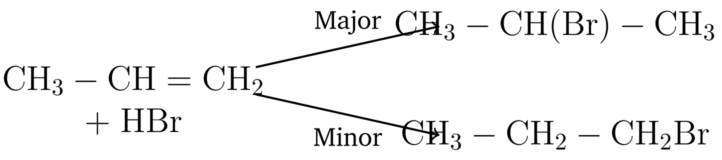
BITSAT Chemistry Sample Paper – 14

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 mark. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. Which of the following reactions best illustrates Markovnikov addition of HBr to propene?



(A) 1-bromopropane is the major product

(B) 2-bromopropane is the major product

(C) Both 1-bromopropane and 2-bromopropane form in equal amounts

(D) Propene does not react with HBr

Q2. Benzene undergoes electrophilic substitution rather than addition because:

(A) Addition reactions are thermodynamically less favoured

(B) Substitution restores the aromatic stabilisation energy (delocalization) of the ring

(C) Benzene lacks the pi electrons needed for addition

(D) The activation energy for addition to benzene is zero

Q3. Which of the following compounds gives a silver mirror with Tollens' reagent but does NOT give a red precipitate with Fehling's solution?

(A) Glucose

(B) Formaldehyde

(C) Benzaldehyde

(D) Acetaldehyde

Q4. The reaction of a primary amine with nitrous acid ($\mathrm{HNO_2}$) at $0–5\,^{\circ}\mathrm{C}$ produces:

(A) A secondary amine

(B) An amide

(C) A diazonium salt

(D) An alcohol directly

Q5. Identify the product of the reaction of ethanoic acid with ethanol in the presence of concentrated $\mathrm{H_2SO_4}$:

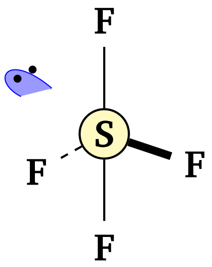
(A) Diethyl ether

(B) Ethyl ethanoate and water

(C) Acetaldehyde and water

(D) Acetic anhydride

Q6. According to VSEPR theory, the shape of $\mathrm{SF_4}$ is:



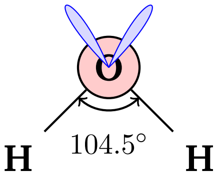
(A) Tetrahedral

(B) See-saw (seesaw)

(C) Square planar

(D) Trigonal pyramidal

Q7. The bond angle in H_2O is less than the tetrahedral angle of $109.5\,°$ primarily because:



(A) Oxygen has a smaller atomic radius than carbon

(B) Two lone pairs on oxygen exert greater repulsion than bonding pairs

(C) The O–H bond is polar covalent

(D) Hydrogen atoms are very small

Q8. In molecular orbital theory, the bond order of O_2^{2-} (peroxide ion) is:

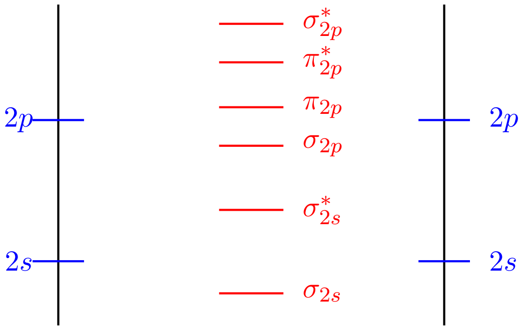
(A) 3

(B) 2

(C) 1

(D) 0

[Refer to the MO diagram below for reference.]



MO Energy Levels (schematic)

Q9. The de Broglie wavelength of an electron accelerated through a potential difference of V volts is proportional to:

(A) V

(B) $\sqrt{V}$

(C) $1/\sqrt{V}$

(D) $1/V$

Q10. Which set of quantum numbers is NOT allowed for an electron in an atom?

(A) $n = 3,\ l = 2,\ m_l = +2,\ m_s = +\frac{1}{2}$

(B) $n = 2,\ l = 1,\ m_l = 0,\ m_s = -\frac{1}{2}$

(C) $n = 4,\ l = 0,\ m_l = +1,\ m_s = +\frac{1}{2}$

(D) $n = 3,\ l = 1,\ m_l = -1,\ m_s = +\frac{1}{2}$

Q11. The correct order of acidic strength among the oxoacids of chlorine is:

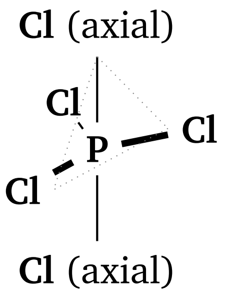
(A) $\mathrm{HOCl > HClO_2 > HClO_3 > HClO_4}$

(B) $\mathrm{HClO_4 > HClO_3 > HClO_2 > HOCl}$

(C) $\mathrm{HClO_3 > HClO_4 > HOCl > HClO_2}$

(D) $\mathrm{HClO_2 > HClO_3 > HClO_4 > HOCl}$

Q12. Which of the following statements about $\mathrm{PCl_5}$ is correct?



(A) All five P–Cl bonds in $\mathrm{PCl_5}$ are equivalent

(B) $\mathrm{PCl_5}$ has a trigonal bipyramidal geometry with two types of P–Cl bonds

(C) $\mathrm{PCl_5}$ is a planar molecule

(D) Phosphorus uses only $3p$ orbitals in bonding

Q13. $4.9\,\mathrm{g}$ of $\mathrm{H_2SO_4}$ is dissolved to make $500\,\mathrm{mL}$ of solution. The molarity of the solution is: (Molar mass of $\mathrm{H_2SO_4} = 98\,\mathrm{g\,mol^{-1}}$)

(A) $0.05\,\mathrm{M}$

(B) $0.10\,\mathrm{M}$

(C) $0.50\,\mathrm{M}$

(D) $1.00\,\mathrm{M}$

Q14. In the reaction $2\mathrm{Al} + 3\mathrm{Cl_2} \to 2\mathrm{AlCl_3}$, how many moles of $\mathrm{AlCl_3}$ are produced from 0.6 mol Al reacting with excess $\mathrm{Cl_2}$?

(A) 0.2 mol

(B) 0.3 mol

(C) 0.6 mol

(D) 0.9 mol

Q15. For the reaction $\mathrm{N_2(g)} + 3\mathrm{H_2(g)} \rightleftharpoons 2\mathrm{NH_3(g)}$, the relation between K_p and K_c at temperature T is:

(A) $K_p = K_c(RT)^2$

(B) $K_p = K_c(RT)^{-1}$

(C) $K_p = K_c(RT)^{-2}$

(D) $K_p = K_c$

Q16. A buffer solution is prepared by mixing $\mathrm{CH_3COOH}$ and $\mathrm{CH_3COONa}$ in 1:1 molar ratio. If $\mathrm{p}K_a$ of acetic acid is 4.74, the pH of the buffer is:

(A) 3.74

(B) 4.74

(C) 5.74

(D) 7.00

Q17. For a spontaneous process at constant temperature and pressure, the correct thermodynamic criterion is:

(A) $\Delta G > 0$

(B) $\Delta G = 0$

(C) $\Delta G < 0$

(D) $\Delta H < 0$ always

Q18. The standard enthalpy of combustion of methane is $-890\,\mathrm{kJ\,mol^{-1}}$. The heat released when $8\,\mathrm{g}$ of methane (molar mass $= 16\,\mathrm{g\,mol^{-1}}$) burns completely is:

(A) $222.5\,\mathrm{kJ}$

(B) $445\,\mathrm{kJ}$

(C) $890\,\mathrm{kJ}$

(D) $1780\,\mathrm{kJ}$

Q19. The standard EMF of the cell $\mathrm{Zn}\,|\,\mathrm{Zn^{2+}}\,||\,\mathrm{Cu^{2+}}\,|\,\mathrm{Cu}$ is $+1.10\,\mathrm{V}$. Given $E^\circ(\mathrm{Cu^{2+}/Cu}) = +0.34\,\mathrm{V}$, what is $E^\circ(\mathrm{Zn^{2+}/Zn})$?

(A) $+0.76\,\mathrm{V}$

(B) $-0.76\,\mathrm{V}$

(C) $+1.44\,\mathrm{V}$

(D) $-1.44\,\mathrm{V}$

Q20. How many faradays of charge are required to deposit $2.7\,\mathrm{g}$ of aluminium (molar mass $= 27\,\mathrm{g\,mol^{-1}}$, $n = 3$) from a molten salt?

