JCECE Chemistry Sample Paper-12

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains **50** Multiple Choice Questions (Single Correct Answer), modelled on the Physics portion of JCECE entrance.
- Each correct answer carries **+1** mark. Incorrect answer: **−0.25** marks.unattempted questions get 0.
- Only one option is correct. Choose carefully.
- Syllabus level: **Class 11 and Class 12 NCERT Physics (Jharkhand JAC / CBSE aligned)**
- Use of mobile phones, calculators, or electronic gadgets is strictly prohibited.

Q1. An organic compound on analysis gave C = 40%, H = 6.67%, and O = 53.33%. If the vapour density of the compound is 30, what is its molecular formula?

(A) CH_2O

(B) $C_2H_4O_2$

(C) $C_3H_6O_3$

(D) $C_4H_8O_2$

Q2. Which of the following arrangements represents the correct order of increasing electron gain enthalpy with negative sign for elements O, S, F, and Cl?

(A) Cl < F < S < O

(B) O < S < F < Cl

(C) F < Cl < O < S

(D) S < O < Cl < F

Q3. In the reaction of propyne with $HgSO_4$ and H_2SO_4, the major organic product formed is:

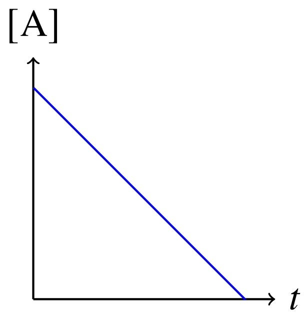
(A) Propanal

(B) Propan-2-ol

(C) Acetone

(D) Propanoic acid

Q4. For a general reaction A → B, the plot of concentration of reactant [A] vs time t gives a straight line with a negative slope. The order of this reaction is:



(A) Zero

(B) First

(C) Second

(D) Half-order

Q5. Which of the following coordination complex ions is expected to exhibit the maximum paramagnetic behaviour? (Atomic numbers: $\mathrm{Mn} = 25, \mathrm{Fe} = 26, \mathrm{Co} = 27, \mathrm{Ni} = 28$)

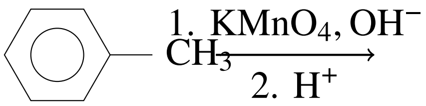
(A) $[Fe(CN)_6]^{3-}$

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

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

(D) $[Ni(H_2O)_6]^{2+}$

Q6. The major product formed when toluene is heated with $KMnO_4$ in alkaline medium followed by acidification is:



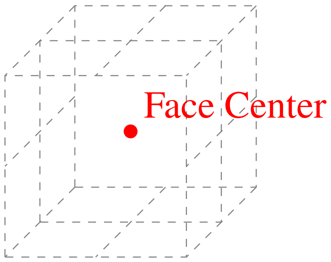
(A) Benzyl alcohol

(B) Benzaldehyde

(C) Benzoic acid

(D) Benzoyl chloride

Q7. In a face-centered cubic (fcc) lattice, an atom at the face-center is shared equally by how many unit cells?



(A) 4 unit cells

(B) 2 unit cells

(C) 1 unit cell

(D) 6 unit cells

Q8. Which of the following oxoacids of phosphorus contains a direct P – P bond?

(A) $H_4P_2O_7$

(B) $H_4P_2O_6$

(C) H_3PO_3

(D) $H_4P_2O_5$

Q9. Equal volumes of two solutions with pH = 3 and pH = 5 are mixed together. The pH of the resulting solution will be closest to:

(A) 4.0

(B) 3.3

(C) 4.5

(D) 3.7

Q10. The major product obtained in the reaction of 2-bromobutane with alcoholic KOH is:

(A) 1-Butene

(B) trans-2-Butene

(C) cis-2-Butene

(D) 2-Butanol

Q11. The standard reduction potentials of three metals X, Y, and Z are +0.52 V, −2.87 V, and −1.18 V respectively. The reducing power of these metals follows the order:

(A) X > Y > Z

(B) Y > Z > X

(C) Z > X > Y

(D) Y > X > Z

Q12. Which of the following statements about the roasting process in metallurgy is incorrect?

(A) It is generally used for sulphide ores.

(B) The ore is heated regularly below its melting point in the presence of excess air.

(C) It helps remove volatile impurities like arsenic and antimony.

(D) It converts the metal ore directly into pure liquid metal.

Q13. Identify the strongest acid among the following options:

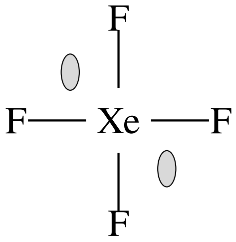
(A) CH_3COOH

(B) $ClCH_2COOH$

(C) FCH_2COOH

(D) NO_2CH_2COOH

Q14. The total number of lone pairs of electrons present on the central atom in a XeF_4 molecule is:



(A) 1

(B) 2

(C) 3

(D) 4

Q15. Vapor pressure of pure water at 298 K is 23.8 mmHg. If 50 g of urea (NH_2CONH_2) is dissolved in 850 g of water, the relative lowering of vapor pressure is:

(A) 0.0173

(B) 0.0346

(C) 0.0085

(D) 0.0521

Q16. The correct IUPAC name of the compound $CH_3-CH(OH)-CH_2-CO-CH_3$ is:

(A) 4-Hydroxypentan-2-one

(B) 2-Hydroxypentan-4-one

(C) 4-Oxopentan-2-ol

(D) 2-Oxopentan-4-ol

Q17. For the reversible endothermic reaction $A(s) + B(g) \rightleftharpoons 2C(g)$, the equilibrium yield of C can be increased by:

(A) Increasing the pressure

(B) Decreasing the temperature

(C) Increasing the temperature

(D) Adding more of solid A

Q18. Which structural property accounts for the higher stability of a phenoxide ion compared to an ethoxide ion?

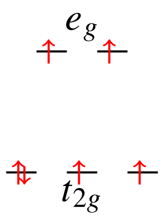
(A) Inductive effect of the alkyl group

(B) Hyperconjugation in the aromatic ring

(C) Resonance stabilization of the negative charge over the benzene ring

(D) Steric hindrance in the ethoxide ion

Q19. The configuration of the complex ion $[CoF_6]^{3-}$ according to crystal field theory is:



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

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

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

(D) $t_{2g}^3 e_g^3$

Q20. When 1 Faraday of electricity is passed through aqueous solutions of $AgNO_3$, $CuSO_4$, and $AlCl_3$ connected in series, the ratio of the molar amounts of Ag, Cu, and Al deposited at the cathodes will be:

(A) 1 : 2 : 3

(B) 3 : 2 : 1

(C) 6 : 3 : 2

(D) 1 : 1 : 1

Q21. Which carbohydrate is known as non-reducing sugar?

(A) Maltose

(B) Lactose

(C) Glucose

(D) Sucrose

Q22. According to Molecular Orbital Theory, which of the following species is diamagnetic and has a fractional bond order?

(A) O_2^+

(B) He_2^+

(C) H_2^-

(D) None of these

Q23. In an ideal solution, which thermodynamic parameter is not equal to zero during the mixing of the pure components?

(A) ΔV_{mixing}

(B) ΔH_{mixing}

(C) ΔS_{mixing}

(D) ΔP (deviation from Raoult's Law)

Q24. Aniline reacts with nitrous acid ($NaNO_2$ + HCl) at $0 - 5°C$ to give a compound X. When X is warmed with CuCN, it produces Y. Compound Y is:

(A) Benzylamine

(B) Benzonitrile

(C) Chlorobenzene

(D) Nitrobenzene

Q25. Which one of the following noble gases has the lowest boiling point?

(A) He

(B) Ne

(C) Ar

(D) Kr

Q26. For a first-order reaction, the time required for 99.9% completion is how many times the half-life ($t_{1/2}$) of the reaction?

(A) 2 times

(B) 5 times

(C) 10 times

(D) 100 times

Q27. The basicity of the following amines in aqueous solution decreases in the sequence:

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

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

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

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

Q28. The number of octahedral and tetrahedral voids per atom in a close-packed hexagonal (hcp) structure are respectively:

(A) 1 and 2

(B) 2 and 1

(C) 4 and 8

(D) 2 and 4

Q29. Which element among the 3d transition series exhibits the maximum number of oxidation states?

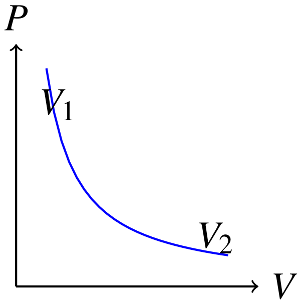
(A) Cr

(B) Fe

(C) Mn

(D) V

Q30. The work done during the isothermal reversible expansion of 2 moles of an ideal gas from a volume of 10 L to 100 L at 300 K is approximately:



(A) −11.5 kJ

(B) −5.74 kJ

(C) −2.30 kJ

(D) −23.0 kJ

Q31. Phenol when treated with $CHCl_3$ and aqueous NaOH at 340 K followed by hydrolysis yields salicylaldehyde. This reaction is known as:

(A) Kolbe's reaction

(B) Reimer-Tiemann reaction

(C) Rosenmund reaction

(D) Friedel-Crafts acylation

Q32. In the extraction of iron from hematite ore in a blast furnace, the composition of the slag formed is:

(A) $FeSiO_3$

(B) $CaSiO_3$

(C) $MgSiO_3$

(D) Al_2O_3

Q33. If the solubility product (K_{sp}) of a sparingly soluble salt MX_2 is 3.2×10^{-11}, its solubility (s) in mol L^{-1} is:

(A) 2.0×10^{-4}

(B) 4.0×10^{-4}

(C) 5.6×10^{-6}

(D) 3.2×10^{-4}

Q34. The functional group isomer of ethyl alcohol is:

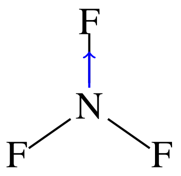
(A) Dimethyl ether

(B) Diethyl ether

(C) Methyl alcohol

(D) Acetone

Q35. Which of the following molecules has a permanent non-zero dipole moment?



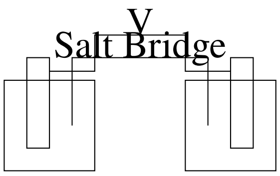
(A) BF_3

(B) CCl_4

(C) NF_3

(D) CO_2

Q36. The standard EMF (E°_{cell}) for the cell reaction $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ is 1.10 V. The equilibrium constant (K_c) for this reaction at 298 K is of the order of:



(A) 10^{18}

(B) 10^{37}

(C) 10^{-18}

(D) 10^{-37}

Q37. Which of the following is an outer orbital high-spin complex?

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

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

(C) $[Ni(NH_3)_6]^{2+}$

(D) $[Mn(CN)_6]^{3-}$

Q38. In the Williamson synthesis of ethers, the reaction mechanism proceeds via:

(A) S_N1 pathway

(B) S_N2 pathway

(C) E1 pathway

(D) E2 pathway

Q39. For a spontaneous process at constant temperature and pressure, which condition is absolutely necessary?

(A) $\Delta H < 0$

(B) $\Delta S > 0$

(C) $\Delta G < 0$

(D) $\Delta E < 0$

Q40. Which of the following statement is incorrect regarding the p-block elements?

(A) PbX_2 is more stable than PbX_4 due to the inert pair effect.

(B) Nitrogen cannot expand its valency beyond 4 due to the absence of d-orbitals.

(C) BiH_3 is the strongest reducing agent among the hydrides of Group 15.

