BITSAT Chemistry Sample Paper-20

Duration: 40 Minutes **Maximum Marks: 90**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+3 marks**. Each incorrect answer carries: **−1** marks. Unattempted questions carry **0** marks.
- Only one option is correct for each question.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. When 2-methyl-2-butene is treated with HBr, the major product is:

(A) 2-bromo-3-methylbutane

(B) 1-bromo-3-methylbutane

(C) 2-bromo-2-methylbutane

(D) 1-bromo-2-methylbutane

Q2. An electron has the quantum numbers $n = 4$, $l = 2$. The maximum number of electrons in this subshell is:

(A) 2

(B) 6

(C) 10

(D) 14

Q3. The shape of PCl_5 molecule is:

(A) Square planar

(B) Trigonal bipyramidal

(C) Octahedral

(D) Tetrahedral

Q4. Which alcohol gives a secondary halide when treated with HBr?

(A) Propan-1-ol

(B) Propan-2-ol

(C) Butan-1-ol

(D) Butan-2-ol

Q5. How many moles of O_2 are needed to completely combust 2 moles of C_2H_6?

(A) 5

(B) 7

(C) 3.5

(D) 10

Q6. Iodine is less reactive than chlorine because:

(A) I_2 is larger and has weaker I–I bond

(B) Cl is more electronegative and more easily reduced

(C) I–halide bond is weaker than Cl–halide bond

(D) I is in a lower period and less reactive

Q7. For the reaction $2NO_2 \rightleftharpoons N_2O_4$, if $K_c = 4.63$ at 298 K, the units of K_c are:

(A) mol L^{-1}

(B) L mol^{-1}

(C) dimensionless

(D) $\text{mol}^2\,\text{L}^{-2}$

Q8. A weak acid HA has $K_a = 1.8 \times 10^{-5}$. The pK_a is:

(A) 4.74

(B) 5.26

(C) 3.21

(D) 6.18

Q9. The reduction of Na^+ in aqueous solution is very difficult because:

(A) Water is reduced preferentially ($E^\circ = -0.83$ V vs $E^\circ(Na^+/Na) = -2.71$ V)

(B) Na is too reactive and explodes

(C) The electrode cannot support high current

(D) Na salts are too soluble

Q10. A reaction is first-order with rate constant $k = 0.1\,s^{-1}$. The time for 50% completion is:

(A) 6.93 s

(B) 10 s

(C) 5 s

(D) 2.3 s

Q11. Acetylene (C_2H_2) has a triple bond. What is the hybridisation of each carbon atom?

(A) sp^2

(B) sp^3

(C) sp

(D) sp^3d

Q12. For a spontaneous reaction at all temperatures, which condition must be satisfied?

(A) $\Delta H < 0$ and $\Delta S < 0$

(B) $\Delta H < 0$ and $\Delta S > 0$

(C) $\Delta H > 0$ and $\Delta S > 0$

(D) $\Delta H > 0$ and $\Delta S < 0$

Q13. The Clemmensen reduction of acetone gives:

(A) Propan-1-ol

(B) Propane

(C) Propan-2-ol

(D) Propanal

Q14. In $[Cu(NH_3)_4]^{2+}$, the coordination number of Cu is:

(A) 2

(B) 4

(C) 6

(D) 8

Q15. Which of the following shows Frenkel defect in ionic crystals?

(A) NaCl

(B) AgBr

(C) AgI

(D) CsCl

Q16. The reaction of benzoic acid with $SOCl_2$ gives:

(A) Benzaldehyde

(B) Benzoyl chloride

(C) Benzene

(D) Benzyl alcohol

Q17. Cellulose and starch both are polysaccharides. They differ in:

(A) Type of monosaccharide unit

(B) Glycosidic linkage type

(C) Solubility in water

(D) None of the above

Q18. Which alkali metal forms a peroxide when burned in excess oxygen?

(A) Li

(B) Na

(C) K

(D) Cs

Q19. Primary amines have higher boiling points than tertiary amines of similar molar mass because:

(A) Primary amines are more polar

(B) Primary amines form hydrogen bonds

(C) Tertiary amines are gases at room temperature

(D) Primary amines are weaker bases

Q20. The freezing point depression is given by $\Delta T_f = iK_f m$. For a non-electrolyte, i is:

(A) 0

(B) 1

(C) 2

(D) Depends on the solute

Q21. Saponification of an ester occurs in:

(A) Acidic medium

(B) Neutral medium

(C) Basic medium

(D) Any pH

Q22. Vulcanisation of rubber involves:

(A) Addition of sulfur to create cross-links

(B) Addition of chlorine gas

(C) Heating without additives

(D) Addition of carbon only

Q23. CO_2 is a linear molecule because:

(A) Carbon is sp^3 hybridised

(B) Carbon is sp hybridised

(C) Carbon forms four bonds

(D) The molecule has no lone pairs

Q24. Which process describes the adhesion of gas molecules to a solid surface?