(A) 1 F

(B) 0.3 F

(C) 3 F

(D) 0.1 F

Q21. For a first-order reaction, if the initial concentration of the reactant is $[\mathrm{A}]_0$ and the rate constant is k, the half-life $t_{1/2}$ is:

(A) $\dfrac{[\mathrm{A}]_0}{2k}$

(B) $\dfrac{0.693}{k}$

(C) $\dfrac{k}{0.693}$

(D) $\dfrac{2}{k[\mathrm{A}]_0}$

Q22. Which of the following is a reducing sugar?

(A) Sucrose

(B) Maltose

(C) Cellulose

(D) Starch

Q23. The primary structure of a protein refers to:

(A) The three-dimensional folding stabilised by hydrogen bonds

(B) The sequence of amino acids linked by peptide bonds

(C) The coiling into an alpha helix

(D) The association of two or more polypeptide chains

Q24. In a face-centred cubic (FCC) unit cell, the number of atoms per unit cell is:

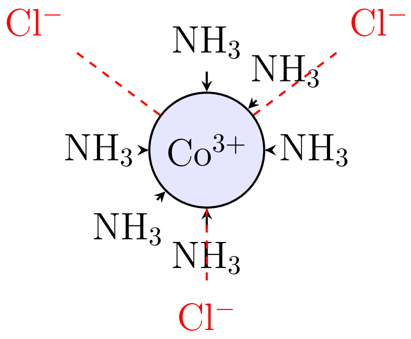
(A) 2

(B) 4

(C) 6

(D) 8

Q25. According to Werner's theory, in the complex $[\mathrm{Co(NH_3)_6}]\mathrm{Cl_3}$, the primary valency of cobalt is:



(A) 3, satisfied by the 3 chloride ions

(B) 6, satisfied by the 6 ammonia ligands

(C) 3, satisfied by the 6 ammonia ligands

(D) 6, satisfied by both chloride and ammonia

Q26. Which of the following properties of lithium makes it anomalous compared to other alkali metals?

(A) It has the highest ionisation enthalpy in Group 1

(B) It reacts explosively with cold water

(C) Its compounds show a diagonal relationship with magnesium

(D) It does not form any oxides

Q27. Adsorption of a gas on a solid surface is generally:

(A) Endothermic, because the gas molecules must gain energy to bind

(B) Exothermic, because the surface energy decreases on adsorption

(C) Neither endothermic nor exothermic

(D) Endothermic only for chemisorption, exothermic for physisorption

Q28. Which of the following alcohols is oxidised by $K_2Cr_2O_7/H_2SO_4$ directly to a carboxylic acid (without stopping at the aldehyde stage under normal conditions)?

(A) 2-methyl-2-propanol (tert-butyl alcohol)

(B) Ethanol

(C) Propan-1-ol

(D) Cyclohexanol

Q29. Identify the IUPAC name of the compound formed when acetylene ($HC \equiv CH$) reacts with one equivalent of HCl:

(A) Chloroethane

(B) Chloroethene (vinyl chloride)

(C) 1,1-dichloroethane

(D) 1,2-dichloroethane

Q30. The below reaction scheme shows the conversion of aniline to fluorobenzene via the Balz–Schiemann reaction.

$$C_6H_5NH_2 \xrightarrow{HNO_2,\ BF_4^-} C_6H_5N_2^+\,BF_4^- \xrightarrow{\Delta} C_6H_5F$$

What is the intermediate in this reaction?

(A) Phenol

(B) Aniline diazonium tetrafluoroborate

(C) Aniline hydrochloride

(D) Benzyne

Detailed Solutions

Q1.

Solution

Concept:
The reaction involves the addition of a polar reagent (HBr) to an unsymmetrical alkene (propene). According to Markovnikov's rule, when an unsymmetrical reagent adds to an unsymmetrical alkene, the negative part of the addendum (Br^-) attaches itself to the carbon atom carrying the fewer number of hydrogen atoms, while the positive part (H^+) goes to the carbon with more hydrogen atoms. This pathway is governed by the formation and stability of the intermediate carbocation.

Solution:
Step 1: Write down the chemical structure of propene. Propene is an unsymmetrical alkene represented as $CH_3 - CH = CH_2$. It contains two vinylic carbons: one with one hydrogen atom ($-CH-$) and one with two hydrogen atoms ($= CH_2$).

Step 2: Analyze the mechanism of electrophilic addition. The first step is the attack of the electrophile (H^+) from HBr on the pi bond. This protonation can yield two distinct carbocation intermediates:
Path A: Protonation at the terminal carbon ($= CH_2$) gives a secondary (2°) carbocation, $CH_3 - CH^+ - CH_3$.
Path B: Protonation at the central carbon ($-CH-$) gives a primary (1°) carbocation, $CH_3 - CH_2 - CH_2^+$.

Step 3: Evaluate carbocation stability. The secondary carbocation has six hyperconjugative hydrogens (from two methyl groups) which stabilize the positive charge through hyperconjugation and inductive effects. The primary carbocation has only two hyperconjugative hydrogens and is significantly less stable.

Step 4: Form the major product. Because the activation energy leading to the more stable 2° carbocation is lower, it forms much faster. In the subsequent step, the nucleophile (Br^-) rapidly attacks this stable secondary carbocation.

$$CH_3 - CH^+ - CH_3 + Br^- \rightarrow CH_3 - CH(Br) - CH_3$$

This results in the exclusive formation of 2-bromopropane as the major regioisomer.

Final Answer: 2-bromopropane is the major product

Answer: (B) Go Back to Question 1

Q2.

Solution

Concept:

Benzene (C_6H_6) is a planar, cyclic conjugated hydrocarbon that possesses a high degree of thermodynamic stability due to aromaticity. According to Hückel's criteria, its six pi electrons are completely delocalized across the ring system, yielding a substantial resonance stabilization energy (around $152\,\mathrm{kJ\,mol^{-1}}$). The chemical reactivity of benzene is dictated by the preservation of this stable, low-energy closed shell of pi electrons.

Solution:

Step 1: Examine what happens during a hypothetical addition reaction. If an electrophilic reagent adds across one of the formal double bonds of benzene, two new sigma bonds would form at the expense of one pi bond. However, this addition would break the continuous cyclic conjugation of the cloud.

Step 2: Evaluate the energy consequences of addition. Breaking the cyclic conjugation destroys the aromaticity entirely, transforming the ring into a non-aromatic conjugated diene system. This results in the complete loss of the massive aromatic stabilization energy, making addition reactions highly unfavorable under ordinary conditions.

Step 3: Examine the substitution pathway. In an electrophilic aromatic substitution ($\mathrm{S_EAr}$) mechanism, an incoming electrophile attacks the ring to form a temporary, non-aromatic carbocation intermediate (the sigma complex or Arenium ion).

Step 4: Analyze the final stage of substitution. The sigma complex rapidly eliminates a proton (H^+) from the sp3 hybridized carbon. The departure of this proton allows the remaining electron pair to re-enter the ring system, instantly regenerating the fully conjugated, cyclic pi cloud.

Step 5: Conclude why substitution is favored. Because the proton elimination step restores the highly stable aromatic configuration and recovers the resonance stabilization energy, substitution is energetically preferred over addition.

Final Answer: Substitution restores the aromatic stabilisation energy (delocalization) of the ring

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:

Tollens' reagent (ammoniacal silver nitrate) and Fehling's solution (alkaline copper sulfate with sodium potassium tartrate) are mild oxidizing agents used to distinguish aldehydes from ketones. Tollens' reagent is a relatively stronger oxidizing agent than Fehling's solution and can oxidize both aliphatic and aromatic aldehydes. Fehling's solution, being a weaker oxidizing agent, can easily oxidize aliphatic aldehydes but fails to oxidize aromatic aldehydes due to structural and electronic constraints.

Solution:

Step 1: Identify the nature of the compounds listed in the options. Glucose, formaldehyde, and acetaldehyde are aliphatic aldehydes (or contain free aliphatic formyl groups in solution). Benzaldehyde (C_6H_5CHO) is a classic aromatic aldehyde where the carbonyl carbon is directly bonded to an sp2 hybridized phenyl ring.

