JELET Chemistry Sample Paper-8

Duration: 45 Minutes **Maximum Marks: 50**

Instructions

- This paper contains **20** Multiple Choice Questions divided into two Sections.
- **Section A (Q1–Q15):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section B (Q16–Q20):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section–A — 15 Questions × 1 Mark Each
(Negative Marking: –0.25) [Single Correct]

Q1. An industrial water sample contains 120 ppm of $MgSO_4$ and 111 ppm of $CaCl_2$. What is the total hardness of this water sample expressed in terms of $CaCO_3$ equivalents?

(A) 100 ppm

(B) 200 ppm

(C) 231 ppm

(D) 300 ppm

Q2. Which of the following statements is correct regarding the biochemical mechanisms of the greenhouse effect and global warming?

(A) Carbon dioxide molecules trap solar radiation because they possess a permanent dipole moment in their ground state.

(B) Infrared radiation is absorbed by CO_2 via asymmetric stretching and bending vibrational modes that induce a transient dipole moment.

(C) Nitrogen (N_2) and Oxygen (O_2) molecules contribute significantly to the greenhouse effect because of their high atmospheric abundance.

(D) Ultraviolet radiation re-radiated from the Earth's surface is efficiently captured by tropospheric ozone.

Q3. In the IUPAC nomenclature system, what is the correct priority-based name of the compound given below?

$$CH_3 - CH(OH) - CH_2 - C(O) - CH_2 - COOH$$

(A) 5-Hydroxy-3-oxohexanoic acid

(B) 2-Hydroxy-4-oxohexanoic acid

(C) 1-Carboxy-4-oxopentan-2-ol

(D) 5-Hydroxy-3-ketohexanal

Q4. In a reversible chemical process, the equilibrium constants for a reaction at 300 K and 400 K are 2.0×10^{-2} and 5.0×10^{-2} respectively. If a catalyst is introduced into this system at 300 K, what will be the new value of the equilibrium constant?

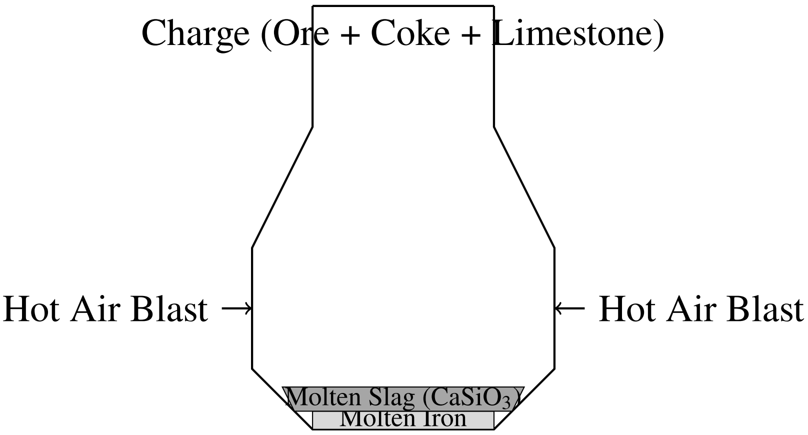
(A) 2.0×10^{-2}

(B) 5.0×10^{-2}

(C) 1.0×10^{-1}

(D) 4.0×10^{-2}

Q5. During the extraction of iron in the blast furnace, the primary function of adding limestone ($CaCO_3$) to the charge is to act as a slag-forming flux to remove acidic silica impurities (SiO_2).



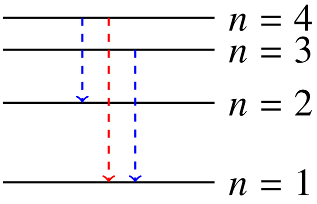
(A) Reducing agent to convert Fe_2O_3 to molten iron.

(B) Slag-forming flux to remove acidic silica impurities (SiO_2).

(C) Oxidizing agent to burn away elemental sulfur and phosphorus.

(D) Refractory lining material to protect the inner walls of the furnace.

Q6. Consider the hydrogen atom spectrum. If an electron falls from an outer orbit to an inner orbit where the maximum number of spectral lines possible in the emission spectrum is 6, what are the principal quantum numbers ($n_2 \rightarrow n_1$) corresponding to this transition if the lowest level is the ground state?



(A) $3 \rightarrow 1$

(B) $4 \rightarrow 1$

(C) $4 \rightarrow 2$

(D) $5 \rightarrow 2$

Q7. What is the total number of sigma (σ) and pi (π) bonds present in the product formed when calcium carbide (CaC_2) undergoes complete hydrolysis with water?

(A) 2σ and 2π

(B) 3σ and 2π

(C) 3σ and 1π

(D) 5σ and 1π

Q8. An aqueous solution of a weak acid HA has a pH of 4.0. If the initial concentration of the acid is 0.01 M, what is its degree of dissociation (α) and the acid dissociation constant (K_a)?