(A) Absorption

(B) Adsorption

(C) Desorption

(D) Sublimation

Q25. In nitration of benzene with HNO_3/H_2SO_4, the electrophile is:

(A) NO_3^-

(B) NO_2^+

(C) N^{5+}

(D) HNO_3

Q26. In the reaction $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$, permanganate is:

(A) Oxidised

(B) Reduced

(C) Neither oxidised nor reduced

(D) Both oxidised and reduced

Q27. $[Fe(H_2O)_6]^{3+}$ is pale yellow because:

(A) Fe^{3+} is colourless in solution

(B) d-d transitions in Fe^{3+} absorb yellow light

(C) Water absorbs visible light

(D) Charge-transfer transitions occur

Q28. Cyclopropane is more reactive than other cycloalkanes due to:

(A) Ring strain from the 60° bond angles

(B) High number of C–C bonds

(C) Presence of π bonds

(D) Resonance stabilisation

Q29. The Cannizzaro reaction is specific to aldehydes that:

(A) Have an α-hydrogen atom

(B) Lack an α-hydrogen atom

(C) Are aromatic in nature

(D) Contain a benzene ring

Q30. For a galvanic cell, the cell potential E°_{cell} must be:

(A) Positive for a spontaneous reaction

(B) Negative for a spontaneous reaction

(C) Zero for all reactions

(D) Independent of the electrodes used

Detailed Solutions

Q1.

Solution

Concept: Markovnikov's rule states that in addition reactions to asymmetric alkenes, the hydrogen adds to the carbon with more hydrogens, and the halogen adds to the carbon with fewer hydrogens (more substituted carbon). The carbocation intermediate must be the most stable.

Step 1: 2-methyl-2-butene: $CH_3 - C(CH_3)(CH_2CH_3) = CH_2$. The C=C has one carbon with zero hydrogens (quaternary) and one with two hydrogens.

Step 2: H^+ adds to the terminal (less substituted) carbon, forming a secondary carbocation at the internal carbon: $CH_3 - C^+(CH_3)(CH_2CH_3) - CH_3$ (more stable, 2° carbocation).

Step 3: Br^- attacks the carbocation, forming: $CH_3 - CBr(CH_3)(CH_2CH_3) - CH_3$ = 2-bromo-2-methylbutane.

Trap: Without invoking Markovnikov, students might naively add Br to the terminal carbon, giving the wrong answer. The rule mandates formation of the most stable carbocation (secondary > primary).

Final Answer: 2-bromo-2-methylbutane $\Rightarrow \boxed{C}$

Answer: (C)

Go Back to Q1

Q2.

Solution

Concept:
The distribution of electrons within an atom is governed by quantum numbers, which define the energy levels, shapes, and orientations of atomic orbitals. The principal quantum number n specifies the primary electron shell or energy level. The azimuthal quantum number l, also known as the orbital angular momentum quantum number, defines the subshell shape. Each specific subshell contains a set number of orbitals determined by the magnetic quantum number m_l, and each individual orbital can accommodate a maximum of two electrons with opposing spins according to the Pauli Exclusion Principle.

Solution:

(a) The problem states that the electron has a principal quantum number of $n = 4$ and an azimuthal quantum number of $l = 2$. An azimuthal quantum number of $l = 2$ specifically designates a d-subshell.

(b) To find the number of individual orbitals present within any given subshell, we use the mathematical relationship given by the formula $2l + 1$. Substituting the value of $l = 2$ into this expression yields $2(2) + 1 = 5$ distinct orbitals.

(c) These five individual orbitals correspond directly to the five allowed values of the magnetic quantum number m_l, which range from $-l$ to $+l$, specifically being $-2, -1, 0, +1$, and $+2$.

(d) According to the Pauli Exclusion Principle, a single atomic orbital can hold a maximum capacity of only two electrons, which must possess opposite spin quantum numbers of $+1/2$ and $-1/2$.

(e) Therefore, the maximum capacity of electrons within this entire subshell is calculated by multiplying the number of orbitals by two, giving $5 \times 2 = 10$ electrons. This matches option C.

Final Answer: The maximum number of electrons is 10.

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept:

Valence Shell Electron Pair Repulsion theory dictates that the dimensional geometry of a covalent molecule depends entirely on minimizing the electrostatic repulsion forces separating its valence electron domains. For five-coordinate systems with no non-bonding valence pairs, this energetic optimization produces a highly symmetrical dual-environment structural framework.

Solution:

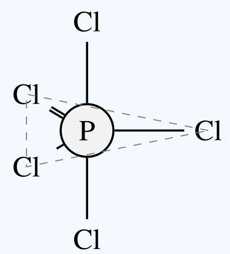
(a) Phosphorus belongs to Group 15 of the periodic table, possessing exactly five valence electrons in its outer electronic shell. In the neutral phosphorus pentachloride molecule, the central phosphorus atom shares these five outer electrons with five distinct chlorine atoms through single sigma bonds.

(b) This distribution establishes a steric coordination number of five, corresponding to an sp^3d hybridization state at the central nucleus with zero unshared lone pairs remaining on the central phosphorus atom.

(c) To maintain maximum spatial separation and minimum electron pair repulsion, the five bonding domains organize themselves into a definitive trigonal bipyramidal molecular configuration.