Step 2: Understand the Tollens' test response. Tollens' reagent contains the silver coordination complex $[Ag(NH_3)_2]^+$. It is capable of oxidizing benzaldehyde to the benzoate ion while being reduced to metallic silver, which deposits on the inner wall of the vessel to form a silver mirror. Therefore, benzaldehyde gives a positive Tollens' test.

Step 3: Analyze the Fehling's test mechanism. Fehling's solution contains Cu^{2+} ions complexed with tartrate ligands. The oxidation of an aldehyde requires the abstraction of the formyl hydrogen atom. In aromatic aldehydes like benzaldehyde, the electron-donating resonance effect $(+R)$ of the phenyl ring decreases the electrophilicity of the carbonyl carbon and strengthens the $C - H$ bond of the formyl group via conjugation.

Step 4: Conclude the difference. Due to this resonance stabilization and lower electrophilic reactivity, the weaker oxidizing agent ($\text{Fehling's solution}$) is thermodynamically and kinetically unable to oxidize benzaldehyde under normal test conditions. Thus, no red precipitate of copper(I) oxide (Cu_2O) is observed.

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

$\boxed{\textbf{Answer: (C)}}$ **Go Back to Question 3**

Q4.

Solution

Concept:
The reaction of primary amines with nitrous acid (HNO_2) is highly characteristic and depends significantly on whether the amine is aliphatic or aromatic. Nitrous acid is unstable and must be prepared in situ by reacting sodium nitrite ($NaNO_2$) with a strong mineral acid such as hydrochloric acid (HCl) at low temperatures ($0–5\,^\circ C$). This reaction proceeds via electrophilic attack of the nitrosonium ion (NO^+) on the amine.

Solution:
Step 1: Formulate the active electrophile. When sodium nitrite is mixed with cold hydrochloric acid, nitrous acid forms and undergoes protonation and subsequent dehydration to yield the reactive nitrosonium electrophile:

$$NaNO_2 + HCl \rightarrow HNO_2 + NaCl$$

$$HNO_2 + H^+ \rightleftharpoons H_2O^+ - NO \rightarrow H_2O + NO^+$$

Step 2: Track the nucleophilic attack. The lone pair on the nitrogen atom of the primary amine ($R - NH_2$ or $Ar - NH_2$) attacks the nitrosonium ion to form an N-nitrosamine intermediate.

Step 3: Prototropic shifts and dehydration. The N-nitrosamine undergo rapid tautomerization through a series of proton transfers to yield a diazo-hydroxide intermediate ($R - N = N - OH$). Subsequent protonation of the hydroxyl group followed by the loss of a water molecule leads to the generation of a diazonium cation.

$$R - NH_2 + NO^+ \rightarrow \cdots \rightarrow R - N \equiv N^+ + H_2O$$

Step 4: Analyze the stability at $0–5\,^\circ C$. If the starting material is a primary aromatic amine (like aniline), the resulting benzenediazonium salt is stabilized by resonance with the aromatic ring and remains intact in solution at ice-cold temperatures. If it is an aliphatic primary amine, the alkyldiazonium salt is extremely unstable and decomposes immediately to release nitrogen gas and form a carbocation, which yields an alcohol as a final decomposition product. However, the immediate initial product of the reaction chemistry at this specific temperature range is classified generally as a diazonium salt.

Final Answer: $\boxed{\text{A diazonium salt}}$

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

Go Back to Question 4

Q5.

Solution

Concept:
The interaction between a carboxylic acid and an alcohol in the presence of an acid catalyst is known as Fischer esterification. This reaction is a reversible condensation process where a molecule of water is eliminated to produce an ester. Concentrated sulfuric acid (H_2SO_4) plays a dual role in this process: it acts as a catalytic proton donor to increase the electrophilicity of the carbonyl carbon, and it serves as a dehydrating agent to shift the equilibrium forward according to Le Chatelier's principle.

Solution:
Step 1: Identify the chemical structures of the reactants. Ethanoic acid (acetic acid) is written as CH_3COOH, and ethanol (ethyl alcohol) is written as CH_3CH_2OH or C_2H_5OH.

Step 2: Understand the mechanism. The acid catalyst protonates the carbonyl oxygen of ethanoic acid, making the carbonyl carbon highly electrophilic. The nucleophilic oxygen atom of ethanol then attacks this carbon atom to form a tetrahedral intermediate.

Step 3: Proton transfer and dehydration. A proton shift occurs within the tetrahedral intermediate, turning one of the original carboxylic hydroxyl groups into an excellent leaving group ($-H_2O^+$). The lone pair from an adjacent oxygen expels the water molecule.

Step 4: Final deprotonation to yield the product. Loss of a proton from the oxonium ion restores the acid catalyst and yields the neutral ester product. The balanced chemical equation is represented as follows:

$$CH_3COOH + C_2H_5OH \xrightarrow{\text{conc.}H_2SO_4} CH_3COOC_2H_5 + H_2O$$

The resulting ester is ethyl ethanoate (commonly called ethyl acetate), which possesses a characteristic sweet, fruity odor.

Final Answer: $\boxed{\text{Ethyl ethanoate and water}}$

$\boxed{\textbf{Answer: (B)}}$ **Go Back to Question 5**

Q6.

Solution

Concept:

The Valence Shell Electron Pair Repulsion (VSEPR) theory states that the spatial arrangement of bonds around a central atom depends entirely on the total number of valence shell electron pairs (both bonding and non-bonding pairs) surrounding it. These electron pairs organize themselves in space to minimize mutual electrostatic repulsion and maximize geometric distance.

Solution:

Step 1: Determine the number of valence electrons on the central atom. Sulfur (S) belongs to Group 16 of the periodic table and possesses six valence electrons (ns^2np^4).

Step 2: Count the electrons contributed by the ligands. There are four fluorine (F) atoms, and each monovalent fluorine atom shares one electron to form a single covalent sigma bond with sulfur. This provides four bonding electrons.

Step 3: Calculate the total number of electron pairs (Steric Number).

$$\text{Total valence electrons involved} = 6 \text{ (from S)} + 4 \times 1 \text{ (from F)} = 10 \text{ electrons}$$

$$\text{Steric Number} = \frac{10}{2} = 5 \text{ electron pairs}$$

Step 4: Distribute the electron pairs between bonding and non-bonding states. Since there are 4 fluorine atoms attached, there are exactly 4 bonding pairs (BP) and:

$$\text{Lone pairs (LP)} = \text{Steric Number} - \text{BP} = 5 - 4 = 1 \text{ lone pair}$$

Step 5: Determine the parent geometry and actual shape. A steric number of 5 corresponds to a parent trigonal bipyramidal (TBP) electron-pair geometry. According to VSEPR theory, to minimize strong lone pair-bonding pair ($\text{LP} - \text{BP}$) repulsions, the lone pair must occupy an equatorial position where it experiences fewer 90° interactions. This specific distribution (AX_4E notation) distorts the geometry away from an ideal trigonal bipyramid, leaving the four fluorine atoms arranged in an asymmetric spatial conformation known as a see-saw shape.

Final Answer: See-saw (seesaw)

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:
The geometry and bond angles of a molecule are deeply influenced by the relative repulsive strengths of the electron pairs in the valence shell of the central atom. According to VSEPR theory, the magnitude of electron pair repulsions follows a strict hierarchical order:

$$\text{LP - LP} > \text{LP - BP} > \text{BP - BP}$$

Lone pair electrons are localized closer to the nucleus of the central atom and occupy more space compared to bonding pair electrons, which are constrained between two nuclei.

Solution:
Step 1: Determine the steric hybridization of the oxygen atom in water (H_2O). Oxygen has 6 valence electrons. It forms 2 single sigma bonds with 2 hydrogen atoms, consuming 2 electrons. The remaining 4 electrons form 2 non-bonding lone pairs.

Step 2: Calculate the steric number.

$$\text{Steric Number} = 2 \text{ bonding pairs} + 2 \text{ lone pairs} = 4$$

A steric number of 4 implies sp^3 hybridization, which possesses an ideal tetrahedral parent geometry with standard bond angles of 109.5°.

Step 3: Analyze the repulsive forces in action. In an ideal tetrahedral molecule like methane (CH_4), there are only $\text{BP} - \text{BP}$ repulsions, which are perfectly balanced, maintaining the 109.5° angle. In H_2O, the 2 lone pairs on the oxygen atom exert powerful $\text{LP} - \text{LP}$ repulsion against each other, causing them to expand their spatial boundaries.