(A) $\alpha = 0.01, K_a = 1.0 \times 10^{-6}$

(B) $\alpha = 0.10, K_a = 1.0 \times 10^{-5}$

(C) $\alpha = 0.01, K_a = 1.0 \times 10^{-4}$

(D) $\alpha = 0.10, K_a = 1.0 \times 10^{-7}$

Q9. Equal volumes of three solutions with pH values of 3, 4, and 5 are mixed thoroughly in a vessel. What will be the approximate pH of the resulting mixture?

(A) 4.00

(B) 3.44

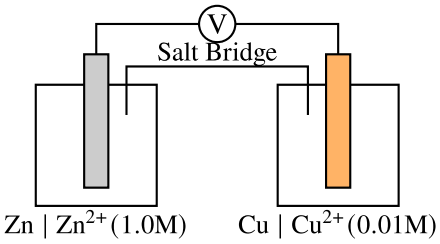
(C) 3.12

(D) 4.56

Q10. For a specific electrochemical cell operating at 298 K, the cell reaction is written as:

$$\mathrm{Zn}(s) + \mathrm{Cu}^{2+}(aq, 0.01\ \mathrm{M}) \rightarrow \mathrm{Zn}^{2+}(aq, 1.0\ \mathrm{M}) + \mathrm{Cu}(s)$$

Given that the standard cell potential $E^\circ_{\text{cell}} = 1.10$ V, what is the observed cell potential (E_{cell}) for this configuration? (Take $\frac{2.303RT}{F} = 0.06$ V)



(A) 1.16 V

(B) 1.10 V

(C) 1.04 V

(D) 0.98 V

(E)

Q11. The hybridization states of the central nitrogen atoms in the species NO_2^+, NO_3^-, and NH_4^+ are respectively:

(A) sp, sp^2, and sp^3

(B) sp^2, sp, and sp^3

(C) sp^2, sp^3, and sp

(D) sp, sp^3, and sp^2

Q12. During the steady electrolysis of an aqueous solution of copper sulfate ($CuSO_4$) using inert platinum electrodes, a constant current is passed through the cell. If 0.635 g of copper metal (Atomic mass = 63.5 g/mol) deposits at the cathode, what volume of oxygen gas (O_2) is liberated at the anode under STP conditions?

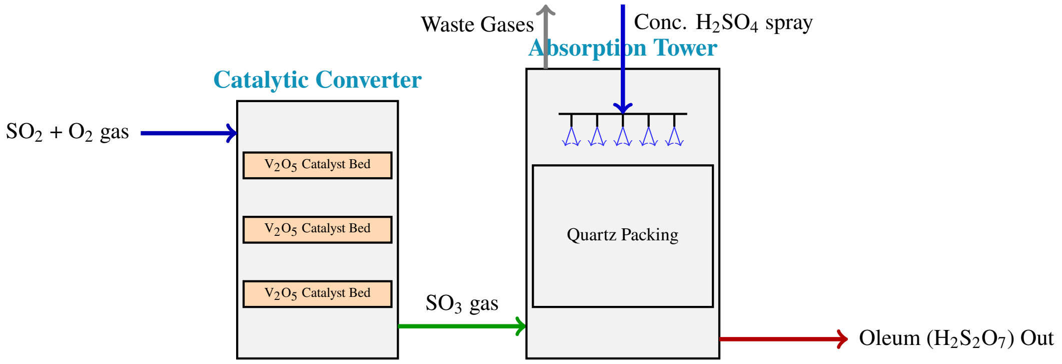
(A) 112 mL

(B) 224 mL

(C) 448 mL

(D) 560 mL

Q13. In the contact process for the industrial manufacture of sulfuric acid, what is the primary reason why sulfur trioxide (SO_3) gas is absorbed in concentrated H_2SO_4 to form oleum rather than being dissolved directly in water?



(A) The direct dissolution of SO_3 in water is highly endothermic and stops the reaction.

(B) Direct dissolution forms a dense, stable acid mist that does not condense easily.

(C) Water acts as a reducing agent and converts SO_3 back to SO_2.

(D) SO_3 is completely insoluble in pure water under operational temperatures.

Q14. An organic hydrocarbon contains two sp^3 hybridized carbons, two sp^2 hybridized carbons, and two sp hybridized carbons in its skeletal chain. Which of the following structures satisfies this specific configuration?

(A) Hexa-1,3-dien-5-yne

(B) Hex-1-en-4-yne

(C) But-1-en-3-yne

(D) 3-Methylpent-1-en-4-yne

Q15. Consider the quantum mechanical description of electrons in an atom. What is the maximum number of electrons that can accommodate a subshell characterized by the quantum numbers $n = 4$ and $l = 2$?