(d) This geometry places three equatorial chlorine atoms in a single coplanar plane forming a mutual triangle with internal bond angles of exactly 120°.

(e) The remaining two chlorine atoms occupy axial positions projecting straight up and down perpendicular to this central plane, creating a distinct 90° bond angle with the equatorial ligands.



Final Answer:

Trigonal bipyramidal

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: Primary (1°), secondary (2°), tertiary (3°) alcohols are classified by the number of alkyl groups on the carbon bearing the OH. Primary gives primary halide; secondary gives secondary halide.

Step 1: Propan-1-ol: $CH_3CH_2CH_2OH$ (C bearing OH has 2 H's) $\Rightarrow$ primary.

Step 2: Propan-2-ol: $CH_3CH(OH)CH_3$ (C bearing OH has 1 H, 2 alkyl groups) $\Rightarrow$ secondary. HBr converts it to secondary bromide: $CH_3CHBrCH_3$ (isopropyl bromide).

Step 3: Butan-1-ol and butan-2-ol: evaluate similarly. Butan-2-ol is secondary.

Note: Primary alcohols form primary carbocations (very unstable) so undergo SN2 with HBr. Secondary alcohols form secondary carbocations (stable) $\Rightarrow$ SN1 favoured.
Final Answer: Propan-2-ol or butan-2-ol give secondary halides. Best answer: propan-2-ol $\Rightarrow$ $\boxed{B}$

Answer: (B)
Go Back to Q4

Q5.

Solution

Concept: Combustion of hydrocarbons: $C_xH_y + (x + y/4)O_2 \rightarrow xCO_2 + (y/2)H_2O$. Stoichiometry requires balancing molar ratios.

Step 1: Ethane: C_2H_6. Balanced combustion: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$.

Step 2: Molar ratio: $C_2H_6 : O_2 = 2 : 7$. For 1 mole C_2H_6, need $7/2 = 3.5$ moles O_2.

Step 3: For 2 moles C_2H_6: moles $O_2 = 2 \times 3.5 = 7$ moles.

Check: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ (balanced: 4 C on left, 4 on right; 12 H on left, 12 on right; 14 O on left, 8+6=14 on right).
Final Answer: 7 moles $O_2 \Rightarrow \boxed{B}$

Answer: (B)
Go Back to Q5

Q6.

Solution

Concept:
The chemical reactivity profile of halogen group elements decreases downward within the column due to modifications in core atomic parameters. Reactivity trends are governed by how effectively a neutral halogen atom can pull an additional electron into its valence shell from a foreign reducing agent during single-displacement pathways.

Solution:

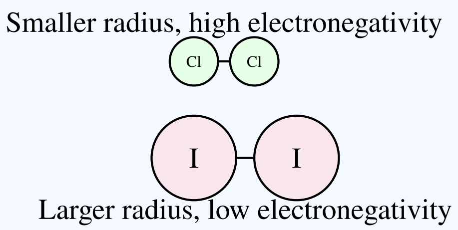
(a) Chlorine and iodine are members of the same periodic group but occupy different rows, with chlorine residing higher in period three and iodine located lower in period five.

(b) Moving downward through the halogen family, the principal quantum number increases, adding successive electron shells that shift the valence boundaries significantly farther away from the positively charged atomic nucleus.

(c) This structural expansion increases the atomic radius of iodine, which significantly diminishes the electrostatic attractive pull exerted by its core nucleus on incoming valence electrons.

(d) Consequently, chlorine exhibits a much higher electronegativity value and a more positive standard reduction potential than iodine, enabling it to attract electrons and undergo reduction far more readily during interactions. at (0,0) [anchor=center] ;

(e) While iodine possesses a weaker covalent bond than chlorine, the greater electronegativity and higher electron affinity of chlorine dictate its superior energetic drive to capture electrons, making iodine less chemically reactive.



Final Answer:

Cl is more electronegative and more easily reduced

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:
The chemical property evaluated here relates to chemical equilibrium in a homogeneous gaseous system. The equilibrium constant expressed in terms of molar concentrations, denoted as K_c, is defined as the ratio of the product of the equilibrium concentrations of the chemical products to that of the reactants, with each concentration raised to the power of its stoichiometric coefficient. The general unit for K_c is derived using the relation $(\text{mol}\,\text{L}^{-1})^{\Delta n_g}$, where Δn_g represents the change in the number of moles of gaseous products minus the gaseous reactants.

Solution:

(a) Consider the given balanced chemical equilibrium equation: $2NO_2(g) \rightleftharpoons N_2O_4(g)$. Both chemical species exist in the gaseous phase.

(b) Write the mathematical expression for the equilibrium constant based on concentration: $K_c = \frac{[N_2O_4]}{[NO_2]^2}$.

(c) Substitute the standard unit of concentration, which is moles per litre ($\text{mol}\,\text{L}^{-1}$), into this equation to determine its dimensional units.

(d) This substitution yields the corresponding unit expression: $\frac{\text{mol}\,\text{L}^{-1}}{(\text{mol}\,\text{L}^{-1})^2}$, which simplifies directly by canceling terms to give $\frac{1}{\text{mol}\,\text{L}^{-1}}$.