Step 4: Quantify the effect on the bond angle. As the lone pairs expand, they exert a strong downward $\text{LP} - \text{BP}$ repulsion against the two $\text{O} - \text{H}$ bonding pairs. This pushes the two $\text{O} - \text{H}$ bonds closer together, significantly compressing the internal $\text{H} - \text{O} - \text{H}$ bond angle down from the ideal tetrahedral value of 109.5° to approximately 104.5°.

Final Answer: Two lone pairs on oxygen exert greater repulsion than bonding pairs

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

Molecular Orbital (MO) theory describes the electronic structure of molecules by constructing molecular orbitals over the entire molecule via the Linear Combination of Atomic Orbitals (LCAO). The bond order, which reflects the thermodynamic stability and strength of a chemical bond, is mathematically evaluated using the formula:

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

where N_b is the total number of electrons residing in bonding molecular orbitals and N_a is the total number of electrons residing in antibonding molecular orbitals.

Solution:

Step 1: Calculate the total electron count for the peroxide ion (O_2^{2-}). A single neutral oxygen atom has an atomic number of 8 and contains 8 electrons. Therefore, a homonuclear diatomic O_2 molecule contains 16 electrons. The peroxide ion carries a net -2 charge, indicating that it has gained 2 additional electrons.

$$\text{Total electrons in } O_2^{2-} = 8 + 8 + 2 = 18 \text{ electrons}$$

Step 2: Fill the molecular orbitals sequentially in increasing order of energy according to the Aufbau principle for heavy diatomic molecules ($Z \geq 8$):

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

Step 3: Enumerate the bonding electrons (N_b). The electrons in non-starred orbitals are:

$$\sigma_{1s}(2) + \sigma_{2s}(2) + \sigma_{2p_z}(2) + \pi_{2p_x}(2) + \pi_{2p_y}(2) = 10 \text{ electrons}$$

Step 4: Enumerate the antibonding electrons (N_a). The electrons in starred orbitals are:

$$\sigma_{1s}^*(2) + \sigma_{2s}^*(2) + \pi_{2p_x}^*(2) + \pi_{2p_y}^*(2) = 8 \text{ electrons}$$

Step 5: Compute the final bond order using the mathematical definition:

$$\text{Bond Order} = \frac{10 - 8}{2} = \frac{2}{2} = 1$$

A bond order of 1 indicates that the peroxide ion is stabilized by a single covalent sigma bond.

Final Answer: $\boxed{1}$

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept:

The dual nature of matter, postulated by Louis de Broglie, asserts that any moving material particle exhibits wave-like characteristics. The fundamental de Broglie relationship relates the wavelength (λ) of a matter wave to its momentum (p) via Planck's constant (h):

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

When a charged particle like an electron is accelerated from rest through an electrostatic potential difference, its gained electrical potential energy is converted entirely into kinetic energy.

Solution:

Step 1: Express the kinetic energy (KE) of an electron accelerated through a potential of V volts. If e represents the elementary charge of the electron, the work done on the particle is given by:

$$\text{KE} = eV$$

Step 2: Relate kinetic energy to momentum (p). We know that kinetic energy can be expressed in terms of mass (m) and velocity (v), or momentum (p), as:

$$\text{KE} = \frac{1}{2}mv^2 = \frac{p^2}{2m} \implies p = \sqrt{2m(\text{KE})}$$

Step 3: Substitute the electrical potential energy expression into the momentum formula:

$$p = \sqrt{2meV}$$

Step 4: Substitute this expression for momentum back into the primary de Broglie equation:

$$\lambda = \frac{h}{\sqrt{2meV}}$$

Step 5: Identify the functional dependency on the potential difference V. Since Planck's constant h, the electron mass m, and the fundamental charge e are invariant physical constants, the equation can be factored as:

$$\lambda \propto \frac{1}{\sqrt{V}}$$

Therefore, the de Broglie wavelength is inversely proportional to the square root of the accelerating voltage.

Final Answer: $\boxed{1/\sqrt{V}}$

Answer: (C) Go Back to Question 9

Q10.

Solution

Concept:

The quantum state of an electron in an atom is completely specified by a set of four quantum numbers: the principal quantum number (n), the azimuthal (orbital angular momentum) quantum number (l), the magnetic quantum number (m_l), and the spin magnetic quantum number (m_s). These values must adhere to strict mathematical boundary conditions derived from the solutions to the Schrödinger wave equation.

Solution:

Step 1: Review the mathematical rules and limits governing each individual quantum number:

1. n must be a positive integer: $n = 1, 2, 3, 4, \ldots$
2. l depends on n and can have any integer value from 0 up to $(n-1)$.
3. m_l depends on l and can take any integer value ranging from $-l$ to $+l$, including zero (giving a total of $2l+1$ values).
4. m_s represent the intrinsic spin orientation and can only ever be either $+\frac{1}{2}$ or $-\frac{1}{2}$.

Step 2: Methodically test Option A: $n = 3, l = 2, m_l = +2, m_s = +\frac{1}{2}$. Here, $l = 2$ is within the allowed range (0 to 2), and $m_l = +2$ is valid since $-2 \leq m_l \leq +2$. This represents an electron in a $3d$ orbital. This set is fully allowed.

Step 3: Methodically test Option B: $n = 2, l = 1, m_l = 0, m_s = -\frac{1}{2}$. Here, $l = 1$ is within the allowed range (0 to 1), and $m_l = 0$ is valid since $-1 \leq m_l \leq +1$. This represents an electron in a $2p$ orbital. This set is fully allowed.

Step 4: Methodically test Option C: $n = 4, l = 0, m_l = +1, m_s = +\frac{1}{2}$. Here, $l = 0$ corresponds to an s subshell, which is perfectly valid for $n = 4$. However, for $l = 0$, the magnetic quantum number m_l can only be 0 (since $-0 \leq m_l \leq +0$). The value $m_l = +1$ explicitly violates this boundary condition. Therefore, this set is physically impossible and not allowed.

Final Answer: $\boxed{n = 4,\ l = 0,\ m_l = +1,\ m_s = +\frac{1}{2}}$

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:

The acidic strength of a series of oxoacids containing the same central heteroatom in different oxidation states is governed by the structural stability of the resulting conjugate base. As the oxidation state of the central chlorine atom increases, the number of highly electronegative oxygen atoms coordinated to it increases. This enhances the inductive electron withdrawal and spreads the negative charge over multiple oxygen atoms via resonance, stabilizing the conjugate anion and making the parent acid stronger.

Solution:

Step 1: Determine the formal chemical formulas of the oxoacids of chlorine. The four common oxoacids are hypochlorous acid ($HOCl$), chlorous acid ($HClO_2$), chloric acid ($HClO_3$), and perchloric acid ($HClO_4$).

Step 2: Calculate the formal oxidation state of the central chlorine (Cl) atom in each acid, assuming oxygen is -2 and hydrogen is $+1$:

For HOCl: $(+1) + x + (-2) = 0 \implies x = +1$

For $HClO_2$: $(+1) + x + 2(-2) = 0 \implies x = +3$

For $HClO_3$: $(+1) + x + 3(-2) = 0 \implies x = +5$

For $HClO_4$: $(+1) + x + 4(-2) = 0 \implies x = +7$

Step 3: Analyze the structure of the conjugate bases formed upon deprotonation (OCl^-, ClO_2^-, ClO_3^-, and ClO_4^-). In the perchlorate ion (ClO_4^-), the negative charge is fully delocalized across four equivalent oxygen atoms through resonance. In ClO_3^-, it is delocalized over three; in ClO_2^-, over two; and in OCl^-, the charge is localized entirely on a single oxygen atom.

Step 4: Correlate structural stability to acidic strength. The greater the number of resonant oxygen structures, the more stable the conjugate base, and the more readily the parent acid releases its proton. Therefore, perchloric acid ($HClO_4$) is the strongest acid, while hypochlorous acid ($HOCl$) is the weakest.

Final Answer: $\boxed{HClO_4 > HClO_3 > HClO_2 > HOCl}$

Answer: (B)

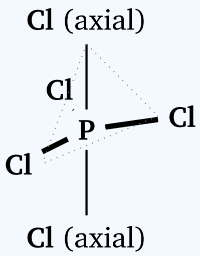
Go Back to Question 11

Q12.