(D) Oxygen shows a maximum covalency of 6.

Q41. Ozonolysis of 2-Methylbut-2-ene followed by treatment with Zn/H_2O gives:

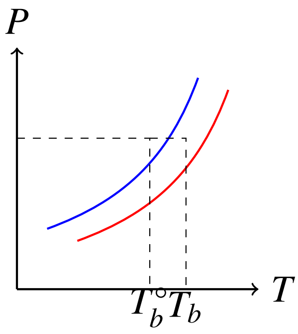
(A) Propanone and Ethanal

(B) Propanal and Ethanal

(C) Ethanal only

(D) Butanone and Methanal

Q42. A solution containing 10.2 g of a non-volatile solute in 100 g of water boils at 100.52°C. Given that the molal boiling point elevation constant (K_b) of water is 0.52 K kg mol^{-1}, the molar mass of the solute is:



(A) 51 g mol^{-1}

(B) 102 g mol^{-1}

(C) 204 g mol^{-1}

(D) 26 g mol^{-1}

Q43. Which of the following elements does not form a stable pentachloride?

(A) P

(B) As

(C) Sb

(D) N

Q44. Cannizzaro's reaction is not given by which of the following compounds?

(A) Formaldehyde

(B) Benzaldehyde

(C) Acetaldehyde

(D) Trimethylacetaldehyde

Q45. The rate constant (k) of a reaction is found to be 2.5×10^{-2} L mol^{-1} s^{-1}. What is the total order of this reaction?

(A) First order

(B) Second order

(C) Third order

(D) Zero order

Q46. Lanthanoid contraction is principally due to:

(A) Imperfect shielding of one $4f$ electron by another in the same subshell.

(B) Highly effective shielding of $4f$ electrons.

(C) The strong shielding of $5d$ electrons.

(D) Continuous decrease in effective nuclear charge.

Q47. Silver mirror test can be used to distinguish between:

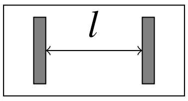
(A) Acetone and Benzophenone

(B) Acetaldehyde and Benzaldehyde

(C) Formaldehyde and Acetone

(D) Ethanol and Propan-2-ol

Q48. The unit of cell constant for an electrolytic conductivity cell is:



(A) S cm^{-1}

(B) S cm

(C) cm^{-1}

(D) Ω cm

Q49. Hydrolysis of sucrose yields an equimolar mixture of:

(A) α-D-glucose and β-D-fructose

(B) α-D-glucose and α-D-galactose

(C) β-D-glucose and β-D-fructose

(D) α-D-fructose and β-D-galactose

Q50. Which species among the following has a linear molecular shape?

(A) SO_2

(B) I_3^-

(C) O_3

(D) NO_2^-

Detailed Solutions

Q1.

Solution

Concept:

The empirical formula represents the simplest whole-number ratio of various atoms present in a compound, whereas the molecular formula represents the actual number of atoms of each element present. The relationship between the empirical formula weight and the molecular weight is given by the factor n, where $n = \frac{\text{Molecular Weight}}{\text{Empirical Formula Weight}}$. The molecular weight is calculated as $2 \times$ Vapour Density.

Solution:

Step 1: Determine the relative number of moles of each element by dividing the percentage composition by the respective atomic mass of the elements:

For Carbon (C): $\frac{40}{12} = 3.33$

For Hydrogen (H): $\frac{6.67}{1} = 6.67$

For Oxygen (O): $\frac{53.33}{16} = 3.33$

Step 2: Obtain the simplest molar ratio by dividing each value by the smallest value among them, which is 3.33:

Ratio for C $= \frac{3.33}{3.33} = 1$

Ratio for H $= \frac{6.67}{3.33} = 2$

Ratio for O $= \frac{3.33}{3.33} = 1$

Hence, the empirical formula of the organic compound is CH_2O.

Step 3: Calculate the empirical formula mass of CH_2O:

Empirical formula mass $= 12 + (2 \times 1) + 16 = 30$ g mol^{-1}.

Step 4: Determine the actual molecular mass of the compound from the given vapour density:

Molecular mass $= 2 \times$ Vapour Density $= 2 \times 30 = 60$ g mol^{-1}.

Step 5: Calculate the value of the multiplier factor n:

$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{60}{30} = 2.$

Step 6: Determine the molecular formula by multiplying the empirical formula by n:

Molecular formula $= (CH_2O) \times 2 = C_2H_4O_2$.

Final Answer: $\boxed{C_2H_4O_2}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:
Electron gain enthalpy ($\Delta_{eg}H$) is the energy change associated with the addition of an electron to a gaseous isolated atom. Generally, it becomes more negative across a period due to increased nuclear charge and less negative down a group due to increased size. However, second-period elements like O and F have an exceptionally lower negative electron gain enthalpy than their third-period counterparts (S and Cl) because of severe inter-electronic repulsions in the compact $2p$ subshell.

Solution:
Step 1: Analyze the trends between groups and periods. Halogens (Group 17) have the most negative electron gain enthalpies in their respective periods because they achieve a stable noble gas configuration upon gaining one electron. Therefore, F and Cl will have higher negative values than O and S (Group 16).

Step 2: Compare the elements within Group 17 (F and Cl). Chlorine (Cl) has a more negative electron gain enthalpy than fluorine (F). The extremely small size of the fluorine atom results in high electron density in its compact $2p$ valence shell, which strongly repels incoming electrons, lowering the energy released. Thus, $|\Delta_{eg}H_{\text{Cl}}| > |\Delta_{eg}H_{\text{F}}|$.

Step 3: Compare the elements within Group 16 (O and S). Due to similar inter-electronic repulsions in the small $2p$ shell of oxygen, sulfur (S) has a significantly more negative electron gain enthalpy than oxygen (O). In fact, oxygen has the least negative value in the entire set.

Step 4: Combine the individual trends to establish the full increasing order of negative electron gain enthalpy:
$\text{O} < \text{S} < \text{F} < \text{Cl}$.

Final Answer: $\boxed{\text{O} < \text{S} < \text{F} < \text{Cl}}$

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

Go Back to Question 2

Q3.

Solution

Concept:

The hydration of alkynes in the presence of mercuric sulphate ($HgSO_4$) and dilute sulphuric acid (H_2SO_4) is known as Kucherov's reaction. It involves the electrophilic addition of a water molecule across the carbon-carbon triple bond following Markovnikov's rule. The initial addition forms an unstable enol intermediate, which immediately undergoes rapid tautomerization (keto-enol tautomerism) to yield a stable carbonyl compound.

Solution:

Step 1: Write down the chemical formula of the starting material, propyne: $CH_3 - C \equiv CH$.

Step 2: Apply Markovnikov's addition of water (H^+ and OH^-) across the triple bond. The electrophilic hydrogen atom attacks the terminal carbon to form a more stable secondary carbocation at the central carbon atom. The nucleophilic hydroxyl group (OH^-) then attacks this central carbocation:

$CH_3 - C \equiv CH + H_2O \xrightarrow{Hg^{2+}/H^+} CH_3 - C(OH) = CH_2$.

Step 3: Identify the intermediate structure. The molecule $CH_3 - C(OH) = CH_2$ is prop-1-en-2-ol, which belongs to the unstable class of enols because the hydroxyl group is directly attached to a doubly bonded carbon atom.

Step 4: Shift the proton from the oxygen atom of the hydroxyl group to the terminal CH_2 carbon, while simultaneously moving the π-bond to form a carbon-oxygen double bond ($C = O$). This rapid keto-enol tautomerization gives a stable ketone:

$CH_3 - C(OH) = CH_2 \rightleftharpoons CH_3 - CO - CH_3$.

Step 5: Conclude that the final major stable product obtained is acetone (propan-2-one).

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

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

Go Back to Question 3

Q4.

Solution

Concept:

The integrated rate equations describe the dependence of reactant concentrations on time for reactions of various orders. For any reaction, plotting the reactant concentration as a function of time yields a geometric curve characteristic of its kinetics. A straight line plot with a negative slope for concentration versus time indicates that the rate of the reaction is entirely independent of the instantaneous concentration of the reactants.

Solution:

Step 1: Write the differential rate law for a zero-order reaction A $\longrightarrow$ B:
$-\frac{d[\mathrm{A}]}{dt} = k[\mathrm{A}]^0 = k.$

Step 2: Separate the variables and integrate both sides within proper limits from time 0 to t:
$\int_{[\mathrm{A}]_0}^{[\mathrm{A}]} d[\mathrm{A}] = -k\int_0^t dt.$
This integrates directly to the linear expression:
$[\mathrm{A}] = -kt + [\mathrm{A}]_0.$

Step 3: Compare this integrated rate equation with the slope-intercept form of a straight line equation, $y = mx + c$:
Here, $y = [\mathrm{A}]$, $x = t$, the slope $m = -k$ (which is negative), and the y-intercept $c = [\mathrm{A}]_0$.

Step 4: Observe that for higher-order processes, such linear relationships are only obtained by plotting logarithmic functions (like $\ln[\mathrm{A}]$ for first-order) or reciprocal functions (like $1/[\mathrm{A}]$ for second-order) against time. Therefore, a direct plot of $[\mathrm{A}]$ vs t giving a straight line with a negative slope uniquely belongs to a zero-order reaction.

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

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:

The magnitude of paramagnetic behaviour in coordination complexes depends directly on the number of unpaired electrons (n) present in the central metal ion's d-orbitals. According to the spin-only formula, the magnetic moment is given by $\mu = \sqrt{n(n+2)}$ Bohr Magnetons (BM). The distribution of electrons in d-orbitals is dictated by Crystal Field Theory (CFT), based on whether the attached ligands are weak field or strong field.

Solution:

Step 1: Evaluate option (A), $[Fe(CN)_6]^{3-}$. Here, Fe is in the +3 oxidation state. The electronic configuration of Fe^{3+} is $3d^5$. Since CN^- is a strong field ligand, it forces pairing of electrons in the t_{2g} orbitals, leaving only 1 unpaired electron ($n = 1$).

Step 2: Evaluate option (B), $[Co(NH_3)_6]^{3+}$. Here, Co is in the +3 oxidation state. The configuration of Co^{3+} is $3d^6$. Ammonia (NH_3) acts as a strong field ligand for Co^{3+}, resulting in complete pairing of electrons in t_{2g} ($t_{2g}^6 e_g^0$). The number of unpaired electrons is zero ($n = 0$), making it diamagnetic.

Step 3: Evaluate option (C), $[Mn(H_2O)_6]^{2+}$. Here, Mn is in the +2 oxidation state. The configuration of Mn^{2+} is $3d^5$. Water (H_2O) is a weak field ligand and cannot cause electron pairing. The electrons occupy separate orbitals according to Hund's rule ($t_{2g}^3 e_g^2$), resulting in 5 unpaired electrons ($n = 5$).

Step 4: Evaluate option (D), $[Ni(H_2O)_6]^{2+}$. Here, Ni is in the +2 oxidation state. The configuration of Ni^{2+} is $3d^8$. For a $3d^8$ system in an octahedral field, the arrangement is always $t_{2g}^6 e_g^2$, which contains exactly 2 unpaired electrons ($n = 2$).

Step 5: Compare the values of n. The complex $[Mn(H_2O)_6]^{2+}$ contains the maximum number of unpaired electrons ($n = 5$), thus demonstrating the greatest paramagnetic behaviour.