(A) 2

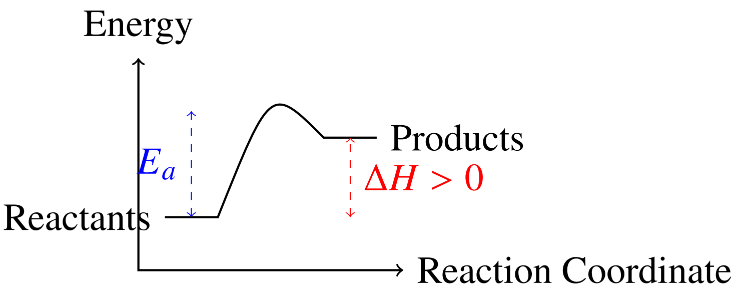
(B) 6

(C) 10

(D) 14

Section–B — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q16. Which of the following parameters change when a chemical system at equilibrium is subjected to an increase in temperature for an endothermic reaction?



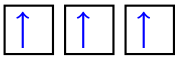
(A) The value of the equilibrium constant (K_{eq}) increases.

(B) The activation energy of the forward reaction decreases significantly.

(C) The rate constants of both the forward and backward reactions increase.

(D) The total enthalpy change (ΔH) of the system changes its mathematical sign.

Q17. Which of the following statements match the electronic behavior governed by Pauli's exclusion principle, Hund's rule of maximum multiplicity, or Bohr's atomic postulates?



Degenerate Orbitals (p^3)

(A) No two electrons in an isolated atom can share an identical set of four quantum numbers.

(B) Pairing of electrons in degenerate orbitals of a subshell cannot occur until each orbital is singly occupied.

(C) The angular momentum of an electron moving in any stationary circular orbit is an integral multiple of $\frac{h}{2\pi}$.

(D) Electrons fill up atomic orbitals in the strict order of decreasing $(n + l)$ values.

Q18. Consider a standard galvanic cell using the following two half-cells:

$$\mathrm{Fe^{3+}}(aq) + e^- \longrightarrow \mathrm{Fe^{2+}}(aq) \quad (E^\circ = +0.77\ \mathrm{V})$$

$$\mathrm{MnO_4^-}(aq) + 8\mathrm{H^+}(aq) + 5e^- \longrightarrow \mathrm{Mn^{2+}}(aq) + 4\mathrm{H_2O}(l) \quad (E^\circ = +1.51\ \mathrm{V})$$

Which of the following statements regarding this electrochemical system are correct under standard conditions?

(A) The standard potential of the complete galvanic cell (E°_{cell}) is +0.74 V.

(B) $\mathrm{MnO_4^-}(aq)$ acts as the oxidizing agent at the cathode during discharge.

(C) Multiplying the iron half-reaction coefficients by 5 changes its standard potential to +3.85 V.

(D) The spontaneous cell reaction involves the oxidation of $\mathrm{Fe^{2+}}$ ions to $\mathrm{Fe^{3+}}$ ions.

Q19. In the industrial extraction and refining metallurgy of copper, which of the following processes or reactions take place correctly?

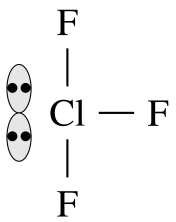
(A) The copper matte obtained from the blast furnace consists primarily of Cu_2S and FeS.

(B) Silica (SiO_2) is added in the converter to remove FeO impurities as an iron silicate slag ($FeSiO_3$).

(C) Blister copper is formed during the final stage due to the evolution of carbon dioxide (CO_2) gas.

(D) During electrolytic refining, blister copper acts as the anode while pure copper deposits at the cathode.

Q20. Which of the following options correctly pair a molecule with its molecular geometry and spatial distribution of lone pairs around its central atom?



(A) SF_4 – See-saw geometry with one lone pair in an equatorial position.

(B) XeF_4 – Square planar geometry with two lone pairs in trans axial positions.

(C) ClF_3 – T-shaped geometry with two lone pairs in equatorial positions.

(D) H_2O – Bent geometry with two lone pairs oriented at an angle of 180° to each other.

Detailed Solutions

Q1.

Solution

Concept:

Water hardness is caused by multivalent metallic cations, primarily calcium and magnesium. It is conventionally quantified as parts per million (ppm) equivalent of calcium carbonate ($CaCO_3$). The conversion of a given salt concentration to its $CaCO_3$ equivalent utilizes its chemical equivalence factor:

$$\text{Equivalent } CaCO_3 = \text{Mass of Salt} \times \left(\frac{\text{Molar Mass of } CaCO_3}{\text{Molar Mass of Salt}}\right)$$

Given that the molar mass of $CaCO_3$ is 100 g/mol, the individual hardness contributions of the component salts are computed and summed to determine the total hardness of the solution.