Solution

Concept:
Phosphorus pentachloride (PCl_5) features a central phosphorus atom with five valence electrons, all forming single covalent bonds with chlorine atoms. This results in a steric number of 5, which corresponds to sp^3d orbital hybridization. The spatial layout that minimizes electron pair repulsion for five bonding pairs is a trigonal bipyramidal geometry. This geometry inherently contains two chemically distinct environments for the ligands.

Solution:
Step 1: Visualize the trigonal bipyramidal framework of PCl_5. The central phosphorus atom is surrounded by five chlorine atoms arranged in two distinct planes: three equatorial positions and two axial positions.



Step 2: Differentiate between equatorial and axial bonds. The three equatorial $P-Cl$ bonds lie in a single horizontal plane forming a mutual bond angle of $120°$. The two axial $P-Cl$ bonds lie along a perpendicular vertical axis, pointing straight up and straight down, making a $90°$ angle with the equatorial plane.

Step 3: Analyze the repulsive forces acting on each bond type. The axial chlorine atoms experience significant steric and electrostatic repulsion from three neighboring equatorial electron pairs at an angle of $90°$. In contrast, the equatorial chlorine atoms experience fewer close-range interactions.

Step 4: Correlate repulsion with bond parameters. To reduce this strong repelling force, the axial pairs are pushed further away from the central nucleus. Consequently, the two axial $P-Cl$ bonds are physically longer and weaker compared to the three equatorial bonds. Therefore, not all five bonds are equivalent.

Final Answer: $\boxed{PCl_5 \text{ has a trigonal bipyramidal geometry with two types of P–Cl bonds}}$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:

Molarity (M) is a fundamental concentration term defined as the total number of moles of solute dissolved per liter ($1000\,\mathrm{mL}$) of solution. The mathematical formula used to evaluate the molar concentration is expressed as:

$$\text{Molarity } (M) = \frac{\text{Mass of solute (g)}}{\text{Molar mass of solute } (\mathrm{g\,mol^{-1}})} \times \frac{1000}{\text{Volume of solution (mL)}}$$

Solution:

Step 1: Extract the given quantities from the problem.

Mass of sulfuric acid solute $(w) = 4.9\,\mathrm{g}$

Molar mass of sulfuric acid $(M_w) = 98\,\mathrm{g\,mol^{-1}}$

Volume of the prepared solution $(V) = 500\,\mathrm{mL}$

Step 2: Calculate the number of moles of solute present in the sample.

$$\text{Moles of } \mathrm{H_2SO_4} = \frac{\text{Given Mass}}{\text{Molar Mass}} = \frac{4.9\,\mathrm{g}}{98\,\mathrm{g\,mol^{-1}}} = 0.05\,\mathrm{mol}$$

Step 3: Normalize the solution volume to liters to compute the concentration. Since the solution volume is exactly $500\,\mathrm{mL}$, which is half of a liter ($0.5\,\mathrm{L}$), the formulation becomes:

$$\text{Molarity } (M) = \frac{0.05\,\mathrm{mol}}{0.5\,\mathrm{L}} = 0.10\,\mathrm{mol\,L^{-1}}$$

Step 4: Conclude that the clear, final molar concentration of the solution is $0.10\,\mathrm{M}$.

Final Answer: $\boxed{0.10\,\mathrm{M}}$

Answer: (B) Go Back to Question 13

Q14.

Solution

Concept:

Stoichiometry deals with the quantitative relationships between the amounts of reactants consumed and products generated in a balanced chemical equation. The coefficients in a balanced reaction provide the stoichiometric mole ratio, allowing for direct transformation calculations between reacting chemical species.

Solution:

Step 1: Write down and inspect the balanced chemical equation.

$$2\mathrm{Al} + 3\mathrm{Cl_2} \rightarrow 2\mathrm{AlCl_3}$$

This expression states that exactly $2\,\mathrm{moles}$ of solid aluminum (Al) react completely with $3\,\mathrm{moles}$ of chlorine gas $(\mathrm{Cl_2})$ to yield exactly $2\,\mathrm{moles}$ of aluminum chloride $(\mathrm{AlCl_3})$.

Step 2: Establish the stoichiometric ratio between the reactant of interest and the product. From the reaction coefficients:

$$\frac{\text{Moles of AlCl}_3\text{ produced}}{\text{Moles of Al consumed}} = \frac{2}{2} = 1$$

This means the mole ratio between aluminum consumed and aluminum chloride produced is exactly $1:1$.

Step 3: Apply the given values. The problem states that $0.6\,\mathrm{mol}$ of Al is reacted in the presence of excess chlorine gas. Because chlorine is in excess, aluminum acts as the limiting reactant and determines the theoretical yield of the product.

Step 4: Calculate the final molar yield of the product.

$$\text{Moles of AlCl}_3 = 0.6\,\mathrm{mol\ Al} \times \frac{2\,\mathrm{mol\ AlCl_3}}{2\,\mathrm{mol\ Al}} = 0.6\,\mathrm{mol}$$

Thus, exactly $0.6\,\mathrm{mol}$ of $\mathrm{AlCl_3}$ is synthesized.

Final Answer: $\boxed{0.6\ \mathrm{mol}}$

Answer: (C) Go Back to Question 14

Q15.

Solution

Concept:

For a reversible chemical reaction involving ideal gaseous components, the equilibrium condition can be quantified using two different constants: K_p (expressed in terms of partial pressures) and K_c (expressed in terms of molar concentrations). These two constants are related through the ideal gas equation as follows:

$$K_p = K_c(RT)^{\Delta n_g}$$

where R is the universal gas constant, T is the absolute temperature in Kelvin, and Δn_g is the net change in the number of moles of gaseous products and gaseous reactants.

Solution:

Step 1: Analyze the specific gaseous reaction given in the problem:

$$\mathrm{N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)}$$

$$\underset{n_R = 1 + 3 = 4}{\mathrm{N_2\boxed{(g) + 3H_2}(g)}} \longrightarrow \underset{n_P = 2}{\boxed{\mathrm{2NH_3(g)}}}$$

Step 2: Calculate the total number of moles of gaseous reactants (n_R). Here, $1\,\text{mole}$ of nitrogen gas reacts with $3\,\text{moles}$ of hydrogen gas:

$$n_R = 1 + 3 = 4\,\text{moles}$$

Step 3: Identify the total number of moles of gaseous products (n_P). The balanced equation shows $2\,\text{moles}$ of ammonia gas are produced:

$$n_P = 2\,\text{moles}$$

Step 4: Compute the value of Δn_g.

$$\Delta n_g = n_P - n_R = 2 - 4 = -2$$

Step 5: Substitute this calculated value of Δn_g back into the primary relation formula:

$$K_p = K_c(RT)^{-2}$$

This represents the precise relationship between the two constants for Haber's ammonia synthesis.

Final Answer: $\boxed{K_p = K_c(RT)^{-2}}$

Answer: (C) **Go Back to Question 15**

Q16.

Solution

Concept:
A buffer solution consisting of a weak acid and its conjugate base salt is an acidic buffer. The pH of such a system is calculated using the Henderson-Hasselbalch equation:

$$\text{pH} = \text{p}K_a + \log_{10}\left(\frac{[\text{Salt}]}{[\text{Acid}]}\right)$$

where $\text{p}K_a$ is the negative logarithm of the acid dissociation constant, $[\text{Salt}]$ represents the molar concentration of the conjugate base anion, and $[\text{Acid}]$ represents the equilibrium concentration of the un-ionized weak acid.

Solution:
Step 1: Identify the chemical components of the buffer system. The weak acid is acetic acid (CH_3COOH) and the salt providing the conjugate base is sodium acetate (CH_3COONa).

Acidic Buffer System
CH_3COOH (Acid) - - - → Molar Ratio $= 1 : 1$
CH_3COONa (Salt)

Step 2: Note the given quantities. The problem states that the acid and salt are mixed in a strict $1 : 1$ molar ratio, meaning:

$$[\text{Salt}] = [\text{Acid}] \implies \frac{[\text{Salt}]}{[\text{Acid}]} = 1$$

The given value for the logarithmic dissociation constant ($\text{p}K_a$) of acetic acid is 4.74.

Step 3: Substitute these values into the Henderson-Hasselbalch relation:

$$\text{pH} = 4.74 + \log_{10}(1)$$

Step 4: Evaluate the logarithmic term. Since the base-10 logarithm of 1 is exactly zero ($\log_{10}(1) = 0$), the expression simplifies to:

$$\text{pH} = 4.74 + 0 = 4.74$$

When the concentration of a weak acid equals that of its conjugate salt, the pH of the buffer system is equal to the $\text{p}K_a$ of the acid.