(e) Rearranging this expression into standard index notation gives $\text{mol}^{-1}\,\text{L}$, which can be alternatively written as $\text{L}\,\text{mol}^{-1}$, matching option B.

Final Answer: The units of K_c are $\text{L}\,\text{mol}^{-1}$.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:
The chemical property evaluated here belongs to ionic equilibrium and acid-base chemistry. The term pK_a is defined mathematically as the negative logarithm to the base 10 of the acid dissociation constant (K_a) of a weak acid. It serves as a scale to measure the strength of an acid, where a lower pK_a value indicates a stronger acid due to greater dissociation. Logarithmic identities, specifically the product rule $\log(ab) = \log a + \log b$ and the power rule $\log(a^b) = b \log a$, are used to simplify and solve the mathematical expression.

Solution:

(a) The given acid dissociation constant for the weak acid HA is expressed as $K_a = 1.8 \times 10^{-5}$.

(b) We apply the definition formula for the logarithmic scale, which is given by the expression: p$K_a = -\log_{10}(K_a)$.

(c) Substituting the given value of K_a into the equation gives: p$K_a = -\log_{10}(1.8 \times 10^{-5})$.

(d) Using the logarithmic product identity, we expand this expression to get: p$K_a = -[\log_{10}(1.8) + \log_{10}(10^{-5})]$.

(e) Applying the power rule to the second term gives $-5\log_{10}(10)$, which simplifies to -5. Thus, the equation becomes: p$K_a = -[\log_{10}(1.8) - 5] = 5 - \log_{10}(1.8)$.

(f) Knowing the standard logarithmic value where $\log_{10}(1.8) \approx 0.255$, we substitute this back into our simplified relation to compute the final value: p$K_a = 5 - 0.255 = 4.745$. Rounding to two decimal places gives 4.74, matching option A.

Final Answer: The pK_a is 4.74.

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: Reduction potentials determine which species is reduced preferentially. A species with higher (more positive) $E°$ is more easily reduced.

Step 1: Two half-reactions in aqueous solution: (1) $Na^+ + e^- \rightarrow Na$, $E° = -2.71$ V; (2) $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$, $E° = -0.83$ V.

Step 2: The half-reaction with higher $E°$ occurs at the cathode. Since $-0.83 > -2.71$, water is reduced preferentially, not Na^+.

Step 3: At the cathode, H_2 gas is produced. Na metal is not formed from aqueous solution; it can only be obtained by molten salt electrolysis of NaCl (Downs process).

Note: This explains why we cannot get Na metal by aqueous electrolysis—water is a competing reductant.

Final Answer: Water is reduced preferentially (higher $E°$) $\Rightarrow \boxed{A}$

Answer: (A)

Go Back to Q9

Q10.

Solution

Concept:
Chemical reaction kinetics use specific differential rate laws to model concentration changes over elapsed time intervals. For a first-order chemical process, the total time required to consume exactly half of the initial starting material is independent of its starting concentration, relying solely on the specific system velocity constant.

Solution:

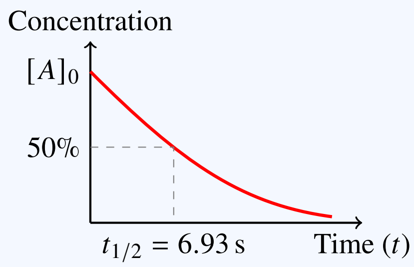
(a) A first-order reaction follows an integrated rate equation expressed mathematically as $k = (2.303/t)\log([A]_0/[A])$, where the remaining quantity of active reactant is monitored over time.

(b) The half-life period represents the exact duration where the remaining substrate concentration reaches exactly fifty percent of its initial value, allowing the fraction parameter to substitute simply as $[A] = 0.5[A]_0$.

(c) Substituting this concentration ratio into the primary integrated equation simplifies the logarithmic term directly to $\log(2)$, which transforms the relationship into the standard half-life expression: $t_{1/2} = \ln(2)/k$.

(d) Utilizing the constant value for the natural logarithm of two reduces the equation to $t_{1/2} = 0.693/k$.

(e) Introducing the given rate constant value of 0.1 inverse seconds yields the calculation: $t_{1/2} = 0.693/0.1$, which equals exactly 6.93 seconds for fifty percent completion.



Final Answer:

$$\boxed{6.93\ \text{s}}$$

Answer: (A)

[Go Back to Question 10]

Q11.

Solution

Concept: Hybridisation is determined by steric number (bonding pairs + lone pairs). Each triple bond (CC) in acetylene contributes 1 bond pair to each carbon.

Step 1: Acetylene: H–CC–H. Each C has 2 bond pairs (1 C–H, 1 CC, counting the triple as 1 pair per linear geometry) and 0 lone pairs. Steric number = 2.

Step 2: Steric number 2 $\Rightarrow$ linear geometry $\Rightarrow$ sp hybridisation. The carbon uses one s orbital and one p orbital.

Step 3: sp hybridisation gives two sp hybrids (linear, 180°) and two unhybridised p orbitals perpendicular to the axis. These form the π bonds of the triple bond.