Solution:

Step 1: Determine the molar masses of the chemical constituents present in the water sample.
Molar mass of magnesium sulfate ($MgSO_4$) = $24 + 32 + (4 \times 16) = 120$ g/mol
Molar mass of calcium chloride ($CaCl_2$) = $40 + (2 \times 35.5) = 111$ g/mol
Molar mass of calcium carbonate ($CaCO_3$) = $40 + 12 + (3 \times 16) = 100$ g/mol Step 2: Convert the concentration of $MgSO_4$ into its equivalent concentration of $CaCO_3$.

$$CaCO_3 \text{ equivalent of 120 ppm } MgSO_4 = 120 \text{ ppm} \times \left(\frac{100}{120}\right) = 100 \text{ ppm}$$

Step 3: Convert the concentration of $CaCl_2$ into its equivalent concentration of $CaCO_3$.

$$CaCO_3 \text{ equivalent of 111 ppm } CaCl_2 = 111 \text{ ppm} \times \left(\frac{100}{111}\right) = 100 \text{ ppm}$$

Step 4: Compute the total cumulative hardness of the water sample by summing the individual calculated values.

$$\text{Total Hardness} = \text{Equivalent of } MgSO_4 + \text{Equivalent of } CaCl_2$$

$$\text{Total Hardness} = 100 \text{ ppm} + 100 \text{ ppm} = 200 \text{ ppm}$$

Final Answer: $\boxed{\text{200 ppm}}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:

The greenhouse effect relies on the absorption of long-wave thermal infrared radiation emitted from the Earth's surface by atmospheric trace gases. For a molecular species to absorb infrared light, the interaction with the electromagnetic field must induce a dynamic change in its molecular dipole moment during vibration. Symmetrical homonuclear diatomic molecules like N_2 and O_2 cannot absorb infrared radiation because their vibrations do not generate a dipole moment. Conversely, linear polyatomic molecules can change their dipole asymmetry dynamically during specific vibrational transformations.

Solution:

Step 1: Analyze the ground state structure of the carbon dioxide (CO_2) molecule. Carbon dioxide is a linear molecule ($O = C = O$) belonging to the point group $D_{\infty h}$. Due to its perfect center of inversion, the individual bond dipoles cancel out completely, giving it a permanent dipole moment of zero. Thus, statement A is false.

Step 2: Examine the vibrational modes of CO_2. It has four fundamental vibrational modes: symmetric stretching, asymmetric stretching, and two degenerate bending modes.

Step 3: During symmetric stretching, the carbon-oxygen bonds lengthen and shorten simultaneously, preserving the molecular symmetry and keeping the dipole moment at zero. This mode is infrared inactive.

Step 4: During asymmetric stretching and bending vibrations, the physical symmetry of the charge distribution is broken. This creates a transient, oscillating molecular dipole moment that couples with incoming infrared photons, rendering these specific modes highly infrared active and allowing the gas to trap heat. Therefore, statement B is accurate.

Step 5: Verify options C and D. Homonuclear diatomic molecules like N_2 and O_2 do not contribute to the greenhouse effect. The radiation re-radiated by the Earth is infrared, not ultraviolet. Thus, options C and D are false.

Final Answer: $\boxed{\text{Infrared radiation is absorbed by } CO_2 \text{ via asymmetric stretching and bending vibrational modes that induce a transient dipole moment.}}$

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

Go Back to Question 2

Q3.

Solution

Concept:

According to the IUPAC nomenclature guidelines for polyfunctional organic compounds, a principal functional group must be selected based on a strict priority hierarchy. The group with the highest priority acts as the principal suffix, while all remaining functional groups are treated as prefixes and listed alphabetically. The priority order for the functional groups present here is:

$$\text{Carboxylic acid } (-\text{COOH}) > \text{Ketone } (-\text{C(O)}-) > \text{Alcohol } (-\text{OH})$$

The carbon chain must be numbered starting from the principal functional group carbon to assign the lowest possible locants to all substituents.

Solution:

Step 1: Identify and locate the functional groups within the molecular structure:

$$CH_3 - CH(OH) - CH_2 - C(O) - CH_2 - COOH$$

The functional groups present are a carboxylic acid (−COOH), a keto group (−C(O)−), and a hydroxyl group (−OH). Step 2: Establish the numbering of the parent carbon chain based on priority. The carboxylic acid carbon gets the highest priority and is designated as carbon-1:

$$C^6H_3 - C^5H(OH) - C^4H_2 - C^3(O) - C^2H_2 - C^1OH$$

The total length of the continuous carbon chain containing the primary functional group is 6 carbons, making the parent alkane "hexane".

Step 3: Identify the prefixes for the remaining functional groups along with their locants.