Final Answer: $\boxed{4.74}$

Answer: (B) Go Back to Question 16

Q17.

Solution

Concept:

The spontaneity of a physical or chemical process happening at constant temperature (T) and pressure (P) is dictated by the second law of thermodynamics. It is governed by a state function called the Gibbs Free Energy (G). The total change in Gibbs Free Energy (ΔG) combines both the enthalpy factor (ΔH) and the entropy factor (ΔS) into a single condition:

$$\Delta G = \Delta H - T\Delta S$$

Solution:

Step 1: Understand the definition of Gibbs Free Energy. Gibbs Free Energy represents the net amount of useful, non-expansion work available from a thermodynamic system.

Step 2: Analyze the conditions for thermodynamic equilibrium and spontaneity:
If $\Delta G > 0$, the forward process is non-spontaneous; work must be done on the system to make it proceed.
If $\Delta G = 0$, the system has reached a state of dynamic chemical equilibrium.
If $\Delta G < 0$, the forward process is entirely spontaneous and can occur without external assistance.

Step 3: Clarify common misconceptions regarding enthalpy (ΔH). An exothermic reaction ($\Delta H < 0$) often favors spontaneity, but it is not an absolute criterion because highly endothermic processes can still occur spontaneously if they are driven by a sufficiently large increase in system entropy (disorder, $\Delta S > 0$).

Step 4: Conclude that the only absolute criterion for a process to be spontaneous at constant temperature and pressure is a net decrease in the Gibbs Free Energy of the system ($\Delta G < 0$).

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

Answer: (C) Go Back to Question 17

Q18.

Solution

Concept:

The standard enthalpy of combustion (ΔH_c°) is defined as the heat energy released when exactly one mole of a substance is burned completely in excess oxygen gas under standard conditions. Because combustion is an exothermic process, its enthalpy value is conventionally written with a negative sign. The total heat energy (Q) liberated is proportional to the number of moles of the substance consumed:

$$Q = n \times |\Delta H_c^\circ|$$

Solution:

Step 1: Calculate the molar mass of the reacting methane gas ($\mathrm{CH_4}$).

$$\text{Molar Mass of } \mathrm{CH_4} = 12 + (4 \times 1) = 16\,\mathrm{g\,mol^{-1}}$$

Step 2: Determine the total number of moles (n) present in the given sample mass. The problem specifies a mass of $8\,\mathrm{g}$ of methane gas:

$$\text{Moles of } \mathrm{CH_4}\ (n) = \frac{\text{Given Mass}}{\text{Molar Mass}} = \frac{8\,\mathrm{g}}{16\,\mathrm{g\,mol^{-1}}} = 0.5\,\mathrm{mol}$$

Step 3: Relate the calculated moles to the standard enthalpy value. The combustion of $1\,\mathrm{mole}$ of methane releases $890\,\mathrm{kJ}$ of heat energy. Therefore, the combustion of $0.5\,\mathrm{mole}$ of methane releases:

$$\text{Heat Released} = 0.5\,\mathrm{mol} \times 890\,\mathrm{kJ\,mol^{-1}} = 445\,\mathrm{kJ}$$

Step 4: Note that the question asks for the total quantity of "heat released", which is expressed as a positive energy magnitude.

Final Answer: $\boxed{445\,\mathrm{kJ}}$

Answer: (B)

Go Back to Question 18

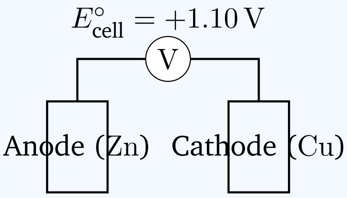
Q19.

Solution

Concept:
The standard electromotive force (E°_{cell}) of a galvanic cell is calculated using the standard reduction potentials of the cathode and anode:

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

Solution:
Step 1: Identify half-cells from the notation $\text{Zn}\,|\,\text{Zn}^{2+}\,||\,\text{Cu}^{2+}\,|\,\text{Cu}$. Oxidation occurs at the left anode ($\text{Zn} \to \text{Zn}^{2+} + 2\text{e}^-$) and reduction at the right cathode ($\text{Cu}^{2+} + 2\text{e}^- \to \text{Cu}$).



Step 2: Assign the electrode potentials based on their roles:

$$E^\circ_{\text{cathode}} = E^\circ(\text{Cu}^{2+}/\text{Cu})$$

$$E^\circ_{\text{anode}} = E^\circ(\text{Zn}^{2+}/\text{Zn})$$

Step 3: Substitute the given values into the cell potential formula ($E^\circ_{\text{cell}} = +1.10\,\text{V}$, $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34\,\text{V}$):

$$+1.10\,\text{V} = (+0.34\,\text{V}) - E^\circ(\text{Zn}^{2+}/\text{Zn})$$

Step 4: Solve for the standard reduction potential of the zinc electrode:

$$E^\circ(\text{Zn}^{2+}/\text{Zn}) = +0.34\,\text{V} - 1.10\,\text{V} = -0.76\,\text{V}$$

The negative value confirms that zinc undergoes oxidation more readily than copper.

Final Answer: $\boxed{-0.76\,\text{V}}$

Answer: (B) **Go Back to Question 19**

Q20.

Solution

Concept:

Faraday's first law of electrolysis states that the mass of a substance deposited at an electrode is directly proportional to the total quantity of electrical charge passed through the electrolytic solution. One Faraday ($1\,\mathrm{F}$) represents the charge of exactly one mole of electrons ($\approx 96485\,\mathrm{C}$). The reduction of one mole of a metal ion requires n Faradays of charge, where n is the valency factor (the number of electrons transferred per metal ion).

Solution:

Step 1: Write down the half-reaction for the reduction of aluminum ions from a molten salt. Aluminum forms a trivalent ion (Al^{3+}), meaning its reduction equation is:

$$\mathrm{Al}^{3+} + 3\mathrm{e}^{-} \rightarrow \mathrm{Al(s)}$$

This equation indicates that depositing exactly $1\,\mathrm{mole}$ of solid aluminum requires $3\,\mathrm{moles}$ of electrons, which is equivalent to $3\,\mathrm{F}$ of electrical charge.

Step 2: Determine the molar mass of aluminum. The molar mass of aluminum is given as $27\,\mathrm{g\,mol^{-1}}$. Therefore, depositing $27\,\mathrm{g}$ of aluminum requires $3\,\mathrm{F}$ of charge.

Step 3: Calculate the number of moles corresponding to the mass given in the problem ($2.7\,\mathrm{g}$).

$$\text{Moles of Al} = \frac{\text{Given Mass}}{\text{Molar Mass}} = \frac{2.7\,\mathrm{g}}{27\,\mathrm{g\,mol^{-1}}} = 0.1\,\mathrm{mol}$$

Step 4: Compute the total charge required in Faradays.

$$\text{Total Charge (F)} = \text{Moles of Al} \times n = 0.1\,\mathrm{mol} \times 3\,\mathrm{F\,mol^{-1}} = 0.3\,\mathrm{F}$$

Thus, exactly $0.3\,\mathrm{F}$ of charge is needed to deposit the aluminum.

Final Answer: $\boxed{0.3\text{ F}}$

Answer: (B) Go Back to Question 20

Q21.

Solution

Concept:

For a first-order chemical reaction, the rate depends linearly on a single reactant's concentration. The integrated rate law is:

$$k = \frac{2.303}{t}\log_{10}\left(\frac{[\mathrm{A}]_0}{[\mathrm{A}]_t}\right)$$

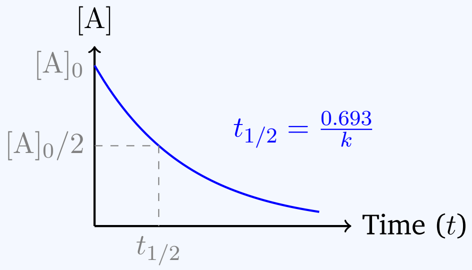
The half-life ($t_{1/2}$) is the time required for the reactant concentration to drop to half its initial value ($[\mathrm{A}]_t = \frac{1}{2}[\mathrm{A}]_0$).