Note: Linear molecules always suggest sp hybridisation (e.g., CO_2, HCN, C_2H_2).
Final Answer: sp hybridisation $\Rightarrow \boxed{C}$

Answer: (C)

Go Back to Q11

Q12.

Solution

Concept: $\Delta G = \Delta H - T\Delta S$. For spontaneity at all temperatures, $\Delta G < 0$ always.

Step 1: At high T, $-T\Delta S$ dominates. If $\Delta S > 0$, then $-T\Delta S < 0$ (favourable). Combined with $\Delta H < 0$, $\Delta G < 0$ at all T.

Step 2: Analysis of all cases:

- $\Delta H < 0, \Delta S > 0$: $\Delta G < 0$ at all T (Spontaneous always)
- $\Delta H > 0, \Delta S > 0$: $\Delta G < 0$ only at high T (spontaneous above threshold)
- $\Delta H < 0, \Delta S < 0$: $\Delta G < 0$ only at low T (spontaneous below threshold)
- $\Delta H > 0, \Delta S < 0$: $\Delta G > 0$ at all T (never spontaneous)

Conclusion: Only $\Delta H < 0$ and $\Delta S > 0$ ensures spontaneity at all T.
Final Answer: $\Delta H < 0$ and $\Delta S > 0 \Rightarrow \boxed{B}$

Answer: (B)

Go Back to Q12

Q13.

Solution

Concept: Clemmensen reduction converts carbonyl (C=O) to methylene (CH_2) using Zn(Hg) amalgam in concentrated HCl. The reaction proceeds through a hydrazone intermediate.

Step 1: Acetone: CH_3COCH_3. Clemmensen reduction: $CH_3COCH_3 \xrightarrow{Zn(Hg)/conc.HCl} CH_3CH_2CH_3$ (propane).

Step 2: Mechanism: (1) C=O + Zn(Hg) $\rightarrow$ organozinc species; (2) hydrazone formation via intermediate; (3) reduction to CH_2.

Step 3: Alternative (Wolff-Kishner): ketone + hydrazine + base (NaOH, heat). Both remove the oxygen and replace with H_2.

Difference from catalytic hydrogenation: H_2/Ni reduces C=O to CHOH (alcohol), not CH_2. Clemmensen removes O entirely.

Final Answer: Propane ($CH_3CH_2CH_3$) $\Rightarrow \boxed{B}$

Answer: (B)

Go Back to Q13

Q14.

Solution

Concept:
Coordination chemistry defines the coordination number of a central transition metal atom or ion inside a complex as the absolute count of sigma bonds established directly between it and its surrounding ligands. Evaluating this structural property requires examining the total number of donating atoms and the characteristic denticity of each attached coordinating species.

Solution:

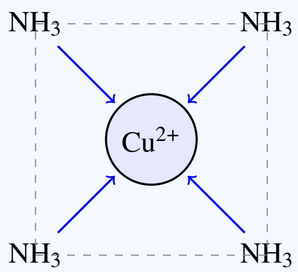
(a) The given chemical formula represents the tetraamminecopper(II) complex cation, which is explicitly written as $[Cu(NH_3)_4]^{2+}$. In this coordination sphere, copper operates as the central transition metal ion surrounded by ammine ligands.

(b) Each ammine molecule (NH_3) serves as a neutral ligand that coordinates to the central copper ion through the single unshared lone pair of electrons residing on its highly electronegative nitrogen atom.

(c) Because each individual ammine ligand can donate only one lone pair to form a single coordinate covalent bond with the metal center, it is classified structurally as a monodentate ligand.

(d) Since the complex framework contains exactly four of these identical monodentate ammine groups bound simultaneously to the single core copper ion, a total of four independent metal-ligand sigma bonds are constructed.

(e) This direct bonding arrangement dictates that the absolute coordination number of the central copper ion is exactly four, arranging the ligands symmetrically into a stable square planar coordination geometry.



Tetrahedral/Square Planar 4-Coordinate Environment

Final Answer:

$$\boxed{4}$$

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: Crystal defects in ionic solids: Schottky (equal numbers of cation and anion vacancies) vs Frenkel (cation displacement to interstitial position, leaving a vacancy).

Step 1: Schottky defect: both cation and anion leave lattice positions, decreasing density. Affects NaCl, CsCl primarily.

Step 2: Frenkel defect: a cation moves to an interstitial site, creating a vacancy at its original site. Density is unchanged. Favoured in compounds with large size difference (e.g., Ag^+ in AgCl, AgBr, AgI).

Step 3: AgI shows Frenkel defect because small Ag^+ can fit into interstitial positions easily. CsCl typically shows Schottky (both ions too large).

Note: Frenkel defects increase ionic conductivity (mobile cations).
Final Answer: AgI shows Frenkel defect $\Rightarrow \boxed{C}$

Answer: (C)

Go Back to Q15

Q16.

Solution

Concept: $SOCl_2$ (thionyl chloride) is a reagent that converts carboxylic acids to their acyl chlorides by replacing –OH with –Cl.

Step 1: Benzoic acid: C_6H_5COOH. Reaction with $SOCl_2$: $C_6H_5COOH + SOCl_2 \rightarrow C_6H_5COCl + SO_2 + HCl$ (by-products: SO_2, HCl).

