electrons and N_a is the number of antibonding electrons. Higher bond orders indicate stronger chemical bonds and greater stability.

Solution:

1. For O_2 (16 electrons), the molecular orbital configuration is:

$$\sigma_{1s}^2 \sigma_{1s}^{*2} \sigma_{2s}^2 \sigma_{2s}^{*2} \sigma_{2z}^2 \pi_{2x}^2 \pi_{2y}^2 \pi_{2x}^{*1} \pi_{2y}^{*1} \implies \text{Bond Order} = \frac{10 - 6}{2} = 2.0$$

2. For the oxygen cation O_2^+ (15 electrons), one electron is removed from an antibonding orbital (π_{2x}^*), which increases its stability:

$$\text{Bond Order} = \frac{10 - 5}{2} = 2.5$$

3. For the superoxide anion O_2^- (17 electrons), an extra electron is added to an antibonding orbital, which decreases its stability:

$$\text{Bond Order} = \frac{10 - 7}{2} = 1.5$$

4. Arranging these species in increasing order of bond order and stability gives: $O_2^-(1.5) < O_2(2.0) < O_2^+(2.5)$.

Final Answer: $O_2^- < O_2 < O_2^+$

Answer: (A)

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Q41.

Solution**Concept:**

The Valence Shell Electron Pair Repulsion (VSEPR) model predicts molecular geometry based on minimizing electrostatic repulsions between electron pairs around a central atom. The overall shape is determined by the total number of bonding links (σ -bonds) and non-bonding lone pairs localized on the central atom.

Solution:

1. In a chlorine trifluoride (ClF_3) molecule, chlorine is the central halogen atom, contributing 7 valence electrons.
2. The central chlorine atom forms 3 covalent σ -bonds with three fluorine atoms, using 3 valence electrons. This leaves 4 unshared valence electrons, which form 2 non-bonding lone pairs.
3. The steric number (SN) is the sum of bonding pairs and lone pairs: $\text{SN} = 3 + 2 = 5$. This requires a trigonal bipyramidal electron-pair geometry.
4. To minimize strong lone pair-lone pair repulsions, the 2 lone pairs occupy less crowded equatorial positions at 120° angles, forcing the 3 bonding fluorine atoms into axial and remaining equatorial sites. This distorts the structure into a T-shaped molecular geometry.

Final Answer: T-shaped geometry, 2 lone pairs

Answer: (B)

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Q42.

Solution**Concept:**

The radial probability distribution function ($4\pi r^2 R^2$) represents the probability of finding an electron within a thin spherical shell of radius r centered at the nucleus. Points where the curve drops to zero between peaks are radial nodes, which are calculated using the quantum number relationship:

$$\text{Radial Nodes} = n - l - 1$$

Solution:

1. Examine the provided radial probability distribution graph. The curve starts at the origin ($r = 0$), rises to a small peak, drops to zero at a single point on the axis, and then rises to a larger primary peak before decaying.
2. Count the number of radial nodes shown in the graph. The single point where the curve touches the horizontal axis between peaks indicates exactly 1 radial node.
3. Test the given choices using the radial node formula:

$$\text{For } 1s: n = 1, l = 0 \implies \text{Nodes} = 1 - 0 - 1 = 0$$

$$\text{For } 2s: n = 2, l = 0 \implies \text{Nodes} = 2 - 0 - 1 = 1$$

$$\text{For } 2p: n = 2, l = 1 \implies \text{Nodes} = 2 - 1 - 1 = 0$$

4. Because the 2s orbital has exactly 1 radial node, its radial probability distribution curve matches the plotted profile.

Final Answer: 2s orbital**Answer: (B)**[Go Back to Question 42](#)

Q43.

Solution**Concept:**

The wavelength (λ) of light emitted or absorbed during electronic transitions in a hydrogen atom is calculated using the Rydberg formula:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

where R_H is the Rydberg constant, n_1 is the lower principal energy level, and n_2 is the higher principal energy level.