Final Answer: $\boxed{[Mn(H_2O)_6]^{2+}}$

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept:

Potassium permanganate ($KMnO_4$) in an alkaline medium is a powerful oxidizing agent capable of completely oxidizing the alkyl side chains of aromatic hydrocarbons into carboxylic acid groups. Regardless of the chain length of the alkyl group, as long as there is at least one benzylic hydrogen atom present, the entire side chain is cleaved and oxidized down to a carboxyl group ($-COOH$) attached to the benzene ring.

Solution:

Step 1: Identify the structure of the reactant. Toluene consists of a single methyl group attached directly to a benzene ring ($C_6H_5 - CH_3$). The methyl group has three benzylic hydrogens, making it highly susceptible to oxidative degradation.

Step 2: Analyze the first stage of the reaction. When toluene is heated with alkaline $KMnO_4$, the methyl group undergoes oxidation to form the water-soluble potassium salt of benzoic acid, which is potassium benzoate ($C_6H_5 - COOK$). Manganese dioxide (MnO_2) precipitates out as a brown-black byproduct during this process.

Step 3: Analyze the second stage of the reaction. The addition of a mineral acid (H^+) protonates the soluble benzoate anions, precipitating the free carboxylic acid out of the aqueous solution.
$C_6H_5 - COOK + H^+ \rightarrow C_6H_5 - COOH + K^+$.

Step 4: Conclude that the final isolated organic product of this sequence is benzoic acid.

Final Answer: $\boxed{\text{Benzoic acid}}$

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

Go Back to Question 6

Q7.

Solution

Concept:

In a crystalline lattice structure, unit cells are stacked repeatedly in three dimensions to form the macroscopic crystal. Atoms located at different geometric positions of a single unit cell are shared distinctively among neighboring unit cells. To determine the net contribution or sharing of an atom, one must visualize how many identical cubes meet at that specific boundary location in a continuous lattice space.

Solution:

Step 1: Visualize the architecture of a face-centered cubic (fcc) unit cell. It consists of atoms at all eight corners and at the centers of all six faces.

Step 2: Focus specifically on a single face of the cube. A face is a flat two-dimensional boundary wall that separates two adjacent cubic unit cells positioned side by side.

Step 3: Any atom situated exactly at the center of this flat face lies precisely on the shared wall. Therefore, it is halved, with one half of its volume residing inside the first unit cell and the other half extending into the adjacent unit cell.

Step 4: Because a face is shared between exactly 2 unit cells, the atom at the face-center is shared equally by 2 unit cells, contributing a net fraction of $\frac{1}{2}$ to each individual cell.

Final Answer: $\boxed{\text{2 unit cells}}$

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

Go Back to Question 7

Q8.

Solution

Concept:
Oxoacids of phosphorus are chemical compounds containing phosphorus, oxygen, and hydrogen. Phosphorus in these compounds typically exhibits a coordination number of 4, forming tetrahedral structures with at least one $P = O$ bond and one $P - OH$ bond. In dimeric oxoacids (pyro- or hypophosphoric acids), the two phosphorus centers can be linked either indirectly through an oxygen bridge ($P-O-P$) or directly through a catenated phosphorus-phosphorus ($P-P$) covalent bond.

Solution:
Step 1: Examine the chemical structure of $H_4P_2O_7$ (Pyrophosphoric acid). It is formed by the dehydration of two molecules of orthophosphoric acid. Its structure features two tetrahedral units connected through an anhydride oxygen bridge: $(HO)_2P(=O) - O - P(=O)(OH)_2$. It contains a $P - O - P$ bond, not a $P - P$ bond.

Step 2: Examine the structure of $H_4P_2O_6$ (Hypophosphoric acid). In this acid, phosphorus is in the +4 oxidation state. To satisfy the valency and stoichiometry without creating peroxide linkages, the two phosphorus atoms bond directly to each other. The structural formula is $(HO)_2P(=O) - P(=O)(OH)_2$. Thus, it contains a direct $P - P$ bond.

Step 3: Examine H_3PO_3 (Orthophosphorous acid). This is a monomeric tautomeric species containing only one phosphorus atom, ruling out any catenated linkages.

Step 4: Examine $H_4P_2O_5$ (Pyrophosphorous acid). This compound contains an oxygen bridge linking the two centers, represented structurally as $H(HO)P(=O) - O - P(=O)(OH)H$.

Step 5: Conclude that $H_4P_2O_6$ is the only oxoacid among the choices possessing a direct $P - P$ single bond.

Final Answer: $\boxed{H_4P_2O_6}$

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:

The pH of an aqueous solution is defined as the negative logarithm to the base 10 of its hydrogen ion activity, or practically, its molar concentration: $\text{pH} = -\log_{10}[\text{H}^+]$. When two solutions containing a strong acid are mixed together, the total number of moles of H^+ ions is additive. The new concentration is then calculated by dividing the total moles by the final combined volume of the mixture.

Solution:

Step 1: Calculate the hydrogen ion concentration $[\text{H}^+]$ in both solutions before mixing:
For the first solution ($\text{pH} = 3$): $[\text{H}^+]_1 = 10^{-3}$ M $= 0.001$ M.
For the second solution ($\text{pH} = 5$): $[\text{H}^+]_2 = 10^{-5}$ M $= 0.00001$ M.

Step 2: Let the volume of each solution mixed be V liters. Calculate the total moles of H^+ ions contributed by both solutions:
Total Moles $= ([\text{H}^+]_1 \times V) + ([\text{H}^+]_2 \times V) = V \times (10^{-3} + 10^{-5})$.

Step 3: Determine the total final volume of the solution upon mixing:
Total Volume $= V + V = 2V$.

Step 4: Compute the final concentration of hydrogen ions $[\text{H}^+]_{\text{mix}}$ in the mixture:
$[\text{H}^+]_{\text{mix}} = \frac{V(10^{-3}+10^{-5})}{2V} = \frac{10^{-3}+0.01\times10^{-3}}{2} = \frac{1.01\times10^{-3}}{2} = 5.05 \times 10^{-4}$ M.

Step 5: Take the negative logarithm of the final concentration to find the pH:
$\text{pH} = -\log_{10}(5.05 \times 10^{-4}) = 4 - \log_{10}(5.05)$.
Since $\log_{10}(5.05) \approx 0.703$:
$\text{pH} = 4 - 0.703 = 3.297 \approx 3.3$.

Final Answer: $\boxed{3.3}$

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:
The reaction of an alkyl halide with alcoholic potassium hydroxide (KOH) is a classic dehydrohalogenation reaction that proceeds via an E2 elimination mechanism. In this reaction, a hydrogen atom from a β-carbon and the halogen atom from the α-carbon are simultaneously eliminated to form a carbon-carbon double bond. When multiple β-carbons are present, the major product is determined by Saytzeff's rule, which states that the highly substituted, more stable alkene is preferentially formed.

Solution:
Step 1: Write out the structure of the starting material, 2-bromobutane:
$CH_3 - CH(Br) - CH_2 - CH_3$. Here, the carbon bearing the bromine atom is the α-carbon (C2).

Step 2: Identify the adjacent β-carbons. There are two distinct β-carbons: the terminal methyl carbon (C1) and the internal methylene carbon (C3). This means elimination can follow two paths:
Path A: Elimination involving the C1 hydrogen yields 1-butene ($CH_2 = CH - CH_2 - CH_3$).
Path B: Elimination involving the C3 hydrogen yields 2-butene ($CH_3 - CH = CH - CH_3$).

Step 3: Evaluate the alkenes using Saytzeff's rule. 1-Butene is a monosubstituted alkene with only 2 α-hydrogens, whereas 2-butene is a disubstituted alkene with 6 α-hydrogens, making it significantly more stable via hyperconjugation.

Step 4: Distinguish between the stereoisomers of 2-butene. The elimination can produce both cis-2-butene and trans-2-butene. The trans isomer is more stable than the cis isomer due to lower steric repulsion between the bulky methyl groups on opposite sides of the double bond. Therefore, trans-2-butene is the major product.

Final Answer: $\boxed{\text{trans-2-Butene}}$

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

Go Back to Question 10

Q11.

Solution

Concept:
The reducing power of a metal reflects its ability to act as a reducing agent by donating electrons and undergoing oxidation. In quantitative terms, a lower (more negative) standard reduction potential (E°) indicates a greater tendency for the metal to lose electrons and a lower tendency to be reduced. Therefore, the lower the standard reduction potential of a species, the stronger its reducing power.

Solution:
Step 1: Note the given standard reduction potentials for the three metals:
$E^\circ_{\text{X}} = +0.52$ V
$E^\circ_{\text{Y}} = -2.87$ V
$E^\circ_{\text{Z}} = -1.18$ V

Step 2: Arrange the reduction potentials in ascending numerical order, from most negative to most positive:
$-2.87 \text{ V} < -1.18 \text{ V} < +0.52 \text{ V}.$
This corresponds to the order of elements: $\text{Y} < \text{Z} < \text{X}$.

Step 3: Apply the inverse relationship between reduction potential and reducing power. The metal with the lowest reduction potential (Y) is oxidized most easily, making it the strongest reducing agent. Conversely, the metal with the highest reduction potential (X) is oxidized least easily, making it the weakest reducing agent.

Step 4: Express the final decreasing order of reducing power:
$\text{Y} > \text{Z} > \text{X}.$

Final Answer: $\boxed{\text{Y} > \text{Z} > \text{X}}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:
Roasting is a pyrometallurgical thermal process commonly applied to concentrated ores, typically sulphide ores. It involves heating the solid ore at high temperatures below its melting point in a controlled excess supply of air or oxygen. This process converts metal sulphides into metal oxides or sulphates while removing volatile impurities as gaseous oxides.

Solution:
Step 1: Evaluate statement (A). Roasting is standardly utilized for sulphide ores (e.g., zinc blende ZnS, galena PbS) to convert them to oxides. This statement is correct.

Step 2: Evaluate statement (B). The temperature during roasting must be strictly kept below the melting point of the ore to prevent sintering or melting, which would block the penetration of oxygen. This statement is correct.

Step 3: Evaluate statement (C). Volatile non-metallic elements present as impurities, such as arsenic (As), antimony (Sb), and sulfur (S), react with oxygen to form volatile oxides (As_4O_6, Sb_4O_6, SO_2) that escape as gases. This statement is correct.

Step 4: Evaluate statement (D). Roasting converts the concentrated sulphide ore into a solid metal oxide (e.g., $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$), not a pure liquid metal. The reduction of the resulting oxide to the actual metal occurs in a separate subsequent step using a reducing agent like carbon. Therefore, statement (D) is false.

Final Answer: $\boxed{\text{It converts the metal ore directly into pure liquid metal.}}$

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

Go Back to Question 12

Q13.

Solution

Concept:
The acidity of carboxylic acids depends on the stability of the carboxylate anion formed after losing a proton (H^+). Electron-withdrawing groups (−I effect) pull electron density away from the negative carboxylate group, dispersing the charge and stabilizing the conjugate base, which increases acidity. The strength of the −I effect follows the order: $-NO_2 > -F > -Cl > -\text{alkyl}$.

Solution:
Step 1: Analyze CH_3COOH (Acetic acid). The methyl group ($-CH_3$) is an electron-donating group due to its +I inductive effect. It increases the electron density on the carboxylate group, destabilizing the anion and making it the weakest acid in the series.

Step 2: Analyze $ClCH_2COOH$ (Chloroacetic acid). Chlorine is electronegative and exerts an electron-withdrawing −I effect, which stabilizes the conjugate base and makes it more acidic than acetic acid.