Step 2: Product is benzoyl chloride: C_6H_5COCl. The carboxyl group (–COOH) becomes an acyl chloride (–COCl).

Step 3: Benzoyl chloride is an acid chloride (acyl halide). It is highly reactive toward nucleophiles and used in subsequent transformations (e.g., acylation, formation of esters/amides).

Other reagents: PCl_5, PCl_3, or DCC also convert COOH to COCl. PBr_3 gives the bromide.
Final Answer: Benzoyl chloride (C_6H_5COCl) $\Rightarrow \boxed{B}$

Answer: (B)

Go Back to Q16

Q17.

Solution

Concept: Polysaccharides are polymers of monosaccharides linked by glycosidic bonds. Cellulose and starch are both polymers of glucose but differ in glycosidic linkage type.

Step 1: Both cellulose and starch are polymers of D-glucose (same monosaccharide unit). They differ in how glucose units are linked.

Step 2: Starch contains $\alpha(1 \rightarrow 4)$ and $\alpha(1 \rightarrow 6)$ glycosidic bonds (branched amylopectin component). Cellulose contains $\beta(1 \rightarrow 4)$ glycosidic bonds (linear).

Step 3: Due to this difference: (a) structure differs (starch branched; cellulose linear); (b) solubility differs (starch soluble in water; cellulose insoluble); (c) enzymes differ (α-amylase breaks starch; cellulase breaks cellulose).

Key: The glycosidic linkage type (α vs β) is the fundamental difference.
Final Answer: Glycosidic linkage type (α vs β) $\Rightarrow \boxed{\text{B}}$

Answer: (B)

Go Back to Q17

Q18.

Solution

Concept: Alkali metals burn in oxygen, but the product depends on the excess of O_2. Limited O_2 gives oxides; excess O_2 may give peroxides (M_2O_2) or superoxides (MO_2).

Step 1: Li: $4Li + O_2 \rightarrow 2Li_2O$ (oxide only). Li forms only oxides, not peroxides.

Step 2: Na: $2Na + O_2 \rightarrow Na_2O_2$ (sodium peroxide, yellowish). Under limited O_2: $4Na + O_2 \rightarrow 2Na_2O$.

Step 3: K, Rb, Cs: form superoxides KO_2 (potassium superoxide, orange-yellow) under excess O_2.

Trend: Smaller alkali metals (Li, Na) form oxides/peroxides; larger ones (K, Rb, Cs) form superoxides. This reflects the stability of the peroxide and superoxide ions relative to the oxide for each metal.
Final Answer: Na forms peroxide (Na_2O_2) in excess $O_2 \Rightarrow \boxed{\text{B}}$

Answer: (B)

Go Back to Q18

Q19.

Solution

Concept: Boiling point depends on intermolecular forces. Primary amines have N–H bonds that form hydrogen bonds; tertiary amines have no N–H and rely only on van der Waals forces.

Step 1: Primary amine (RNH_2): N–H group acts as both H-bond donor (via H) and acceptor (via N lone pair) $\Rightarrow$ extensive hydrogen bonding network.

Step 2: Tertiary amine (R_3N): no N–H; only van der Waals (dipole-induced dipole) interactions. These are much weaker than H-bonds.

Step 3: Result: primary amines have significantly higher boiling points. For example, butylamine (bp 77°C) vs trimethylamine (bp 3°C), both $C_4H_{11}N$.

Note: Secondary amines (R_2NH) have intermediate boiling points (can form H-bonds but only via one N–H).

Final Answer: Primary amines form hydrogen bonds; tertiary do not $\Rightarrow \boxed{\text{B}}$

Answer: (B)

Go Back to Q19

Q20.

Solution

Concept: Colligative properties depend on the number of dissolved particles, not their identity. The van 't Hoff factor i accounts for dissociation.

Step 1: For a non-electrolyte (e.g., sucrose, ethanol), no dissociation occurs. A single molecule remains as one particle.

Step 2: Therefore, $i = 1$ (one particle per formula unit).

Step 3: For electrolytes, $i > 1$: strong electrolyte NaCl in dilute solution has $i \approx 2$ (dissociates to $Na^+ + Cl^-$). Weak electrolytes have $1 < i < 2$ (partial dissociation).

Note: $\Delta T_f = iK_f m$ shows that freezing point depression depends directly on i. A non-electrolyte with $i = 1$ depresses T_f less than a dissociating salt.

Final Answer: For non-electrolytes, $i = 1 \Rightarrow \boxed{\text{B}}$

Answer: (B)

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Q21.

Solution

Concept:

Saponification describes the base-catalyzed hydrolysis of fatty esters to yield glycerol and corresponding alkali carboxylate salts. Unlike acid-catalyzed pathways that establish reversible thermodynamic equilibria, this transformation drives completely to completion due to stable product formation under appropriate pH conditions.

Solution:

(a) Esters can undergo cleavage under both acidic and alkaline environments. However, the term saponification refers specifically to the irreversible cleavage carried out under strongly alkaline or basic conditions.