Solution:

Step 1: At $t = t_{1/2}$, the remaining concentration is $[\mathrm{A}]_t = \frac{[\mathrm{A}]_0}{2}$.
Step 2: Substituting this into the natural logarithm form of the first-order integrated rate law gives:

$$k = \frac{1}{t_{1/2}}\ln\left(\frac{[\mathrm{A}]_0}{\frac{[\mathrm{A}]_0}{2}}\right)$$

Step 3: Simplifying the concentration terms yields $k = \frac{1}{t_{1/2}}\ln(2)$.



Step 4: Since $\ln(2) \approx 0.693$, substituting this value gives $k = \frac{0.693}{t_{1/2}}$.
Step 5: Rearranging the equation isolates the half-life parameter:

$$t_{1/2} = \frac{0.693}{k}$$

This proves that the half-life of a first-order reaction is a constant and completely independent of its initial concentration.

Final Answer: $\boxed{\frac{0.693}{k}}$

Answer: (B) **Go Back to Question 21**

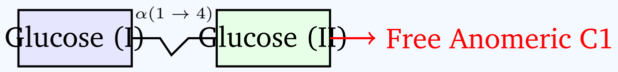
Q22.

Solution

Concept:
Carbohydrates are classified as reducing or non-reducing sugars based on their ability to reduce mild oxidizing agents like Tollens' reagent or Fehling's solution. A sugar acts as a reducing agent if it contains a free, unlinked anomeric carbon atom capable of opening up into an active, acyclic aldehyde or ketone form in aqueous solution.

Solution:
Step 1: Analyze the structural organization of sucrose. Sucrose is a disaccharide composed of an α-D-glucose unit and a β-D-fructose unit. The glycosidic linkage is formed between the anomeric carbon C1 of glucose and the anomeric carbon C2 of fructose. Because both functional anomeric carbons are tied up in the glycosidic bond, sucrose lacks a free reducing group and is a non-reducing sugar.

Step 2: Analyze the structural organization of maltose. Maltose is a disaccharide composed of two α-D-glucose units. The glycosidic bond connects the anomeric carbon C1 of the first glucose molecule to the non-anomeric hydroxyl oxygen at carbon C4 of the second glucose molecule.



Step 3: Identify the presence of a hemiacetal group. Because only one anomeric carbon is involved in the glycosidic link, the C1 anomeric carbon of the second glucose ring remains completely free. In water, this ring can undergo mutarotation to yield an open-chain structure containing an active, oxidizable aldehyde group.

Step 4: Analyze polysaccharides like starch and cellulose. These high-molecular-weight polymers have thousands of monosaccharide units tied up in linkages, leaving only a negligible fraction of reducing ends. Thus, they are practically non-reducing. Maltose retains a highly reactive free hemiacetal group and readily reduces Fehling's solution.

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

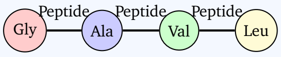
$\boxed{\textbf{Answer: (B)}}$ **Go Back to Question 22**

Q23.

Solution

Concept:
Proteins are complex macromolecular biological polymers built from structural subunits called α-amino acids. To simplify the understanding of their three-dimensional architecture, protein conformation is broken down into four hierarchical levels of structural organization: primary, secondary, tertiary, and quaternary structures.

Solution:
Step 1: Define the primary structure. The primary structure is the foundational, linear framework of a polypeptide chain. It specifies the unique, genetically encoded linear sequence of amino acid residues arranged from the N-terminus to the C-terminus.



Step 2: Understand the bonding involved in the primary backbone. The amino acid building blocks are covalently linked together via strong amide bonds, commonly known in biochemistry as peptide bonds ($-\mathrm{CO}-\mathrm{NH}-$), formed by a condensation reaction between the carboxylic acid group of one amino acid and the amino group of the next.

Step 3: Contrast primary structure with higher-order levels:
Secondary structure refers to localized spatial folding patterns such as the α-helix or β-pleated sheets, stabilized primarily by hydrogen bonding.
Tertiary structure describes the overall three-dimensional folding of a single polypeptide chain, driven by hydrophobic interactions, disulfide bridges, and ionic bonds.
Quaternary structure refers to the spatial alignment of multiple separate polypeptide subunits.

Step 4: Conclude that the primary structure describes only the linear amino acid sequence joined by covalent peptide bonds.

Final Answer: The sequence of amino acids linked by peptide bonds

Answer: (B)

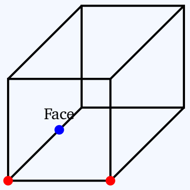
Go Back to Question 23

Q24.

Solution

Concept:
In solid-state chemistry, a crystalline lattice can be broken down into repeating structural blocks called unit cells. The total number of effective lattice atoms contained inside a single unit cell (Z) depends on the geometric coordinates of the atomic positions and how these positions are shared with adjacent neighboring unit cells in the 3D crystal lattice.

Solution:
Step 1: Identify the position coordinates of atoms in a face-centered cubic (FCC) lattice unit cell. An FCC cell contains atoms at all eight corners of the cube and at the centers of all six faces.



Step 2: Compute the effective contribution of the corner atoms. Each corner of a cube is shared among eight identical neighboring unit cells. Therefore, only $\frac{1}{8}$ of each corner atom belongs to a single unit cell:

$$\text{Contribution from corners} = 8 \times \frac{1}{8} = 1 \text{ atom}$$

Step 3: Compute the effective contribution of the face-centered atoms. Each face of a cube is shared directly between two adjacent unit cells. Therefore, exactly $\frac{1}{2}$ of each face atom belongs to a single unit cell:

$$\text{Contribution from faces} = 6 \times \frac{1}{2} = 3 \text{ atoms}$$

Step 4: Sum the contributions to find the total number of effective atoms (Z) in the cell:

$$\text{Total atoms (Z)} = 1 \text{ (from corners)} + 3 \text{ (from faces)} = 4 \text{ atoms}$$

Thus, an FCC unit cell contains exactly 4 net atoms.

Final Answer: $\boxed{4}$

Answer: (B) **Go Back to Question 24**

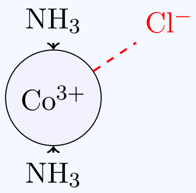
Q25.

Solution

Concept:
Alfred Werner's coordination theory states that transition metal complexes display two distinct types of valency: primary valency and secondary valency. Primary valency corresponds to the formal oxidation state of the central metal ion. It is ionizable and is satisfied by negative anions. Secondary valency corresponds to the coordination number of the metal complex. It is non-ionizable and is satisfied by neutral ligands or anions that donate lone electron pairs via coordinate covalent bonds.

Solution:
Step 1: Analyze the coordination complex compound given: $[\mathrm{Co(NH_3)_6}]\mathrm{Cl_3}$.
When dissolved in water, this compound dissociates into ions as follows:

$$[\mathrm{Co(NH_3)_6}]\mathrm{Cl_3(aq)} \rightarrow [\mathrm{Co(NH_3)_6}]^{3+} + 3\mathrm{Cl}^-$$



Step 2: Determine the primary valency by calculating the oxidation state of the central cobalt atom. Let x be the oxidation state of cobalt. The ammonia (NH_3) ligands are neutral molecules with a charge of 0. The chloride counter-ions each carry a charge of -1.

$$x + 6(0) + 3(-1) = 0 \implies x = +3$$

Thus, the primary valency of cobalt is 3.

Step 3: Identify which species satisfies this primary valency. The primary valency of $+3$ is balanced by the three ionizable chloride (Cl^-) anions in the outer ionization sphere.

Step 4: Identify the secondary valency. The six neutral ammonia molecules are bound inside the inner coordination sphere, satisfying the secondary valency (coordination number = 6).

Final Answer: $\boxed{\text{3, satisfied by the 3 chloride ions}}$

Answer: (A)

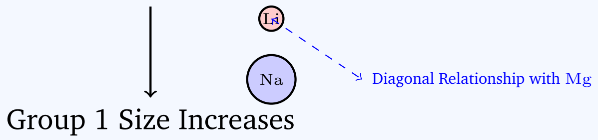
Go Back to Question 25

Q26.

Solution

Concept:
Lithium (Li) is the first element in the Group 1 alkali metal family. The first element of a group often exhibits an anomalous chemical profile that diverges significantly from its heavier congeners (such as Na, K, Rb). This unique behavior stems from its exceptionally small atomic and ionic radius, high ionization enthalpy, high electronegativity, and high polarizing power (charge-to-size ratio).