Step 3: Analyze FCH_2COOH (Fluoroacetic acid). Fluorine is more electronegative than chlorine, so it exerts a stronger −I effect, stabilizing the carboxylate anion more effectively than chlorine.

Step 4: Analyze NO_2CH_2COOH (Nitroacetic acid). The nitro group ($-NO_2$) is a powerful electron-withdrawing group whose −I effect is significantly stronger than that of halogen atoms. This strong pull drastically disperses the negative charge on the $-COO^-$ group, providing exceptional resonance and inductive stabilization to the conjugate base.

Step 5: Conclude that nitroacetic acid is the strongest acid among the given choices.

Final Answer: $\boxed{NO_2CH_2COOH}$

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

Go Back to Question 13

Q14.

Solution

Concept:
The electronic geometry and number of lone pairs on a central atom can be determined using Valence Shell Electron Pair Repulsion (VSEPR) theory. The total number of valence shell electron pairs (steric number) is calculated as $V = \frac{1}{2}(G + M - C + A)$, where G is the number of valence electrons on the central atom, M is the number of monovalent atoms, C is the cationic charge, and A is the anionic charge. The number of lone pairs is the steric number minus the number of bonded atoms.

Solution:
Step 1: Identify the central atom in XeF_4, which is Xenon (Xe). Xenon is a noble gas belonging to Group 18, so it contains 8 valence electrons in its outermost shell ($G = 8$).

Step 2: Count the surrounding monovalent atoms. There are 4 fluorine atoms bonded directly to the xenon center ($M = 4$). The molecule carries no net ionic charge, so $C = 0$ and $A = 0$.

Step 3: Calculate the total steric number (total electron pairs):
Steric Number $= \frac{1}{2}(8 + 4) = \frac{12}{2} = 6$.
A steric number of 6 corresponds to sp^3d^2 hybridization, which forms an octahedral electronic geometry.

Step 4: Determine the number of non-bonding lone pairs on the xenon atom:
Number of Lone Pairs = Steric Number − Number of Bonded Atoms $= 6 - 4 = 2$.

Step 5: Visualize the final molecular geometry. The two lone pairs position themselves opposite one another (180° apart) to minimize electron-electron repulsion, resulting in a square planar molecular shape. The number of lone pairs on the central atom is 2.

Final Answer: $\boxed{2}$

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept:

According to Raoult's Law for dilute solutions containing a non-volatile solute, the relative lowering of vapor pressure is equal to the mole fraction of the solute in the solution. The relative lowering of vapor pressure is expressed mathematically as $\frac{P^\circ - P}{P^\circ} = \chi_{\text{solute}} = \frac{n_0}{n_0 + n_w}$, where n_0 is the number of moles of the solute and n_w is the number of moles of the solvent.

Solution:

Step 1: Calculate the number of moles of the solute, urea (NH_2CONH_2). The molar mass of urea is 14 + 2 + 12 + 16 + 14 + 2 = 60 g mol^{-1}.

$n_{\text{urea}} = \frac{\text{Mass}}{\text{Molar Mass}} = \frac{50\text{ g}}{60\text{ g mol}^{-1}} = 0.8333$ moles.

Step 2: Calculate the number of moles of the solvent, water (H_2O). The molar mass of water is 18 g mol^{-1}.

$n_{\text{water}} = \frac{\text{Mass}}{\text{Molar Mass}} = \frac{850\text{ g}}{18\text{ g mol}^{-1}} = 47.2222$ moles.

Step 3: Determine the total number of moles present in the solution:

Total Moles $= n_{\text{urea}} + n_{\text{water}} = 0.8333 + 47.2222 = 48.0555$ moles.

Step 4: Compute the mole fraction of urea, which represents the relative lowering of vapor pressure:

$\chi_{\text{urea}} = \frac{n_{\text{urea}}}{\text{Total Moles}} = \frac{0.8333}{48.0555} = 0.01734$.

Step 5: Note that the actual vapor pressure value of pure water (23.8 mmHg) is extra information, as the relative lowering of vapor pressure is a dimensionless quantity equal directly to this mole fraction.

Final Answer: $\boxed{0.0173}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:

According to IUPAC nomenclature rules, when a polyfunctional organic compound contains more than one principal functional group, one group is selected as the principal functional group based on a defined priority order. The priority order for the functional groups present here is: Ketone ($> C = O$) > Alcohol ($-OH$). The principal group determines the suffix of the parent chain name, while the lower priority group is treated as a substituent and denoted by a prefix.

Solution:

Step 1: Analyze the given structural formula: $CH_3 - CH(OH) - CH_2 - CO - CH_3$. The two functional groups are a secondary alcohol group at carbon-2 or carbon-4, and a ketone carbonyl group. Because ketones have priority over alcohols, the principal suffix will be "-one" and the alcohol will be named as a "hydroxy" prefix.

Step 2: Find the longest continuous carbon chain containing both groups. The chain has 5 carbon atoms, so the root word is "pentane".

Step 3: Number the carbon chain to give the principal functional group (ketone) the lowest possible locant number. Numbering from right to left gives the ketone position 2:

$\overset{5}{CH_3} - \overset{4}{CH}(OH) - \overset{3}{CH_2} - \overset{2}{CO} - \overset{1}{CH_3}$.

(Numbering from left to right would incorrectly assign position 4 to the ketone).

Step 4: Identify the positions of the substituent and the principal functional group based on this numbering scheme. The hydroxy prefix is at carbon-4, and the ketone suffix is at carbon-2.

Step 5: Combine these parts into the full systematic IUPAC name: 4-Hydroxypentan-2-one.

Final Answer: $\boxed{\text{4-Hydroxypentan-2-one}}$

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept:
Le Chatelier's Principle states that if a system at equilibrium is subjected to a change in temperature, pressure, or concentration of components, the system shifts its equilibrium position in a direction that counteracts the imposed change. For gaseous reactions, changing the pressure affects the side with more moles of gas. For thermal changes, increasing the temperature favors the endothermic direction, which absorbs heat.

Solution:
Step 1: Analyze the given reaction equation: $\mathrm{A}(s) + \mathrm{B}(g) \rightleftharpoons 2\mathrm{C}(g)$. Count the number of moles of gaseous components on both sides. The reactant side features 1 mole of gas (B), since A is a solid. The product side features 2 moles of gas (C).

Step 2: Evaluate the effect of pressure. Increasing the pressure shifts the equilibrium toward the side with fewer moles of gas (the reactant side), decreasing the yield of C. Therefore, option (A) is incorrect.

Step 3: Evaluate the effect of temperature. The reaction is explicitly specified as endothermic ($\Delta H > 0$). According to Le Chatelier's principle, adding heat by increasing the temperature shifts the equilibrium in the forward direction to consume the added thermal energy. This increases the equilibrium yield of the products. Thus, option (C) is correct.

Step 4: Evaluate option (D). Pure solids have constant active mass (activity equal to 1), so adding more solid A does not shift the equilibrium position.

Final Answer: $\boxed{\text{Increasing the temperature}}$

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

Go Back to Question 17

Q18.

Solution

Concept:
The relative stability of anions depends on how effectively their negative charge can be dispersed throughout the molecular structure. A localized charge results in a less stable, more reactive anion, whereas a delocalized charge stabilizes the species. This charge dispersal can occur through inductive effects or via resonance conjugation with an adjacent π-system.

Solution:
Step 1: Examine the structure of the ethoxide ion ($CH_3CH_2O^-$). The negative charge is localized entirely on a single oxygen atom. Furthermore, the attached ethyl group is electron-donating via its +I inductive effect, which pushes electron density toward the oxygen and destabilizes the negative charge.

Step 2: Examine the structure of the phenoxide ion ($C_6H_5O^-$). The lone pair of electrons carrying the negative charge on the oxygen atom is adjacent to the conjugated π-electron cloud of the aromatic benzene ring.

Step 3: Analyze the resonance interactions in the phenoxide ion. The negative charge delocalizes into the ring, shifting the charge to the ortho and para positions via resonance. This distributes the negative charge over multiple carbon atoms in the ring rather than leaving it localized on a single oxygen atom.

Step 4: Conclude that this resonance stabilization makes the phenoxide ion significantly more stable than the ethoxide ion, explaining why phenol is a much stronger acid than ethanol.

Final Answer: $\boxed{\text{Resonance stabilization of the negative charge over the benzene ring}}$

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

Go Back to Question 18

Q19.

Solution

Concept:
According to Crystal Field Theory (CFT), the five degenerate d-orbitals of a transition metal ion split into two sets in an octahedral field: a lower energy triplet t_{2g} ($\mathrm{d}_{xy}, \mathrm{d}_{yz}, \mathrm{d}_{zx}$) and a higher energy doublet e_g ($\mathrm{d}_{x^2-y^2}, \mathrm{d}_{z^2}$). The separation energy between these sets is the crystal field splitting energy (Δ_o). If the ligand is a weak field ligand, Δ_o is smaller than the electron pairing energy (P), resulting in a high-spin configuration that follows Hund's rule.

Solution:
Step 1: Determine the oxidation state of the cobalt ion in $[\mathrm{CoF_6}]^{3-}$. Fluoride is a monovalent anionic ligand (-1). Let x be the oxidation state of Co:
$x + 6(-1) = -3 \implies x = +3.$

Step 2: Write out the ground state electronic configuration for the Co^{3+} ion. Neutral cobalt has an atomic number of 27 ($[Ar]4s^2 3d^7$). Removing three electrons yields a $3d^6$ configuration.

Step 3: Assess the ligand field strength. Fluoride (F^-) is a weak field ligand located near the bottom of the spectrochemical series. Consequently, the splitting energy is less than the pairing energy ($\Delta_o < P$).

Step 4: Distribute the 6 electrons among the split d-orbitals according to Hund's rule for a high-spin field. Fill the lower t_{2g} level with 3 electrons first, then place the next 2 electrons singly into the higher e_g level before pairing the 6th electron in the t_{2g} set.

Step 5: Count the final configuration: the t_{2g} orbitals hold 4 electrons and the e_g orbitals hold 2 electrons, which gives the electronic configuration $t_{2g}^4 e_g^2$.

Final Answer: $\boxed{t_{2g}^4 e_g^2}$

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept:

According to Faraday's Second Law of Electrolysis, when the same quantity of electricity is passed through several electrolytic solutions connected in series, the masses of the substances liberated at the electrodes are directly proportional to their chemical equivalent weights (E). The equivalent weight is defined as the atomic mass divided by the valency or number of electrons (z) required to reduce the respective metal ion: $E = \frac{\text{Atomic Mass}}{z}$.

Solution:

Step 1: Identify the cations and determine their respective oxidation charges in the three solutions connected in series:
In $AgNO_3$, the cation is Ag^+ ($z = 1$).
In $CuSO_4$, the cation is Cu^{2+} ($z = 2$).
In $AlCl_3$, the cation is Al^{3+} ($z = 3$).

Step 2: Write out the reduction half-reactions occurring at the cathodes:
$Ag^+ + 1e^- \longrightarrow Ag$
$Cu^{2+} + 2e^- \longrightarrow Cu$
$Al^{3+} + 3e^- \longrightarrow Al$

Step 3: Calculate the number of moles of electrons required to deposit 1 mole of each metal. Passing 1 Faraday of electricity supply exactly 1 mole of electrons.