(b) The reaction mechanism initiates with a nucleophilic attack by a dissolved hydroxide ion onto the electrophilic carbonyl carbon atom of the ester substrate, forming a transient tetrahedral intermediate.

(c) This unstable intermediate collapses rapidly, displacing an alkoxide leaving group and generating a temporary carboxylic acid molecule directly inside the solution mixture.

(d) Because the reaction occurs within a basic medium, an instantaneous and highly favorable proton transfer transpires between the newly formed carboxylic acid and the strongly basic alkoxide ion.

(e) This neutralisation reaction yields a stable alcohol and a resonance-stabilized carboxylate anion. The continuous removal of free acid locks the process, driving the entire ester conversion irreversibly forward.

$$\text{R-COO-R'} \xrightarrow[\text{Basic Medium}]{OH^-} \text{R-COO}^- + \text{R'-OH}$$

Final Answer:

$$\boxed{\text{Basic medium}}$$

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept: Vulcanisation of rubber involves cross-linking the polymer chains to increase hardness, tensile strength, and resilience. Sulfur is the primary vulcanising agent.

Step 1: Natural rubber is a polymer of isoprene with C=C double bonds. Sulfur atoms form covalent cross-links between adjacent polymer chains via these C=C bonds.

Step 2: The reaction: rubber (with C=C) + S_8 (heat) $\rightarrow$ rubber with S cross-links. Typically 3–5 S atoms per cross-link.

Step 3: Effect: vulcanised rubber is harder, has better tensile strength, lower solubility, and greater elasticity compared to raw rubber. It resists degradation and deformation under stress.

Note: Chlorine or peroxides can also vulcanise rubber, but sulfur is most common and economical.
Final Answer: Vulcanisation involves adding sulfur to create cross-links $\Rightarrow \boxed{A}$

Answer: (A)

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Q23.

Solution

Concept: Molecular shape is determined by hybridisation and VSEPR theory. CO_2 has a linear shape due to sp hybridisation of carbon.

Step 1: Carbon in CO_2 has 4 valence electrons and forms 2 double bonds with O atoms (each C=O counts as 1 bonding pair in terms of geometry).

Step 2: Steric number = 2 (2 bonding regions, 0 lone pairs). This requires sp hybridisation and linear geometry (O–C–O, 180°).

Step 3: The two C=O dipoles point in opposite directions and cancel out $\Rightarrow$ net dipole = 0 $\Rightarrow$ CO_2 is non-polar despite having polar bonds.

Note: sp^3 hybridisation gives tetrahedral (4 regions); sp^2 gives trigonal planar (3 regions); sp gives linear (2 regions).
Final Answer: Carbon is sp hybridised $\Rightarrow \boxed{B}$

Answer: (B)

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Q24.

Solution

Concept: Adsorption is the adhesion of molecules to a surface due to intermolecular forces (van der Waals, electrostatic). Absorption is penetration into the bulk of a material.

Step 1: Adsorption: gas or liquid molecules stick to the surface of a solid (adsorbent). Examples: activated charcoal adsorbing gases, silica gel adsorbing water vapor.

Step 2: Absorption: molecules penetrate into the bulk. Example: sponge absorbing water (water goes into the pores and bulk, not just the surface).

Step 3: Types of adsorption: (a) Physical (physisorption): weak van der Waals forces, reversible; (b) Chemical (chemisorption): strong chemical bonds, often irreversible.

Note: Desorption is the reverse of adsorption (molecules leave the surface). Sublimation is direct conversion of solid to gas without liquid phase.
Final Answer: Adhesion to surface is adsorption $\Rightarrow \boxed{\text{B}}$

Answer: (B)

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Q25.

Solution

Concept: Electrophilic aromatic substitution requires generation of a strong electrophile. In nitration of benzene, HNO_3 is first activated by H_2SO_4.

Step 1: Mechanism: $HNO_3 + H_2SO_4 \rightarrow NO_2^+$ (nitronium ion) $+ HSO_4^- + H_2O$. The NO_2^+ is the electrophile.

Step 2: NO_2^+ has a positive formal charge on nitrogen and is highly electrophilic. It attacks the electron-rich aromatic ring.

Step 3: The aromatic ring attacks NO_2^+, forming a Wheland intermediate, which then loses H^+ to restore aromaticity $\Rightarrow$ nitrobenzene.

Note: Free NO_3^- and HNO_3 are not good electrophiles. The H_2SO_4 protonates HNO_3 to generate NO_2^+.
Final Answer: Electrophile is NO_2^+ (nitronium ion) $\Rightarrow \boxed{\text{B}}$

Answer: (B)

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Q26.

Solution

Concept:
The core principle behind this chemical equation is a reduction-oxidation (redox) reaction, which involves the transfer of electrons between chemical species. To determine whether a substance is oxidised or reduced, we can evaluate either the change in its oxidation state or the gain/loss of electrons during the process. According to the classical definition, oxidation corresponds to the loss of electrons or an increase in the oxidation number, whereas reduction corresponds to the gain of electrons or a decrease in the oxidation number.

Solution:

(a) Consider the given half-reaction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$. We can clearly observe that five moles of electrons ($5e^-$) are explicitly added to the reactant side.