At position 3, there is an oxo group (= O), represented by the prefix "oxo".

At position 5, there is a hydroxyl group (−OH), represented by the prefix "hydroxy".

Step 4: Arrange the prefix groups alphabetically and assemble the complete name. "Hydroxy" precedes "oxo" alphabetically. Combining the components yields:

$$\text{5-Hydroxy} + \text{3-oxo} + \text{hexanoic acid} = \text{5-Hydroxy-3-oxohexanoic acid}$$

Final Answer: $\boxed{\text{5-Hydroxy-3-oxohexanoic acid}}$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept:

The equilibrium constant (K_{eq}) of a chemical reaction is a thermodynamic parameter that depends solely on the temperature of the system and the standard Gibbs free energy change (ΔG°) of the reaction, as defined by the relation:

$$\Delta G^\circ = -RT \ln K_{eq}$$

A chemical catalyst operates entirely on kinetic principles by providing an alternative reaction pathway with a lower activation energy (E_a). It accelerates the rates of both the forward and reverse reactions by the exact same factor. Consequently, the presence of a catalyst helps the system reach equilibrium faster but has absolutely no effect on the final thermodynamic equilibrium composition or the value of the equilibrium constant.

Solution:

Step 1: Evaluate the initial thermodynamic state of the system before adding the catalyst. The question provides two equilibrium constants at two different temperatures: $K_1 = 2.0 \times 10^{-2}$ at $T_1 = 300$ K and $K_2 = 5.0 \times 10^{-2}$ at $T_2 = 400$ K.

Step 2: Analyze the question's prompt regarding the addition of a catalyst. The catalyst is introduced into the reversible system specifically at an operating temperature of 300 K.

Step 3: Apply the chemical principles of catalysis to the system. Since a catalyst does not alter the energies of the reactants or products, it cannot modify the standard free energy change ΔG° or the enthalpy change ΔH° of the reaction. Because these state functions remain unchanged, the value of the equilibrium constant remains entirely unaffected by the catalyst.

Step 4: Match the post-catalytic equilibrium constant to the baseline value at 300 K. The equilibrium constant must remain exactly equal to its initial value at 300 K, which is 2.0×10^{-2}.

Final Answer: $\boxed{2.0 \times 10^{-2}}$

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:
In Pyrometallurgy, extraction of iron from its oxide ores (Fe_2O_3) is carried out inside a blast furnace. The raw charge fed into the furnace consists of hematite ore, coke, and limestone ($CaCO_3$). The iron ore naturally contains acidic impurities, primarily silica (SiO_2). To separate these high-melting impurities from the molten metal, a flux must be introduced to react with them and form a fusible, low-density material known as slag. Limestone serves as a basic flux precursor that thermally decomposes inside the furnace to yield the active basic flux.

Solution:
Step 1: Trace the thermal behavior of limestone inside the mid-temperature zone (900 K – 1200 K) of the blast furnace. The limestone undergoes clean thermal decomposition to produce calcium oxide and carbon dioxide gas:

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

Step 2: Identify the chemical nature of the decomposition product. Calcium oxide (CaO) is a strong alkaline/basic earth metal oxide, which acts as the operational basic flux.

Step 3: Write out the neutralization reaction between the basic flux and the acidic impurities. The calcium oxide reacts directly with the acidic silica (SiO_2) gangue present in the iron ore to form calcium silicate:

$$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$$

Step 4: Understand the properties and removal of the product. Calcium silicate ($CaSiO_3$) is molten slag. Because it is less dense than molten iron and immiscible with it, the slag floats on top of the liquid iron pool at the hearth. This prevents the purified iron from re-oxidizing and allows them to be tapped off separately. Thus, its primary role is acting as a slag-forming flux.

Final Answer: $\boxed{\text{Slag-forming flux to remove acidic silica impurities (SiO}_2\text{).}}$

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:
The total number of distinct emission spectral lines (N) possible when an electron undergoes a relaxation cascade from an excited state n_2 to a lower state n_1 is given by the formula:

$$N = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

For transitions terminating at the ground state ($n_1 = 1$), this relation simplifies to a standard quadratic form: $N = \frac{n_2(n_2-1)}{2}$.

Solution:
Step 1: Set up the equation using the given total spectral lines ($N = 6$) and ground state ($n_1 = 1$).

$$6 = \frac{n_2(n_2 - 1)}{2} \implies n_2^2 - n_2 - 12 = 0$$

Step 2: Factor the quadratic equation to find its roots.

$$(n_2 - 4)(n_2 + 3) = 0$$

Since principal quantum numbers must be positive integers ($n > 0$), we reject $n_2 = -3$. Thus, $n_2 = 4$.

Step 3: Define the transition pathway. The electron drops from initial orbit $n_2 = 4$ to final orbit $n_1 = 1$.