Solution:

1. Identify the initial and final energy levels from the problem: the electron falls from $n_2 = 4$ down to the ground state level $n_1 = 1$.
2. Substitute these integer values into the Rydberg equation:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{1^2} - \frac{1}{4^2} \right) = R_H \left(1 - \frac{1}{16} \right)$$

3. Simplify the terms inside the parentheses:

$$\frac{1}{\lambda} = R_H \left(\frac{15}{16} \right)$$

4. Invert the equation to solve for the emission wavelength λ :

$$\lambda = \frac{16}{15R_H}$$

Final Answer: $\lambda = \frac{16}{15R_H}$

Answer: (A)

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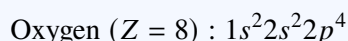
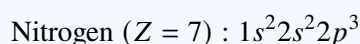
Q44.

Solution**Concept:**

Ionization enthalpy generally increases across a period from left to right due to an increase in effective nuclear charge and a decrease in atomic radius. However, anomalous drops can occur when comparing adjacent elements if one possesses an exceptionally stable electronic configuration, such as a completely filled or half-filled valence subshell.

Solution:

1. Write the ground-state valence electronic configurations for Nitrogen and Oxygen:



2. Nitrogen's $2p$ subshell contains exactly three electrons ($2p_x^1 2p_y^1 2p_z^1$), making it a half-filled configuration. This configuration provides extra stability due to a symmetrical electron distribution and high exchange energy.
3. In contrast, oxygen has four electrons in its $2p$ subshell, meaning one orbital contains a paired set of electrons ($2p_x^2 2p_y^1 2p_z^1$). The electrostatic repulsion between these two electrons in the same orbital makes it easier to remove one.
4. As a result, removing an electron from nitrogen requires more energy, giving it a higher first ionization enthalpy value than oxygen.

Final Answer:

Nitrogen has a higher value because of the extra stability associated with its half-filled $2p^3$ electronic shell configuration.

Answer: (B)[Go Back to Question 44](#)

Q45.

Solution**Concept:**

Hybridization involves the linear combination of atomic orbitals of similar energies on a central atom to form a set of equivalent hybrid orbitals. The specific atomic orbitals chosen dictate the directional properties and spatial orientation of the resulting hybrid lobes.

Solution:

1. Analyze the provided diagram, which shows two perpendicular hybrid orbital lobes oriented along the x and y coordinate axes in a single two-dimensional plane.
2. Evaluate the orbital components required for different hybrid sets: sp^3d^2 and dsp^2 hybrid sets both require contributions from d -orbitals (specifically $d_{x^2-y^2}$), while sp^3d requires the d_z^2 orbital to form its geometry.
3. The sp^2 hybrid set is formed by combining one atomic s orbital with two atomic p orbitals (typically p_x and p_y) within a single two-dimensional plane.
4. Because the sp^2 hybrid configuration contains no d -orbital components, it has zero contribution from the atomic d_z^2 or $d_{x^2-y^2}$ orbitals.

Final Answer: sp^2 **Answer: (C)**[Go Back to Question 45](#)

Q46.

Solution**Concept:**

The net dipole moment (μ) of a polyatomic molecule is the vector sum of its individual bond dipoles. A molecule will possess a permanent, non-zero dipole moment ($\mu \neq 0$) if its spatial geometry is asymmetrical, preventing the individual polar bond dipoles from canceling each other out.

Solution:

1. In XeF_4 , the central atom has a square planar geometry with two lone pairs positioned opposite each other. The four symmetric Xe-F bond dipoles cancel out completely, giving a net dipole moment of zero ($\mu = 0$).
2. In BF_3 , the three polar B-F bonds are arranged symmetrically in a trigonal planar geometry, so their vector sum cancels out completely ($\mu = 0$). In CCl_4 , the four C-Cl bonds cancel in a symmetric tetrahedral geometry ($\mu = 0$).
3. In SF_4 , sulfur has 6 valence electrons and forms 4 bonds with fluorine, leaving 1 non-bonding lone pair. This gives a steric number of 5, which results in a see-saw molecular geometry based on a trigonal bipyramid.
4. Because the lone pair occupies an equatorial position, it distorts the symmetry of the molecule, preventing the individual polar S-F bond dipoles from canceling out and resulting in a permanent, non-zero dipole moment ($\mu \neq 0$).

Final Answer: SF_4 **Answer:** (C)[Go Back to Question 46](#)

Q47.

Solution**Concept:**

Green Chemistry focuses on designing chemical products and processes that reduce or eliminate the use and generation of hazardous substances. Advanced Photocatalytic Oxidation using semiconductor nanoparticles like titanium dioxide (TiO_2) is an eco-friendly technology that uses solar energy to degrade organic pollutants completely into harmless substances without using toxic chemical reagents.