Step 4: Determine the molar amounts of each metal deposited by 1 mole of electrons:
Moles of Ag = $\frac{1}{1}$ = 1 mole
Moles of Cu = $\frac{1}{2}$ = 0.5 moles
Moles of Al = $\frac{1}{3}$ = 0.333 moles

Step 5: Find the simplest whole-number ratio of these molar amounts:
Ratio = $1 : \frac{1}{2} : \frac{1}{3}$.
Multiply the entire ratio by 6 to clear the fractions:
Ratio = 6 : 3 : 2.

Final Answer: $\boxed{6 : 3 : 2}$

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

Go Back to Question 20

Q21.

Solution

Concept:
Sugars are classified as reducing or non-reducing based on their ability to reduce Fehling's or Tollen's reagents. A sugar behaves as a reducing agent if it contains a free, unlinked anomeric carbon atom that can open into a reactive aldehyde or ketone form in solution. If the anomeric carbons of the constituent monosaccharide units are locked in a glycosidic bond, the sugar cannot form an open-chain structure with a free carbonyl group, making it non-reducing.

Solution:
Step 1: Evaluate glucose. Glucose is a monosaccharide containing a free aldehyde group at carbon-1, making it a strong reducing sugar.

Step 2: Evaluate maltose. Maltose is a disaccharide composed of two α-D-glucose units linked by an $\alpha(1 \rightarrow 4)$ glycosidic bond. The anomeric carbon of the second glucose unit remains free, allowing it to act as a reducing sugar.

Step 3: Evaluate lactose. Lactose is a disaccharide composed of β-D-galactose and β-D-glucose linked via a $\beta(1 \rightarrow 4)$ bond. Its glucose residue retains a free anomeric center, making it a reducing sugar.

Step 4: Evaluate sucrose. Sucrose is a disaccharide composed of α-D-glucose and β-D-fructose. The glycosidic linkage is formed between the anomeric carbon-1 of glucose and the anomeric carbon-2 of fructose: $\alpha(1 \rightarrow 2)$. Because both anomeric centers are locked in the glycosidic bond, sucrose cannot open into a free carbonyl form, making it a non-reducing sugar.

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

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

Go Back to Question 21

Q22.

Solution

Concept:

According to Molecular Orbital Theory (MOT), the electronic configurations of homonuclear diatomic molecules are constructed by filling molecular orbitals in order of increasing energy. A species is diamagnetic if all its electrons are completely paired, whereas it is paramagnetic if it contains one or more unpaired electrons. The bond order is calculated using the formula: 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.

Solution:

Step 1: Evaluate option (A), O_2^+. The neutral O_2 molecule has 16 electrons, so O_2^+ has 15 electrons. Its valence molecular orbital configuration is $\sigma_{2p_z}^2 \pi_{2p_x}^2 \pi_{2p_y}^2 \pi_{2p_x}^{*1}$. This configuration contains 1 unpaired electron, making it paramagnetic. Its bond order is $\frac{10-5}{2} = 2.5$, which is fractional but paramagnetic.

Step 2: Evaluate option (B), He_2^+. Helium has 2 electrons, so He_2^+ has $2 + 2 - 1 = 3$ electrons. Its molecular orbital configuration is $\sigma_{1s}^2 \sigma_{1s}^{*1}$. This leaves 1 unpaired electron in the antibonding orbital, making it paramagnetic. Its bond order is $\frac{2-1}{2} = 0.5$.

Step 3: Evaluate option (C), H_2^-. The molecular ion H_2^- contains 3 electrons, giving it the configuration $\sigma_{1s}^2 \sigma_{1s}^{*1}$. This also leaves 1 unpaired electron, making it paramagnetic, with a bond order of $\frac{2-1}{2} = 0.5$.

Step 4: Review the results. All three species (O_2^+, He_2^+, and H_2^-) contain an odd number of electrons, which means they must have at least one unpaired electron and are therefore paramagnetic. None of them are diamagnetic with a fractional bond order, so option (D) is the correct choice.

Final Answer: None of these

Answer: (D)

Go Back to Question 22

Q23.

Solution

Concept:

An ideal solution is defined as a solution that obeys Raoult's Law across the entire range of concentrations and temperatures. In an ideal solution, the intermolecular cohesive forces between the different components (A – B interactions) are identical in magnitude to the forces within the pure components (A – A and B – B interactions). Consequently, mixing the components causes no structural or thermal changes.

Solution:

Step 1: Analyze ΔV_{mixing}. Because the packing efficiency and intermolecular distances remain unchanged upon forming an ideal solution, the total volume is simply the sum of the individual volumes, meaning $\Delta V_{\text{mixing}} = 0$.

Step 2: Analyze ΔH_{mixing}. Because the energy required to break old bonds equals the energy released when forming new interactions, no heat is absorbed or released, meaning $\Delta H_{\text{mixing}} = 0$.

Step 3: Analyze the deviation from Raoult's Law (ΔP). By definition, an ideal solution obeys Raoult's law perfectly, so there is zero deviation ($\Delta P = 0$).

Step 4: Analyze the entropy of mixing (ΔS_{mixing}). Mixing two distinct pure substances increases the disorder of the system due to the larger volume and more configurations available to the molecules. According to the laws of thermodynamics, the diffusion and mixing of substances is a spontaneous process, so the entropy change must be strictly positive: $\Delta S_{\text{mixing}} > 0$. Therefore, ΔS_{mixing} cannot be zero.

Final Answer: $\boxed{\Delta S_{\text{mixing}}}$

Answer: (C)

Go Back to Question 23

Q24.

Solution

Concept:

Primary aromatic amines react with nitrous acid at low temperatures ($0 - 5°C$) to form stable diazonium salts in a process called diazotization. The resulting diazonium group ($-N_2^+Cl^-$) is an excellent leaving group and can be replaced by various nucleophiles (such as halides or cyanides) using copper(I) salts as catalysts, a transformation known as the Sandmeyer reaction.

Solution:

Step 1: Formulate the first reaction stage. Aniline ($C_6H_5NH_2$) reacts with ice-cold nitrous acid ($NaNO_2$ + HCl) to form benzene diazonium chloride, which is compound X:

$$C_6H_5NH_2 + NaNO_2 + 2HCl \xrightarrow{0-5°C} C_6H_5N_2^+Cl^- + NaCl + 2H_2O.$$

Step 2: Identify compound X as $C_6H_5N_2^+Cl^-$.

Step 3: Formulate the second reaction stage. When benzene diazonium chloride (X) is treated with cuprous cyanide (CuCN), the nitrile ion (−CN) replaces the diazonium group, releasing nitrogen gas. This produces compound Y:

$$C_6H_5N_2^+Cl^- + CuCN \xrightarrow{\Delta} C_6H_5CN + N_2\uparrow + CuCl.$$

Step 4: Identify compound Y as C_6H_5CN, which is systematically named benzonitirle (or cyanobenzene).

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

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

Go Back to Question 24

Q25.

Solution

Concept:

Noble gases exist as isolated, monoatomic atoms because they have closed-shell valence electron configurations. The only intermolecular forces acting between these non-polar monoatomic particles are weak transient London dispersion forces. The strength of these dispersion forces depends on the polarizability of the electron cloud, which increases with the size and atomic mass of the atom.

Solution:

Step 1: Compare the sizes of the noble gases given in the options: He ($Z = 2$), Ne ($Z = 10$), Ar ($Z = 18$), and Kr ($Z = 36$). Atomic size increases down Group 18 from helium to krypton.

Step 2: Relate atomic size to the strength of intermolecular forces. Helium has the smallest atomic size and the fewest electrons, giving it an extremely compact electron cloud with minimal polarizability. Consequently, the London dispersion forces between helium atoms are the weakest of any element.

Step 3: Relate the strength of these forces to boiling points. Breaking weaker intermolecular forces requires less thermal energy, resulting in a lower boiling point.

Step 4: Note that helium has a boiling point of approximately 4.2 K (−268.9°C), which is the lowest boiling point of any known substance on Earth.

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

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

Go Back to Question 25

Q26.

Solution

Concept:

The kinetics of a first-order reaction are governed by the integrated rate law: $k = \frac{2.303}{t} \log_{10}\left(\frac{[A]_0}{[A]_t}\right)$, where $[A]_0$ is the initial concentration and $[A]_t$ is the reactant concentration remaining at time t. The half-life period ($t_{1/2}$) is the time required for the concentration to decrease to exactly half its initial value, expressed as $t_{1/2} = \frac{\ln(2)}{k} = \frac{0.693}{k}$.

Solution:

Step 1: Express the concentration remaining at 99.9% completion ($t_{99.9\%}$). If the initial concentration is 100%, the remaining concentration is:
$[A]_t = 100\% - 99.9\% = 0.1\% = 10^{-3} \times [A]_0$.

Step 2: Substitute this value into the integrated rate equation to solve for $t_{99.9\%}$:
$t_{99.9\%} = \frac{2.303}{k} \log_{10}\left(\frac{[A]_0}{0.1\% \text{ of } [A]_0}\right) = \frac{2.303}{k} \log_{10}\left(\frac{100}{0.1}\right)$.
$t_{99.9\%} = \frac{2.303}{k} \log_{10}(1000) = \frac{2.303}{k} \times 3 = \frac{6.909}{k}$.

Step 3: Write out the equation for the half-life of a first-order reaction:
$t_{1/2} = \frac{2.303 \log_{10}(2)}{k} = \frac{2.303 \times 0.3010}{k} = \frac{0.693}{k}$.

Step 4: Determine the ratio between $t_{99.9\%}$ and $t_{1/2}$:
$\frac{t_{99.9\%}}{t_{1/2}} = \frac{\frac{3\times 2.303}{k}}{\frac{0.3010\times 2.303}{k}} = \frac{3}{0.3010} \approx 9.967 \approx 10.$
Thus, the time required for 99.9% completion is exactly 10 times the half-life of the reaction.

Final Answer: $\boxed{\text{10 times}}$

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

Go Back to Question 26

Q27.

Solution

Concept:

The basicity of aliphatic amines in an aqueous medium is determined by a combination of three competing factors: the inductive effect of the alkyl groups, steric hindrance around the nitrogen atom, and solvation stabilization of the resulting ammonium cation via hydrogen bonding with water molecules. Due to these conflicting trends, the basicity order does not follow a simple linear progression based on substitution level.

Solution:

Step 1: Analyze the +I inductive effect. Alkyl groups are electron-donating, so increasing the number of methyl groups increases the electron density on the nitrogen atom, which should increase basic strength: Tertiary > Secondary > Primary > Ammonia.

Step 2: Analyze the solvation effect in water. The smaller, less substituted ammonium cations can form more hydrogen bonds with water molecules, releasing more hydration energy and stabilizing the conjugate base: Ammonia > Primary > Secondary > Tertiary.

Step 3: Combine these factors for methyl-substituted amines (CH_3). The balancing of the +I effect, solvation, and low steric hindrance makes the secondary amine, dimethylamine [$(CH_3)_2NH$], the strongest base.

Step 4: Compare methylamine (CH_3NH_2) and trimethylamine [$(CH_3)_3N$]. For the small methyl group, the loss of stabilization from solvation and increased steric hindrance in the tertiary amine outweighs its inductive advantage, making trimethylamine less basic than the primary amine. Ammonia (NH_3), which lacks electron-donating alkyl groups, is the weakest base in the series.

Step 5: Establish the final decreasing basicity sequence for methyl-substituted amines in water: $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$.

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

Answer: (A)

Go Back to Question 27

Q28.

Solution

Concept:
In any three-dimensional close-packed crystalline lattice structure containing N constituent atoms per unit cell, two types of interstitial voids are formed between the spheres: octahedral voids and tetrahedral voids. The number of octahedral voids formed in the lattice is always exactly equal to the total number of constituent lattice atoms (N), while the number of tetrahedral voids is always double the number of constituent atoms ($2N$).