Final Answer: $\boxed{4 \rightarrow 1}$

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:
Complete hydrolysis of calcium carbide (CaC_2) produces calcium hydroxide and ethyne gas (C_2H_2). To find the total number of σ and π bonds in the product, we analyze the structural Lewis configuration of the resulting ethyne molecule. Every single bond is a σ bond, whereas a triple bond consists of exactly one σ bond and two π bonds.

Solution:
Step 1: Write the balanced chemical reaction for the hydrolysis process.

$$CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + C_2H_2(g)$$

Step 2: Map out the structural bonding of the ethyne molecule ($H - C \equiv C - H$).
- Two $C - H$ single bonds = 2σ bonds.
- One $C \equiv C$ triple bond = 1σ bond + 2π bonds.

Step 3: Sum the individual bonds to determine the final molecular counts.

$$\text{Total } \sigma = 2 + 1 = 3\sigma \text{ bonds}, \quad \text{Total } \pi = 2\pi \text{ bonds}$$

Final Answer: $\boxed{3\sigma \text{ and } 2\pi}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

For a weak monobasic acid HA undergoing partial ionization with initial concentration C and a degree of dissociation α, the equilibrium is expressed as:

$$K_a = \frac{[\mathrm{H^+}][\mathrm{A^-}]}{[\mathrm{HA}]} = \frac{C\alpha^2}{1-\alpha}$$

The hydronium ion concentration is related to the degree of dissociation by the direct equation: $[\mathrm{H^+}] = C\alpha$.

Solution:

Step 1: Determine the equilibrium hydrogen ion concentration from the given pH.

$$[\mathrm{H^+}] = 10^{-\mathrm{pH}} = 10^{-4.0} = 1.0 \times 10^{-4}\ \mathrm{M}$$

Step 2: Calculate the degree of dissociation (α) given the initial concentration $C = 0.01\ \mathrm{M} = 10^{-2}\ \mathrm{M}$.

$$\alpha = \frac{[\mathrm{H^+}]}{C} = \frac{1.0 \times 10^{-4}}{1.0 \times 10^{-2}} = 0.01$$

Step 3: Compute the acid dissociation constant (K_a). Since $\alpha = 0.01 \ll 1$, the expression simplifies to:

$$K_a = C\alpha^2 = (10^{-2}) \times (10^{-2})^2 = 1.0 \times 10^{-6}$$

Final Answer: $\boxed{\alpha = 0.01,\ K_a = 1.0 \times 10^{-6}}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:

Because pH is a logarithmic scale ($\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$), the pH of a mixture cannot be found by taking the arithmetic mean of individual pH values. Instead, one must calculate the absolute number of moles of H^+ ions contributed by each solution, sum them up, and divide by the total combined volume.

Solution:

Step 1: Determine the individual $[\mathrm{H}^+]$ concentrations for equal volumes (V) of each solution.

$$[\mathrm{H}^+]_1 = 10^{-3}\ \mathrm{M}, \quad [\mathrm{H}^+]_2 = 10^{-4}\ \mathrm{M}, \quad [\mathrm{H}^+]_3 = 10^{-5}\ \mathrm{M}$$

Step 2: Set up the total concentration balance over the final volume ($V_{\text{total}} = 3V$).

$$[\mathrm{H}^+]_{\text{mix}} = \frac{V(10^{-3} + 10^{-4} + 10^{-5})}{3V} = \frac{0.001 + 0.0001 + 0.00001}{3} = 3.7 \times 10^{-4}\ \mathrm{M}$$

Step 3: Calculate the final pH of the combined mixture.

$$\mathrm{pH}_{\text{mix}} = -\log_{10}(3.7 \times 10^{-4}) = 4 - \log_{10}(3.7) \approx 3.44$$

Final Answer: $\boxed{3.44}$

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

Go Back to Question 9

Q10.

Solution

Concept:

The non-standard potential (E_{cell}) of an electrochemical cell is computed via the Nernst equation:

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{2.303RT}{nF} \log_{10} Q$$

where n is the moles of electrons transferred, and Q is the reaction quotient containing ion concentrations.

Solution:

Step 1: Determine the electron transfer variable (n) from the balanced reaction equations.

$$\text{Zn}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu}(s) \implies n = 2$$

Step 2: Evaluate the reaction quotient (Q) ignoring solid phases.

$$Q = \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = \frac{1.0}{0.01} = 10^2$$

Step 3: Substitute $E^{\circ}_{\text{cell}} = 1.10$ V and $\frac{2.303RT}{F} = 0.06$ V into the equation.

$$E_{\text{cell}} = 1.10 - \frac{0.06}{2} \log_{10}(10^2) = 1.10 - 0.03 \times 2 = 1.04 \text{ V}$$

Final Answer: $\boxed{1.04 \text{ V}}$

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

Go Back to Question 10

Q11.