Solution:
Step 1: Evaluate the physical trends in Group 1. As you move down the group, atomic radius increases and ionization enthalpy decreases. Because lithium is at the top of the group, its valence electron is closest to the nucleus, giving it the highest first ionization enthalpy among all the alkali metals. This high ionization energy makes it less metallic and more covalent in its bonding properties.



Step 2: Analyze the implications of high polarizing power. Due to its small ionic radius, the Li^+ cation has a high charge density. This allows it to strongly polarize large anions, introducing substantial covalent character into its compounds. This high charge density mirrors that of the magnesium ion (Mg^{2+}), establishing a diagonal relationship between the two elements.

Final Answer: $\boxed{\text{It has the highest ionisation enthalpy in Group 1}}$

Answer: (A)

Go Back to Question 26

Q27.

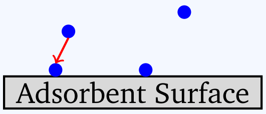
Solution

Concept:
Adsorption is a surface phenomenon where chemical species (adsorbate) accumulate at the boundary surface of a solid or liquid phase (adsorbent), rather than penetrating into the bulk volume. The driving force for adsorption is the minimization of unbalanced residual attractive forces acting on the surface molecules of the adsorbent.

Solution:
Step 1: Analyze the thermodynamic criteria of adsorption. When a gas molecule adheres to a solid surface, its freedom of movement is restricted. The gas molecules transition from a high-entropy three-dimensional gaseous state to a more constrained, ordered two-dimensional state on the adsorbent surface.

Step 2: Determine the sign of entropy change (ΔS). Because molecular disorder decreases during adsorption, the change in entropy is negative:

$$\Delta S < 0$$



$$\Delta H = \text{Negative (Exothermic)}$$

Step 3: Apply the Gibbs-Helmholtz thermodynamic criteria for spontaneity. For the process to occur spontaneously at a given temperature, the change in Gibbs Free Energy must be negative ($\Delta G < 0$):

$$\Delta G = \Delta H - T\Delta S$$

Step 4: Evaluate the sign of enthalpy (ΔH). Since the term $-T\Delta S$ is positive (as ΔS is negative), the only way ΔG can be negative is if the enthalpy change (ΔH) is negative. This requires the process to release heat energy ($\Delta H < 0$). This heat release corresponds to a reduction in the surface residual energy of the adsorbent as new surface interactions are established. Thus, the adsorption of a gas on a solid surface is exothermic.

Final Answer: $\boxed{\text{Exothermic, because the surface energy decreases on adsorption}}$

Answer: (B) **Go Back to Question 27**

Q28.

Solution

Concept:
The oxidation of alcohols using strong chemical oxidizing agents like acidified potassium dichromate ($K_2Cr_2O_7/H_2SO_4$) depends heavily on the structural classification of the alcohol (primary, secondary, or tertiary). This structural variation dictates the number of α-hydrogens available for elimination.

Solution:
Step 1: Categorize the structural type of each alcohol option.
Ethanol (CH_3CH_2OH) and Propan-1-ol ($CH_3CH_2CH_2OH$) are primary (1°) alcohols.
Cyclohexanol is a secondary (2°) alcohol.
2-methyl-2-propanol is a tertiary (3°) alcohol.

$$R - CH_2OH \xrightarrow{[O]} R - CHO \xrightarrow{[O]} R - COOH$$

Primary Alcohol Oxidation Path

Step 2: Analyze the oxidation pathway of primary alcohols. When a 1° alcohol is treated with a powerful oxidizing agent like acidified $K_2Cr_2O_7$, it is first oxidized to an intermediate aldehyde. However, because aldehydes contain a highly reactive formyl hydrogen atom, they are oxidized much faster than the parent alcohol. Under standard laboratory conditions, the reaction cannot be stopped at the aldehyde stage and proceeds directly to yield a carboxylic acid with the same number of carbon atoms. Under normal conditions, both ethanol and propan-1-ol undergo complete oxidation to form ethanoic acid and propanoic acid, respectively. (Note: Propan-1-ol is selected here as the representative primary alcohol matching standard textbook trends for direct conversions without loss of carbon).

Step 3: Analyze secondary and tertiary pathways. Secondary alcohols oxidize to ketones and stop there because ketones lack an easily oxidizable hydrogen atom on the carbonyl carbon. Tertiary alcohols lack α-hydrogens entirely and resist oxidation under neutral or acidic conditions unless subjected to harsh, bond-cleaving environments.

Final Answer: $\boxed{\text{Propan-1-ol}}$

$\boxed{\textbf{Answer: (C)}}$ **Go Back to Question 28**

Q29.

Solution

Concept:
The addition of hydrogen halides (HX) to alkynes is an electrophilic addition reaction. Alkynes contain two orthogonal pi bonds, allowing them to undergo addition reactions in two consecutive stages. When an alkyne reacts with exactly one equivalent of a hydrogen halide, the reaction stops at the alkene stage, yielding a haloalkene.

Solution:
Step 1: Write down the chemical structures of the starting material and the reagent. Acetylene is a symmetrical alkyne with a triple bond, written as $\mathrm{HC \equiv CH}$, and the reagent is hydrochloric acid (HCl).

$$\mathrm{HC \equiv CH \xrightarrow{+HCl\ (1\ eq)} CH_2 = CH - Cl}$$

Step 2: Track the mechanism for the addition of the first equivalent of HCl. The pi electron cloud of acetylene attacks the incoming proton ($\mathrm{H^+}$), forming a vinylic carbocation intermediate ($\mathrm{CH_2 = CH^+}$). The chloride ion ($\mathrm{Cl^-}$) then attacks this vinylic carbocation to produce chloroethene.

$$\mathrm{HC \equiv CH + HCl \rightarrow CH_2 = CH - Cl}$$

Step 3: Identify the common and IUPAC names of the product. The resulting product, $\mathrm{CH_2 = CHCl}$, is commonly known as vinyl chloride. Following the official IUPAC guidelines for substituted alkenes, the two-carbon parent chain contains a double bond, making it an "ethene" base, with a chlorine substituent attached to carbon 1. Thus, its systematic IUPAC name is chloroethene.

Final Answer: $\boxed{\text{Chloroethene (vinyl chloride)}}$

$\boxed{\textbf{Answer: (B)}}$ **Go Back to Question 29**

Q30.

Solution

Concept:
The Balz-Schiemann reaction is a specialized organic substitution process used to synthesize aryl fluorides from primary aromatic amines. Aryl fluorides cannot be prepared easily through direct fluorination due to the highly violent and uncontrollable exothermic nature of fluorine gas reactions. The Balz-Schiemann pathway bypasses this risk by isolating a stable diazonium tetrafluoroborate intermediate, which undergoes controlled thermal decomposition.

Solution:
Step 1: Trace the sequential steps of the chemical scheme. The starting material is aniline ($C_6H_5NH_2$). When treated with nitrous acid (HNO_2) in the presence of fluoroboric acid (HPF_6 or HBF_4), it undergoes a diazotization reaction.

$$C_6H_5NH_2 \longrightarrow \underset{\text{Isolated Intermediate}}{C_6H_5N_2^+BF_4^-} \xrightarrow{\Delta} C_6H_5F$$

Step 2: Identify the intermediate chemical structure. The diazotization process initially forms a benzenediazonium cation. In the presence of the tetrafluoroborate anion (BF_4^-), it precipitates out of solution as a stable salt: benzenediazonium tetrafluoroborate (or aniline diazonium tetrafluoroborate), represented by the chemical formula $C_6H_5N_2^+BF_4^-$.

Step 3: Analyze the thermal decomposition phase. This isolated, dry fluoroborate salt is safe to handle. Upon dry heating (Δ), the salt decomposes via an S_N1-like aromatic pathway, releasing nitrogen gas (N_2) and boron trifluoride gas (BF_3), while the fluorine atom attaches to the phenyl ring to yield fluorobenzene (C_6H_5F).

$$C_6H_5N_2^+BF_4^- \xrightarrow{\Delta} C_6H_5F + N_2\uparrow + BF_3\uparrow$$

Thus, the intermediate captured in this process is aniline diazonium tetrafluoroborate.

Final Answer: $\boxed{\text{Aniline diazonium tetrafluoroborate}}$

$\boxed{\textbf{Answer: (B)}}$ **Go Back to Question 30**

Answer Key

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