Solution:
Step 1: Identify the lattice type mentioned, which is the hexagonal close-packed (hcp) structure.

Step 2: Recall the relationship between the number of atoms and the number of voids. If a close-packed lattice contains N atoms, then:
Number of Octahedral Voids $= N$.
Number of Tetrahedral Voids $= 2N$.

Step 3: Calculate the number of voids per individual atom by dividing the expressions by N:
Octahedral voids per atom $= \frac{N}{N} = 1$.
Tetrahedral voids per atom $= \frac{2N}{N} = 2$.

Step 4: Conclude that the respective values for the number of octahedral and tetrahedral voids per atom are 1 and 2. This ratio remains constant regardless of whether the structure is hcp or fcc.

Final Answer: $\boxed{\text{1 and 2}}$

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

Go Back to Question 28

Q29.

Solution

Concept:
Transition metals exhibit variable oxidation states because the energy difference between their $(n-1)d$ and ns orbitals is extremely small. This allows electrons from both subshells to participate in chemical bonding. The number of oxidation states exhibited by a transition element depends on the number of unpaired d electrons available for sharing and pairing before the electrons begin to pair up.

Solution:
Step 1: Write out the valence shell electronic configurations for the given $3d$ transition elements:
V ($Z = 23$): $3d^3 4s^2$
Cr ($Z = 24$): $3d^5 4s^1$
Mn ($Z = 25$): $3d^5 4s^2$
Fe ($Z = 26$): $3d^6 4s^2$

Step 2: Analyze Manganese (Mn). It sits in the middle of the $3d$ row and has the maximum number of valence electrons available for bonding across both subshells (5 unpaired electrons in the $3d$ subshell plus 2 electrons in the $4s$ subshell, for a total of 7 valence electrons).

Step 3: List the stable oxidation states exhibited by manganese: +2, +3, +4, +5, +6, and +7. This total of six different oxidation states is the highest of any element in the $3d$ transition series.

Step 4: Note that elements after manganese show a decrease in variable oxidation states because the $3d$ electrons begin to pair up, reducing the number of unpaired electrons available for bonding.

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

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

Go Back to Question 29

Q30.

Solution

Concept:

The work done (W) during an isothermal, reversible expansion of an ideal gas is calculated using the thermodynamic formula: $W = -2.303\, nRT \log_{10}\left(\frac{V_2}{V_1}\right)$, where n is the number of moles of the gas, R is the universal gas constant, T is the absolute temperature in Kelvin, V_1 is the initial volume, and V_2 is the final volume. The negative sign follows the IUPAC convention, indicating that work is performed by the system on the surroundings during expansion.

Solution:

Step 1: Identify and list the given parameters from the problem statement:
Number of moles (n) = 2 moles
Universal gas constant (R) = 8.314 J mol^{-1} K^{-1}
Absolute temperature (T) = 300 K
Initial volume (V_1) = 10 L
Final volume (V_2) = 100 L

Step 2: Substitute these values into the integrated work equation:
$W = -2.303 \times 2 \times 8.314 \times 300 \times \log_{10}\left(\frac{100}{10}\right)$.

Step 3: Simplify the logarithmic term:
$\log_{10}\left(\frac{100}{10}\right) = \log_{10}(10) = 1$.

Step 4: Perform the multiplication:
$W = -2.303 \times 2 \times 8.314 \times 300 \times 1$.
$W = -4.606 \times 2494.2 = -11488.28$ J.

Step 5: Convert the calculated work from Joules to kilojoules (kJ):
$W = \frac{-11488.28}{1000}$ kJ ≈ -11.5 kJ.

Final Answer: $\boxed{-11.5 \text{ kJ}}$

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept:
The synthesis of salicylaldehyde from phenol using chloroform and an aqueous alkali is an electrophilic aromatic substitution reaction known as the Reimer-Tiemann reaction. The true reacting electrophile in this transformation is dichlorocarbene ($:CCl_2$), a neutral but highly electron-deficient reactive intermediate generated in situ by the alpha-elimination of a hydrogen chloride molecule from chloroform in the presence of a strong base.

Solution:
Step 1: Analyze the reaction steps. Phenol is treated with chloroform ($CHCl_3$) and aqueous sodium hydroxide (NaOH). The base deprotonates phenol to form a more reactive phenoxide ion, and simultaneously deprotonates chloroform to generate the dichlorocarbene electrophile ($:CCl_2$).

Step 2: The phenoxide ion attacks the dichlorocarbene intermediate, primarily at the ortho position due to a coordinating matrix effect. This forms a substituted benzal chloride intermediate.

Step 3: The alkaline reaction medium hydrolyzes the two geminal chlorine atoms on the side chain into an unstable gem-diol intermediate, which spontaneously loses a water molecule to form a formyl group ($-CHO$).

Step 4: Subsequent acidification converts the sodium phenoxide salt back into a phenol group, yielding ortho-hydroxybenzaldehyde, commonly known as salicylaldehyde. This specific sequence defines the Reimer-Tiemann reaction.

Final Answer: $\boxed{\text{Reimer-Tiemann reaction}}$

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept:

During metallurgical extraction in a blast furnace, a chemical flux is added to react with non-fusible rocky impurities present in the ore, converting them into a fusible, low-density molten mass called slag. In the extraction of iron from hematite, the primary impurity is acidic silicon dioxide (silica, SiO_2). Therefore, a basic flux like limestone ($CaCO_3$) must be introduced to neutralize it.

Solution:

Step 1: Identify the active components in the blast furnace. The impurity present in the hematite ore is acidic sand/silica (SiO_2).

Step 2: Analyze the behavior of the added flux. Limestone ($CaCO_3$) decomposes at high temperatures in the upper zones of the blast furnace to form calcium oxide (CaO) and carbon dioxide gas:
$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$.

Step 3: Formulate the slag-forming reaction. The basic calcium oxide (CaO) flux combines with the acidic silicon dioxide (SiO_2) impurity to form a fusible liquid salt, calcium silicate ($CaSiO_3$):
$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$.

Step 4: Identify this molten calcium silicate ($CaSiO_3$) as the principal slag. Because it is less dense than molten iron, it floats on top of the liquid metal layer, protecting the iron from re-oxidation and allowing it to be tapped off separately.

Final Answer: $\boxed{CaSiO_3}$

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept:

The solubility product constant (K_{sp}) describes the equilibrium established between a dissolved ionic salt and its undissolved solid phase in a saturated aqueous solution. For a sparingly soluble binary salt with the formula MX_2, dissolving the solid yields metal cations and halide anions in a specific stoichiometric ratio. The relationship between K_{sp} and the molar solubility (s) is derived directly from this stoichiometry.

Solution:

Step 1: Write out the balanced dissociation equilibrium equation for the sparingly soluble salt MX_2 in water:

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

Step 2: Express the equilibrium concentrations of the ions in terms of the molar solubility s:

$[M^{2+}] = s$

$[X^-] = 2s$

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

$K_{sp} = [M^{2+}][X^-]^2 = (s) \cdot (2s)^2 = s \cdot 4s^2 = 4s^3$.

Step 4: Substitute the given numerical value of K_{sp} into the equation to solve for s:

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

$s^3 = \frac{3.2\times10^{-11}}{4} = 0.8 \times 10^{-11} = 8.0 \times 10^{-12}$.

Step 5: Take the cube root of both sides to find the molar solubility s:

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

Final Answer: $\boxed{2.0 \times 10^{-4}}$

Answer: (A)

Go Back to Question 33

Q34.

Solution

Concept:
Functional isomers are structural isomers that have the same molecular formula but contain completely different functional groups. This structural difference results in distinct chemical and physical properties. Monohydric saturated open-chain alcohols are functional isomers of dialkyl ethers, as both classes share the same general molecular formula, $C_nH_{2n+2}O$.

Solution:
Step 1: Determine the molecular formula of ethyl alcohol (ethanol). Its structural formula is CH_3CH_2OH, which contains 2 carbon atoms, 6 hydrogen atoms, and 1 oxygen atom, giving it the molecular formula C_2H_6O.

Step 2: Evaluate option (A), dimethyl ether. The structural formula of dimethyl ether is $CH_3 - O - CH_3$. Counting its atoms gives 2 carbons, 6 hydrogens, and 1 oxygen atom, resulting in the identical molecular formula C_2H_6O.

Step 3: Compare the functional groups. Ethyl alcohol contains a hydroxyl group ($-OH$), while dimethyl ether contains an ether oxygen linkage ($-O-$). Because they share the same molecular formula but have different functional groups, they are functional isomers.

Step 4: Verify the other choices. Diethyl ether has the formula $C_4H_{10}O$, methyl alcohol is CH_4O, and acetone is a ketone with the formula C_3H_6O. None of these match the molecular formula of ethyl alcohol.

Final Answer: $\boxed{\text{Dimethyl ether}}$

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

Go Back to Question 34

Q35.

Solution

Concept:

The net dipole moment (μ) of a polyatomic molecule depends on both the polarities of its individual chemical bonds and its spatial geometry. The total molecular dipole moment is the vector sum of the individual bond dipole moments. In highly symmetrical molecules, the individual bond dipoles point in opposite directions and cancel each other out completely, resulting in a net dipole moment of zero ($\mu = 0$).

Solution:

Step 1: Analyze BF_3. Boron trifluoride has a trigonal planar geometry (sp^2 hybridized central atom). The three polar $B - F$ bond dipoles point toward the corners of an equilateral triangle at 120° angles, canceling each other out perfectly to give $\mu = 0$.

Step 2: Analyze CCl_4. Carbon tetrachloride has a symmetrical tetrahedral geometry (sp^3 hybridized). The four polar $C - Cl$ bond vectors cancel each other out completely in three dimensions, giving $\mu = 0$.

Step 3: Analyze CO_2. Carbon dioxide is a linear molecule ($O = C = O$, sp hybridized). The two opposing $C = O$ bond dipoles cancel out completely, giving $\mu = 0$.

Step 4: Analyze NF_3. Nitrogen trifluoride has a trigonal pyramidal geometry due to the presence of three bonding pairs and one non-bonding lone pair on the nitrogen atom (sp^3 hybridized). The polar $N - F$ bond dipoles point downward, away from the lone pair vector. Because the geometry is asymmetrical, these vectors do not cancel out, leaving NF_3 with a permanent, non-zero net dipole moment ($\mu \neq 0$).

Final Answer: $\boxed{NF_3}$

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept:
The standard electromotive force (E°_{cell}) of an electrochemical cell is directly linked to the thermodynamic equilibrium constant (K_c) of the underlying redox reaction. This relationship is derived from the Nernst equation at equilibrium ($E_{\text{cell}} = 0$), and is expressed mathematically as: $E^\circ_{\text{cell}} = \frac{2.303\,RT}{nF} \log_{10} K_c$. At a standard temperature of 298 K, the constant term simplifies to: $E^\circ_{\text{cell}} = \frac{0.0591}{n} \log_{10} K_c$.

Solution:
Step 1: Identify the number of electrons (n) transferred in the balanced redox reaction:
$\text{Zn}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu}(s)$.
Zinc loses 2 electrons to form Zn^{2+}, while copper ions gain 2 electrons to form metallic copper. Thus, $n = 2$.

Step 2: Substitute $n = 2$ and the given standard potential $E^\circ_{\text{cell}} = 1.10$ V into the simplified equation:
$1.10 = \frac{0.0591}{2} \log_{10} K_c$.