Solution

Concept:

The hybridization of a central atom is determined by its steric number (V), which equals the number of bonded σ atoms plus the number of lone pairs on that atom:

$$V = \frac{1}{2}\left[E_{\text{valence}} + M_{\text{monovalent}} - C_{\text{cation}} + A_{\text{anion}}\right]$$

Steric values of 2, 3, and 4 correspond directly to sp, sp^2, and sp^3 configurations.

Solution:

Step 1: Analyze NO_2^+. Nitrogen has 5 valence electrons, oxygen is divalent ($M = 0$), and the charge is $+1$.

$$V = \frac{1}{2}[5 + 0 - 1 + 0] = 2 \implies sp \text{ hybridization}$$

Step 2: Analyze NO_3^-. Nitrogen has 5 valence electrons, oxygen is divalent ($M = 0$), and the charge is -1.

$$V = \frac{1}{2}[5 + 0 - 0 + 1] = 3 \implies sp^2 \text{ hybridization}$$

Step 3: Analyze NH_4^+. Nitrogen has 5 valence electrons, hydrogen is monovalent ($M = 4$), and the charge is $+1$.

$$V = \frac{1}{2}[5 + 4 - 1 + 0] = 4 \implies sp^3 \text{ hybridization}$$

Final Answer: $\boxed{sp,\ sp^2,\ \text{and}\ sp^3}$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:
According to the law of chemical equivalence in electrolysis, the total number of equivalents of chemical change must be identical at both electrodes. The number of equivalents is defined as the product of the number of moles and the respective valence change factor (z). At standard temperature and pressure (STP), one mole of any ideal gas occupies exactly 22400 mL.

Solution:
Step 1: Calculate the equivalents of copper (Cu) metal deposited at the cathode.

$$\text{Moles of Cu} = \frac{\text{Given Mass}}{\text{Molar Mass}} = \frac{0.635\text{ g}}{63.5\text{ g/mol}} = 0.01\text{ mol}$$

Since the reduction process is $\mathrm{Cu}^{2+} + 2e^- \longrightarrow \mathrm{Cu}(s)$, the valence factor z is 2.

$$\text{Equivalents of Cu} = \text{Moles} \times z = 0.01 \times 2 = 0.02\text{ eq}$$

Step 2: Equate the chemical equivalents to determine the moles of oxygen (O_2) gas liberated at the anode.

$$\text{Equivalents of } \mathrm{O_2} = \text{Equivalents of Cu} = 0.02\text{ eq}$$

The anode half-reaction is $2\mathrm{H_2O} \longrightarrow \mathrm{O_2} + 4\mathrm{H}^+ + 4e^-$, giving a valence factor z of 4 for O_2.

$$\text{Moles of } \mathrm{O_2} = \frac{\text{Equivalents}}{z} = \frac{0.02}{4} = 0.005\text{ mol}$$

Step 3: Convert the calculated moles of oxygen gas to volume at STP conditions.

$$\text{Volume of } \mathrm{O_2} = 0.005\text{ mol} \times 22400\text{ mL/mol} = 112\text{ mL}$$

Final Answer: $\boxed{112\text{ mL}}$

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept:

In the industrial Contact Process for manufacturing sulfuric acid (H_2SO_4), sulfur trioxide (SO_3) gas is generated by oxidizing sulfur dioxide (SO_2) over a vanadium pentoxide (V_2O_5) catalyst. Although the ultimate goal is to hydrate SO_3 to produce H_2SO_4, the gas is not dissolved directly in water. The reaction between pure SO_3 gas and water is intensely exothermic. This extreme heat rapidly vaporizes the water, causing the acid to form a dense aerosol mist of fine droplets that is difficult to condense or capture. To avoid this, SO_3 is absorbed in concentrated sulfuric acid to form oleum, which can then be safely diluted with water.

Solution:

Step 1: Evaluate the thermodynamics of dissolving sulfur trioxide (SO_3) gas directly in water. The hydration reaction $SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(l)$ has a highly negative enthalpy change ($\Delta H \ll 0$), meaning it is violently exothermic.

Step 2: Understand the physical consequences of this intense heat release. The localized energy instantly vaporizes surrounding water molecules, creating a turbulent mixture of steam and acid. Instead of condensing cleanly into a liquid phase, the sulfuric acid forms a stable, dense colloidal mist of microscopic droplets.

Step 3: Analyze the operational challenges posed by this acid mist. This aerosol mist resists condensation and flows right through conventional industrial scrubbers, escaping into the environment and damaging equipment. Thus, statement B correctly describes why direct dissolution is avoided.