(b) By definition, any chemical process where a chemical species gains electrons is classified as a reduction reaction. Here, the permanganate ion (MnO_4^-) is actively gaining these electrons.

(c) Alternatively, we can analyze the oxidation states of manganese. In the reactant permanganate ion (MnO_4^-), let the oxidation number of manganese be x. Since oxygen typically has an oxidation state of -2, we set up the algebraic equation: $x + 4(-2) = -1$, which yields $x = +7$.

(d) In the product side, manganese exists as a monoatomic ion (Mn^{2+}), which means its oxidation state is equal to its ionic charge, which is $+2$.

(e) Comparing the two states, the oxidation number of manganese decreases significantly from $+7$ to $+2$. A decrease in the oxidation number confirms that the species has undergone reduction. Therefore, permanganate is reduced.

Final Answer:

$$\boxed{\text{(B) Reduced}}$$

Answer: (B)

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Q27.

Solution

Concept: Colour in transition metal complexes arises from *d*-*d* electronic transitions (crystal field splitting) or charge-transfer transitions.

Step 1: $[Fe(H_2O)_6]^{3+}$: Fe^{3+} is d^5 (high-spin). The colour is pale yellow.

Step 2: Explanation: d^5 configuration in octahedral field has all five *d* orbitals singly occupied. Transitions between split t_{2g} and e_g levels are symmetry-forbidden (Laporte rule), so *d*-*d* absorption is weak.

Step 3: The pale yellow colour is due to weak *d*-*d* transitions. Additionally, charge-transfer transitions (O → Fe electron transfer) may contribute to the observed colour.

Note: Fe^{2+} (d^6) is more intensely coloured (green); Fe^{3+} (d^5) is pale yellow. The weak colour of Fe^{3+} is characteristic.

Final Answer: *d*-*d* transitions in Fe^{3+} absorb yellow light (are weak) $\Rightarrow \boxed{B}$

Answer: (B)

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Q28.

Solution

Concept: Ring strain occurs when bond angles deviate from the ideal tetrahedral angle (109.5°). Smaller rings have greater strain.

Step 1: Cyclopropane: C_3H_6, a 3-membered ring. The C–C–C bond angle = 60° (much less than 109.5°). Each C uses sp^3 hybrids, but the geometry forces a 60° angle.

Step 2: Strain energy: The orbital overlap is reduced due to bent sp^3 orbitals. The C–C bonds are weaker (σ overlap is poor). This makes cyclopropane much more reactive than cyclohexane.

Step 3: Cyclopropane undergoes ring-opening reactions readily (e.g., addition of HX, hydration). Relief of ring strain is the driving force.

Note: Cyclopropane is less strained than cyclobutane (90° angle) but more strained than cyclopentane (108° angle).

Final Answer: Ring strain from 60° angles (deviation from 109.5°) $\Rightarrow \boxed{A}$

Answer: (A)

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Q29.

Solution

Concept: The Cannizzaro reaction is a disproportionation where an aldehyde without an α-hydrogen undergoes self-condensation in base to form an alcohol and carboxylic acid.

Step 1: Requirement: Aldehyde must lack an α-hydrogen (no H on the carbon next to the CHO group). Examples: benzaldehyde (Ph–CHO), formaldehyde (H–CHO), pivalaldehyde ((tert-Bu)–CHO).

Step 2: Mechanism: In NaOH, an aldehyde molecule attacks the carbonyl carbon of another aldehyde, forming a β-hydroxy aldehyde (aldol-like intermediate). Since no α-H, the intermediate cannot undergo aldol elimination. Instead, hydride transfer occurs internally.

Step 3: Products: one aldehyde molecule is oxidised to carboxylate ($RCOO^-$), the other is reduced to primary alcohol (RCH_2OH). Net: $2\ RCHO \rightarrow RCH_2OH + RCOO^-$.

Note: With α-hydrogens, regular aldol condensation occurs instead.
Final Answer: Cannizzaro requires no α-hydrogen $\Rightarrow \boxed{B}$

Answer: (B)

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Q30.

Solution

Concept: For a galvanic cell (electrochemical cell that spontaneously produces electricity), the cell potential must be positive.

Step 1: $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$ (standard reduction potentials). For spontaneous reaction: $E^\circ_{cell} > 0$.

Step 2: Thermodynamic relation: $\Delta G = -nFE^\circ$. For spontaneity, $\Delta G < 0 \Rightarrow E^\circ > 0$.

Step 3: If $E^\circ < 0$, the reaction is non-spontaneous in the forward direction. To drive it forward, external potential must be applied (electrolytic cell).

Note: E°_{cell} depends only on the electrodes and their reduction potentials, not on concentrations (which affect E via the Nernst equation).
Final Answer: E°_{cell} must be positive for spontaneity $\Rightarrow \boxed{A}$

Answer: (A)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	C	3	B	4	B	5	B
6	B	7	B	8	A	9	A	10	A
11	C	12	B	13	B	14	B	15	C
16	B	17	B	18	B	19	B	20	B
21	C	22	A	23	B	24	B	25	B
26	B	27	B	28	A	29	B	30	A