Step 3: Isolate and solve for the logarithmic term:
$\log_{10} K_c = \frac{1.10 \times 2}{0.0591} = \frac{2.20}{0.0591} \approx 37.22$.

Step 4: Convert the expression from logarithmic form to exponential form to find the order of magnitude of the equilibrium constant:
$K_c = 10^{37.22} \approx 1.6 \times 10^{37}$.
Therefore, the equilibrium constant for this spontaneous reaction is extremely large, on the order of 10^{37}.

Final Answer: $\boxed{10^{37}}$

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept:

In octahedral coordination chemistry, transition metal complexes are classified as inner orbital or outer orbital based on which d-orbitals are utilized in hybridization. Inner orbital complexes utilize the internal $(n-1)d$ orbitals (d^2sp^3 hybridization) and are typically low-spin, whereas outer orbital complexes utilize the external nd orbitals (sp^3d^2 hybridization) and are high-spin. This distribution is dictated by whether the attached ligands are strong field or weak field.

Solution:

Step 1: Evaluate option (A), $[\text{Co}(\text{NH}_3)_6]^{3+}$. Co^{3+} is a $3d^6$ system. Because NH_3 behaves as a strong field ligand for cobalt, it pairs all the electrons, vacating two $3d$ orbitals to form an inner orbital low-spin complex (d^2sp^3).

Step 2: Evaluate option (B), $[\text{Fe}(\text{CN})_6]^{4-}$. Fe^{2+} is a $3d^6$ system. Cyanide (CN^-) is a powerful strong field ligand that forces electron pairing, forming a low-spin inner orbital complex (d^2sp^3).

Step 3: Evaluate option (C), $[\text{Ni}(\text{NH}_3)_6]^{2+}$. Ni^{2+} has a $3d^8$ electronic configuration ($t_{2g}^6 e_g^2$). It contains two unpaired electrons in the e_g subshell. Because these two electrons occupy the two $3d$ orbitals, it is geometrically impossible to vacate them for hybridization, regardless of the ligand field strength.

Step 4: Analyze the hybridization of the nickel complex. To accommodate 6 incoming ligand pairs, the central Ni^{2+} ion must use its outer $4s$, $4p$, and $4d$ atomic orbitals, resulting in an outer orbital sp^3d^2 hybridization. This creates a high-spin complex containing two unpaired electrons.

Final Answer: $\boxed{[\text{Ni}(\text{NH}_3)_6]^{2+}}$

Answer: (C)

Go Back to Question 37

Q38.

Solution

Concept:

Williamson's ether synthesis is an organic reaction used to prepare asymmetrical and symmetrical ethers. The reaction involves a nucleophilic substitution where a sodium alkoxide salt ($R-O^-Na^+$) reacts with an alkyl halide ($R'-X$). This reaction occurs via a concerted bimolecular nucleophilic substitution (S_N2) pathway.

Solution:

Step 1: Identify the reacting species. The nucleophile is an alkoxide ion ($R-O^-$), which carries a negative charge on the oxygen atom and acts as a strong nucleophile and base. The substrate is an alkyl halide ($R'-X$).

Step 2: Analyze the step-by-step mechanism. The alkoxide ion attacks the backside of the carbon atom bonded to the halogen atom. This single-step, concerted mechanism forms a transition state where the new $C-O$ bond forms at the same time the old $C-X$ bond breaks.

Step 3: Identify the kinetic pathway. Because the rate-determining transition state involves both the nucleophilic alkoxide and the alkyl halide substrate, the reaction follows second-order kinetics, defining an S_N2 pathway.

Step 4: Note that because this is an S_N2 mechanism, it is highly sensitive to steric hindrance. The reaction works best when the alkyl halide substrate is primary (1°). If a tertiary alkyl halide is used instead, the strongly basic alkoxide ion causes an elimination reaction (E2) to occur preferentially, yielding an alkene rather than an ether.

Final Answer: $\boxed{S_N2 \text{ pathway}}$

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

Go Back to Question 38

Q39.

Solution

Concept:
The spontaneity of a chemical process under conditions of constant temperature (T) and pressure (P) is determined by the Second Law of Thermodynamics, which can be evaluated using Gibbs free energy (G). Gibbs free energy combines the effects of enthalpy (heat changes) and entropy (disorder changes) into a single thermodynamic criterion: $\Delta G = \Delta H - T\Delta S$.

Solution:
Step 1: State the definitive free energy criterion for spontaneity. For any process occurring at constant temperature and pressure, the change in Gibbs free energy (ΔG) must be negative ($\Delta G < 0$). This means a spontaneous process always leads to a decrease in the free energy of the system.

Step 2: Evaluate option (A), $\Delta H < 0$. An exothermic reaction ($\Delta H < 0$) often favors spontaneity, but it is not a required condition. For example, endothermic processes like ice melting at room temperature are spontaneous because they are driven by a large positive entropy change ($T\Delta S > \Delta H$).

Step 3: Evaluate option (B), $\Delta S > 0$. An increase in system entropy favors spontaneity, but it is not a sufficient condition on its own, as a highly endothermic enthalpy change can override a positive entropy term.

Step 4: Conclude that while individual changes in enthalpy or entropy can influence a process, a negative change in Gibbs free energy ($\Delta G < 0$) is the sole absolute requirement for spontaneity at constant T and P.

Final Answer: $\boxed{\Delta G < 0}$

Answer: (C)

Go Back to Question 39

Q40.

Solution

Concept:
The p-block elements exhibit unique periodic trends and chemical properties influenced by their electron configurations, atomic radii, and the presence or absence of accessible d-orbitals in their valence shells. Elements in the second period (such as N and O) are restricted in their maximum valency because they lack available d-orbitals, preventing them from expanding their octets unlike the heavier elements in their groups.

Solution:
Step 1: Analyze statement (A). Due to the inert pair effect, the heavier post-transition elements like lead (Pb) show increased stability in an oxidation state two units lower than their maximum group valency. Therefore, Pb^{2+} compounds (PbX_2) are more stable than Pb^{4+} compounds (PbX_4). This statement is correct.

Step 2: Analyze statement (B). Nitrogen has a valence configuration of $2s^22p^3$. Because there are no $2d$ orbitals, it has a maximum of four bonding orbitals (one $2s$ and three $2p$), limiting its maximum covalency to 4 (as seen in NH_4^+). This statement is correct.

Step 3: Analyze statement (C). Down Group 15, the $M - H$ bond length increases and bond dissociation enthalpy drops significantly. Because BiH_3 has the weakest $M - H$ bond, it readily releases hydrogen atoms, making it the strongest reducing agent in the group. This statement is correct.

Step 4: Analyze statement (D). Oxygen has a valence shell configuration of $2s^22p^4$. Like nitrogen, it lacks vacant d-orbitals, restricting its maximum covalency to 4 (though it typically exhibits a valency of 2). Oxygen cannot form 6 covalent bonds, making statement (D) incorrect.

Final Answer: $\boxed{\text{Oxygen shows a maximum covalency of 6.}}$

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

Go Back to Question 40

Q41.

Solution

Concept:
Ozonolysis is an organic reaction that oxidatively cleaves the carbon-carbon double bonds in alkenes. Treating an alkene with ozone (O_3) forms a cyclic ozonide intermediate. Subsequent reductive workup using zinc dust and water (Zn/H_2O) cleaves this ozonide intermediate, converting the carbons of the original double bond into carbonyl groups ($> C = O$) without causing further oxidation to carboxylic acids.

Solution:
Step 1: Draw out the structural formula of the starting material, 2-methylbut-2-ene:
$(CH_3)_2C = CH - CH_3$.

Step 2: Locate the carbon-carbon double bond. The double bond links carbon-2 and carbon-3:
Carbon-2 is bonded to two methyl groups: $(CH_3)_2C =$.
Carbon-3 is bonded to a hydrogen atom and a methyl group: $= CH - CH_3$.

Step 3: Simulate the oxidative cleavage during ozonolysis. Visually break the $C = C$ double bond and attach an oxygen atom to each of the two carbonyl carbons:
The carbon-2 fragment becomes: $(CH_3)_2C = O$.
The carbon-3 fragment becomes: $O = CH - CH_3$.

Step 4: Name the resulting carbonyl compounds:
$(CH_3)_2C = O$ is propanone, commonly known as acetone.
CH_3CHO is ethanal, commonly known as acetaldehyde.

Step 5: Conclude that the reductive ozonolysis of 2-methylbut-2-ene yields a mixture of propanone and ethanal.

Final Answer: $\boxed{\text{Propanone and Ethanal}}$

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

Go Back to Question 41

Q42.

Solution

Concept:

The elevation of boiling point (ΔT_b) is a colligative property, meaning its magnitude depends solely on the total concentration of solute particles in the solution. For a solution containing a non-volatile, non-electrolyte solute, the boiling point elevation is directly proportional to the molality (m) of the solution: $\Delta T_b = K_b \cdot m$, where K_b is the molal ebullioscopic constant of the solvent.

Solution:

Step 1: Calculate the boiling point elevation (ΔT_b) of the solution. The boiling point of pure water is 100°C, and the solution boils at 100.52°C:

$\Delta T_b = T_{\text{solution}} - T^{\circ}_{\text{solvent}} = 100.52^{\circ}\text{C} - 100.00^{\circ}\text{C} = 0.52^{\circ}\text{C}$ (or 0.52 K).

Step 2: Write out the complete formula for molality (m) and substitute it into the colligative property equation:

$\Delta T_b = K_b \times \left(\frac{\text{Mass of solute in g}}{\text{Molar Mass of solute}} \times \frac{1000}{\text{Mass of solvent in g}}\right)$.

Step 3: Substitute the given values into the equation:

$\Delta T_b = 0.52$ K

$K_b = 0.52$ K kg mol^{-1}

Mass of solute $= 10.2$ g

Mass of solvent (water) $= 100$ g

$0.52 = 0.52 \times \left(\frac{10.2}{M} \times \frac{1000}{100}\right)$.

Step 4: Simplify the equation by canceling 0.52 from both sides:

$1 = \frac{10.2}{M} \times 10$.

$1 = \frac{102}{M}$.

Step 5: Solve for the unknown molar mass (M):

$M = 102$ g mol^{-1}.

Final Answer: $\boxed{102 \text{ g mol}^{-1}}$

Answer: (B)

Go Back to Question 42

Q43.

Solution

Concept:

The ability of an element to expand its valence shell and form hypervalent compounds (such as pentahalides or hexahalides) depends on the availability of vacant, energetically accessible d-orbitals in its outermost shell. Elements belonging to the second period of the periodic table are limited to a maximum of 8 valence electrons because their outermost shell contains only s and p subshells ($n = 2$). Heavy elements in the third period and below possess vacant d-orbitals, allowing them to expand their octets.

Solution:

Step 1: Identify the positions and electron configurations of the elements listed in the options, which all belong to Group 15 (the Nitrogen family):
N ($Z = 7$): $1s^2 2s^2 2p^3$ (Period 2)
P ($Z = 15$): $[Ne]3s^2 3p^3$ (Period 3)
As ($Z = 33$): $[Ar]3d^{10} 4s^2 4p^3$ (Period 4)
Sb ($Z = 51$): $[Kr]4d^{10} 5s^2 5p^3$ (Period 5)

Step 2: Analyze Nitrogen (N). As a second-period element, its valence shell has a principal quantum number of $n = 2$, which contains only one $2s$ orbital and three $2p$ orbitals. Because there is no such thing as a $2d$ subshell, nitrogen has a maximum of four bonding orbitals, limiting its covalency to 4. It cannot expand its octet to form 5 covalent bonds, meaning nitrogen cannot form a pentachloride (NCl_5).