Solution:

1. Traditional wastewater treatments often rely on aggressive chemical oxidants or hazardous solvents, which can generate harmful secondary waste.
2. In advanced photocatalytic oxidation, TiO_2 nanoparticles absorb ultraviolet or visible light from sunlight, exciting valence electrons into the conduction band.
3. This electron excitation generates highly reactive electron-hole pairs (h^+/e^-) on the catalyst surface. These holes react with moisture to produce powerful, non-selective hydroxyl radicals ($\cdot\text{OH}$).
4. These hydroxyl radicals attack and oxidize volatile organic pollutants, breaking them down into harmless carbon dioxide (CO_2) and water (H_2O) without producing toxic residues.

Final Answer: Advanced Photocatalytic Oxidation using TiO_2 nanoparticles under sunlight illumination

Answer: (B)

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Q48.

Solution**Concept:**

The Tyndall effect is an optical phenomenon observed when a beam of light passes through a colloidal dispersion. While true solutions do not scatter light because their solute particles are too small, colloidal particles have dimensions comparable to the wavelength of visible light (1 – 1000 nm), allowing them to scatter the light rays.

Solution:

1. A clear colloidal sulfur solution contains suspended clusters of sulfur molecules with particle sizes within the colloidal range.
2. When a focused beam of white light passes through this mixture, the light path illuminates against a dark background, becoming clearly visible from the side.
3. This illumination occurs because the individual colloidal sulfur particles scatter the incoming light rays in all directions.
4. This optical scattering phenomenon is known as the Tyndall effect, and it helps distinguish true solutions from colloidal systems.

Final Answer: Tyndall Effect, caused by the scattering of light by colloidal particles

Answer: (B)

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Q49.

Solution**Concept:**

Photochemical smog forms in urban areas from reactions involving primary pollutants like nitrogen oxides (NO_x) and unburned hydrocarbons under the influence of solar ultraviolet radiation ($h\nu$). These atmospheric interactions produce secondary pollutants that act as toxic irritants in the air.

Solution:

1. Primary emissions from combustion engines (NO_x and volatile organic compounds) accumulate in the lower atmosphere during the day.
2. Sunlight breaks down nitrogen dioxide (NO_2) into nitric oxide and highly reactive oxygen atoms, which combine with molecular oxygen to form ozone (O_3).
3. These reactive species oxidize unburned hydrocarbons to form peroxyacyl radicals.
4. These peroxyacyl radicals then react with nitrogen dioxide to form peroxyacetyl nitrate ($\text{CH}_3\text{COONO}_2$, or PAN). PAN is a characteristic component of photochemical smog that causes severe eye irritation and respiratory distress.

Final Answer: Peroxyacetyl Nitrate (PAN)

Answer: (A)

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Q50.

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, and their flocculating power increases dramatically with their valency. The coagulation value is inversely proportional to the flocculating power.

Solution:

1. The given arsenic sulfide (As_2S_3) sol is a negatively charged colloid. Therefore, its coagulation is driven by the positively charged cations introduced by the added electrolyte.
2. Identify the active cations from the given choices: Na^+ from NaCl , Ba^{2+} from BaCl_2 , Al^{3+} from AlCl_3 , and K^+ from K_2SO_4 .
3. According to the Hardy-Schulze rule, the flocculating power of these cations increases as their positive charge increases:

$$\text{Flocculating Power: } \text{Na}^+ < \text{Ba}^{2+} < \text{Al}^{3+}$$

4. Because the trivalent aluminum ion (Al^{3+}) has the highest valency, it possesses the highest flocculating power. This means it requires the smallest concentration to coagulate the sol, giving it the lowest coagulation value.

Final Answer: AlCl_3

Answer: (C)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	A	3	A	4	B	5	B
6	A	7	C	8	B	9	B	10	B
11	B	12	A	13	B	14	C	15	A
16	B	17	A	18	A	19	C	20	A
21	B	22	B	23	B	24	B	25	A
26	B	27	C	28	A	29	A	30	A
31	A	32	A	33	B	34	B	35	B
36	A	37	C	38	C	39	A	40	A
41	B	42	B	43	A	44	B	45	C
46	C	47	B	48	B	49	A	50	C