Step 3: Analyze the remaining elements (P, As, and Sb). These elements belong to the third period and below, so they possess vacant outermost d-orbitals ($3d, 4d, 5d$). They can unpair their valence s-electrons and promote them into these vacant d-orbitals, enabling them to show a covalency of 5 and form stable pentachlorides (PCl_5, $AsCl_5$, $SbCl_5$).

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

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

Go Back to Question 43

Q44.

Solution

Concept:
The Cannizzaro reaction is a redox disproportionation reaction characteristic of aldehydes that lack alpha-hydrogen (α-H) atoms. When treated with a concentrated base, these aldehydes undergo a self-redox reaction where one molecule is reduced to a primary alcohol and another molecule is simultaneously oxidized to a carboxylic acid salt. If an aldehyde contains any α-hydrogen atoms, it will preferentially undergo an aldol condensation reaction due to the acidity of those protons.

Solution:
Step 1: Evaluate option (A), Formaldehyde (HCHO). The carbonyl carbon is bonded only to hydrogen atoms. It has no α-carbon and therefore no α-hydrogen atoms, so it undergoes the Cannizzaro reaction.

Step 2: Evaluate option (B), Benzaldehyde (C_6H_5CHO). The carbonyl group is attached to a benzene ring carbon that forms three bonds within the ring and one bond to the carbonyl group, leaving it with zero attached hydrogen atoms. Lacking α-hydrogens, it undergoes the Cannizzaro reaction.

Step 3: Evaluate option (D), Trimethylacetaldehyde [Pivalaldehyde, $(CH_3)_3CCHO$]. The α-carbon is fully bonded to three methyl groups, meaning it carries no hydrogen atoms. Lacking α-hydrogens, it also undergoes the Cannizzaro reaction.

Step 4: Evaluate option (C), Acetaldehyde (CH_3CHO). The α-carbon is a methyl group containing three α-hydrogen atoms. When treated with a strong base, the base deprotonates one of these acidic α-hydrogens to form a reactive enolate nucleophile, driving an aldol condensation reaction instead. Therefore, acetaldehyde does not undergo Cannizzaro's reaction.

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

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

Go Back to Question 44

Q45.

Solution

Concept:

The units of a reaction's rate constant (k) vary depending on the total overall order (n) of the reaction. The general formula for the units of a rate constant is given by: Unit = $(\text{mol L}^{-1})^{1-n} \cdot \text{s}^{-1} = \text{mol}^{1-n} \cdot \text{L}^{n-1} \cdot \text{s}^{-1}$, where n represents the cumulative order of the chemical kinetic reaction.

Solution:

Step 1: Identify the given units of the rate constant from the problem text:
Units = $\text{L mol}^{-1}\ \text{s}^{-1} = \text{mol}^{-1} \cdot \text{L}^{1} \cdot \text{s}^{-1}$.

Step 2: Set up a system of equations by matching the exponents of the given units with the exponents from the general formula:
For Lithium/Liters exponent: $n - 1 = 1$.
For Moles exponent: $1 - n = -1$.

Step 3: Solve the linear algebraic equation for the total order n:
$n - 1 = 1 \implies n = 1 + 1 = 2$.

Step 4: Double check by verifying the units of other common reaction orders:
For a zero-order reaction ($n = 0$): $\text{mol L}^{-1}\ \text{s}^{-1}$.
For a first-order reaction ($n = 1$): s^{-1}.
For a second-order reaction ($n = 2$): $\text{L mol}^{-1}\ \text{s}^{-1}$.
This confirms that a rate constant with units of $\text{L mol}^{-1}\ \text{s}^{-1}$ represents a second-order reaction.

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

Answer: (B)

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Q46.

Solution

Concept:
Lanthanoid contraction refers to the steady, gradual decrease in the atomic and ionic radii of elements across the lanthanoid series, from lanthanum ($Z = 57$) to lutetium ($Z = 71$). This contraction happens because inner $4f$ electrons are filled across the series. The diffuse shapes of these $4f$ orbitals mean they provide poor shielding against the increasing nuclear charge, which strongly pulls the outer electron shells inward.

Solution:
Step 1: Define shielding or screening capacity. Shielding capacity describes how effectively inner subshell electrons block the positive nuclear charge from pulling on the outermost valence electrons. The shielding efficiency follows the order: $s > p > d > f$.

Step 2: Analyze the $4f$ subshell. The $4f$ wavefunctions are highly diffuse and spread out in space. Because of this diffuse shape, $4f$ electrons are exceptionally poor at shielding each other from the positive charge of the nucleus.

Step 3: Consider the effect of increasing atomic number across the lanthanoid series. Each successive element adds one proton to the nucleus and one electron to the inner $4f$ subshell.

Step 4: Combine these factors. Because the shielding provided by the $4f$ electrons is imperfect and weak, the increasing nuclear charge exerts a stronger pull on the outermost valence electron shells. This steadily pulls the electron cloud inward, causing a regular contraction in atomic and ionic radii across the series.

Final Answer: $\boxed{\text{Imperfect shielding of one } 4f \text{ electron by another in the same subshell.}}$

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

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Q47.

Solution

Concept:

The silver mirror test utilizes Tollen's reagent [ammoniacal silver nitrate solution, $[Ag(NH_3)_2]^+OH^-$] to distinguish between different classes of carbonyl compounds. Tollen's reagent is a mild oxidizing agent that easily oxidizes aldehydes into carboxylate anions while reducing silver ions to metallic silver, which deposits on the inner glass wall to form a reflective mirror. Ketones are less reactive and do not undergo oxidation with Tollen's reagent, meaning they give a negative result.

Solution:

Step 1: Analyze the scope of the test. The silver mirror test is used to differentiate an aldehyde (positive mirror result) from a ketone (negative result).

Step 2: Evaluate option (A), Acetone and Benzophenone. Both substances are ketones, so neither will react with Tollen's reagent to form a silver mirror. This option is incorrect.

Step 3: Evaluate option (B), Acetaldehyde and Benzaldehyde. Both compounds are aldehydes, so both will yield a positive silver mirror test. This option cannot be used to distinguish between them.

Step 4: Evaluate option (D), Ethanol and Propan-2-ol. Both compounds are alcohols, which do not react with Tollen's reagent.

Step 5: Evaluate option (C), Formaldehyde and Acetone. Formaldehyde is an aldehyde, so it will readily reduce Tollen's reagent to form a shiny silver mirror. Acetone is a ketone, so it will not react. Because one gives a positive result and the other gives a negative result, this test can successfully distinguish between formaldehyde and acetone.

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

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

Go Back to Question 47

Q48.

Solution

Concept:

The cell constant (G^*) is an intrinsic geometric property of an electrolytic conductivity cell. It depends entirely on the physical dimensions of the cell's electrodes. Specifically, the cell constant is defined as the ratio of the distance (l) separating the two parallel electro-conductive plates to the cross-sectional area (A) of those electrode plates: $G^* = \frac{l}{A}$.

Solution:

Step 1: State the definitive mathematical equation used to define the cell constant (G^*):
$G^* = \frac{l}{A}$.

Step 2: Identify the standard metric and international units used for the physical dimensions in the equation:
The distance separating the electrodes (l) is measured in centimeters (cm).
The cross-sectional area of the electrodes (A) is measured in square centimeters (cm^2).

Step 3: Substitute these dimensional units into the geometric formula:
Units of $G^* = \frac{\text{cm}}{\text{cm}^2} = \frac{1}{\text{cm}} = \text{cm}^{-1}$.

Step 4: Note that if SI units are used instead, the distance is measured in meters (m) and the area in square meters (m^2), which gives a cell constant unit of m^{-1}. Among the given choices, cm^{-1} is the correct answer.

Final Answer: $\boxed{\text{cm}^{-1}}$

Answer: (C)

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Q49.

Solution

Concept:

Sucrose ($C_{12}H_{22}O_{11}$) is a common disaccharide non-reducing sugar found in many plants. Disaccharides can undergo chemical or enzymatic hydrolysis, a cleavage reaction where a water molecule breaks the glycosidic bond to release the constituent monosaccharide units. Because sucrose is composed of two different hexose sugars, its hydrolysis yields a specific equimolar mixture of monosaccharides.

Solution:

Step 1: Identify the components and linkage of sucrose. Sucrose is formed by a condensation reaction between an α-D-glucose monomer and a β-D-fructose monomer. The glycosidic linkage forms between the anomeric carbon-1 (C1) of the glucose ring and the anomeric carbon-2 (C2) of the fructose ring.

Step 2: Write out the chemical equation for the hydrolysis reaction, which can be catalyzed by a dilute mineral acid or the enzyme invertase:

$C_{12}H_{22}O_{11}$ (sucrose) + $H_2O \xrightarrow{H^+} C_6H_{12}O_6$ (D-glucose) + $C_6H_{12}O_6$ (D-fructose).

Step 3: Specify the exact stereochemical structures of the products released during this cleavage. The hydrolysis breaks the glycosidic bond, releasing free dextrorotatory α-D-glucose and levorotatory β-D-fructose in an exact $1:1$ molar ratio.

Final Answer: $\boxed{\alpha\text{-D-glucose and }\beta\text{-D-fructose}}$

Answer: (A)

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Q50.

Solution

Concept:

The spatial arrangement and final molecular geometry of a polyatomic molecule or ion are determined by its hybridization and steric number according to Valence Shell Electron Pair Resulsion (VSEPR) theory. The total steric number is calculated by adding the number of sigma-bonded atoms to the number of non-bonding lone pairs on the central atom. While electron geometry includes all electron pairs, the actual molecular shape describes only the spatial arrangement of the atomic nuclei.

Solution:

Step 1: Analyze option (A), SO_2. Sulfur has 6 valence electrons. It forms two double bonds with two oxygen atoms, leaving 1 non-bonding lone pair on the sulfur atom. This gives a steric number of 2 + 1 = 3, which corresponds to sp^2 hybridization and results in a bent or V-shaped molecular geometry.

Step 2: Analyze option (C), O_3. Ozone is structurally similar to SO_2. The central oxygen atom forms bonds with two terminal oxygens and retains 1 lone pair, resulting in sp^2 hybridization and a bent molecular shape.

Step 3: Analyze option (D), NO_2^-. Nitrogen has 5 valence electrons plus 1 from the negative charge, for a total of 6. It forms bonds with two oxygen atoms and retains 1 lone pair. This gives a steric number of 3, resulting in sp^2 hybridization and a bent geometry.

Step 4: Analyze option (B), I_3^-. The central iodine atom has 7 valence electrons plus 1 from the negative charge, for a total of 8 electrons in its valence shell. It forms two single $I - I$ covalent bonds with the two terminal iodine atoms, which leaves 6 non-bonding electrons arranged as 3 lone pairs on the central atom.

Step 5: Determine the geometry of I_3^-. The steric number is 2 bond pairs + 3 lone pairs = 5, which corresponds to sp^3d hybridization and forms a trigonal bipyramidal electronic geometry. To minimize electron repulsions, the 3 lone pairs occupy the equatorial positions at 120° angles, forcing the two terminal iodine atoms into the axial positions at a 180° angle. This results in a perfectly linear molecular shape.

Final Answer: $\boxed{I_3^-}$

Answer: (B)

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Answer Key

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