Step 4: Describe the industrial alternative used to prevent mist formation. The SO_3 gas is instead passed into an absorption tower showered with 98% concentrated H_2SO_4. The gas dissolves smoothly and reacts to form liquid oleum ($H_2S_2O_7$):

$$H_2SO_4 + SO_3 \longrightarrow H_2S_2O_7$$

This oleum can then be diluted with the exact amount of water needed to safely yield sulfuric acid of any desired concentration.

Final Answer: $\boxed{\text{Direct dissolution forms a dense, stable acid mist that does not condense easily.}}$

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

Go Back to Question 13

Q14.

Solution

Concept:

The hybridization state of a carbon atom in an organic molecule depends on the number of σ bonds it forms with neighboring atoms. This can be directly determined from its bonding pattern:

- A carbon atom forming 4 single σ bonds is sp^3 hybridized.
- A carbon atom forming 3 σ bonds and 1 π bond (such as a double bond) is sp^2 hybridized.
- A carbon atom forming 2 σ bonds and 2 π bonds (such as a triple bond or two adjacent double bonds) is sp hybridized.

We need to analyze the given options to find the structure that contains exactly two sp^3, two sp^2, and two sp hybridized carbon atoms.

Solution:

Step 1: Evaluate option A: Hexa-1,3-dien-5-yne.
The structural formula is $CH_2 = CH - CH = CH - C \equiv CH$.
Carbons 1, 2, 3, and 4 are part of double bonds, making them sp^2 hybridized (four sp^2 carbons). Carbons 5 and 6 are part of a triple bond, making them sp hybridized (two sp carbons). This structure has zero sp^3 carbons, so option A is incorrect.

Step 2: Evaluate option B: Hex-1-en-4-yne.
The structural formula is $C^1H_2 = C^2H - C^3H_2 - C^4 \equiv C^5 - C^6H_3$.
Let's analyze each carbon atom's hybridization:

- C_1 and C_2 form a double bond, so they are both sp^2 hybridized (2 carbons).
- C_3 forms 4 single σ bonds, so it is sp^3 hybridized. C_6 also forms 4 single σ bonds, so it is sp^3 hybridized. This gives a total of two sp^3 carbons.
- C_4 and C_5 form a triple bond, so they are both sp hybridized (2 carbons).

This perfectly matches the required count of two sp^3, two sp^2, and two sp carbon atoms.

Final Answer: $\boxed{\text{Hex-1-en-4-yne}}$

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

Go Back to Question 14

Q15.

Solution

Concept:
The distribution of electrons within an atom is defined by 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 quantum number (m_s). The azimuthal quantum number (l) specifies the subshell type: $l = 0$ is an s subshell, $l = 1$ is a p subshell, $l = 2$ is a d subshell, and $l = 3$ is an f subshell. For a given subshell characterized by l, there are $(2l + 1)$ degenerate atomic orbitals. According to the Pauli Exclusion Principle, each orbital can hold a maximum of 2 electrons with opposing spins. Therefore, the maximum electron capacity of any subshell is given by the formula $2(2l + 1)$.

Solution:
Step 1: Identify the given subshell from its quantum numbers. We are given a principal quantum number $n = 4$ and an azimuthal quantum number $l = 2$.

Step 2: Determine the subshell type. An azimuthal quantum number of $l = 2$ corresponds to a d subshell. Combined with $n = 4$, this designates the $4d$ atomic subshell. Note that the value of n does not affect the total electron capacity of the subshell itself.

Step 3: Calculate the number of individual spatial orbitals within this subshell using the magnetic quantum number rule.

$$\text{Number of Orbitals} = 2l + 1 = 2(2) + 1 = 5 \text{ orbitals}$$

These five degenerate orbitals correspond to the magnetic quantum numbers $m_l = \{-2, -1, 0, +1, +2\}$.

Step 4: Calculate the total electron capacity of the subshell. Since each orbital can accommodate a maximum of two electrons (one with $m_s = +1/2$ and one with $m_s = -1/2$):

$$\text{Maximum Electrons} = 2 \times (2l + 1) = 2 \times 5 = 10 \text{ electrons}$$

Thus, the subshell can hold a maximum of 10 electrons.

Final Answer: $\boxed{10}$

Answer: (C)

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Q16.

Solution

Concept:

The dependency of the chemical equilibrium constant (K_{eq}) on temperature is quantified by the van 't Hoff equation: $\frac{d(\ln K_{eq})}{dT} = \frac{\Delta H^\circ}{RT^2}$. For an endothermic reaction ($\Delta H^\circ > 0$), raising the temperature shifts the equilibrium state forward, thereby increasing K_{eq}. Separately, the Arrhenius equation $k = Ae^{-E_a/RT}$ governs chemical kinetics. An increase in temperature expands the fraction of molecules with sufficient kinetic energy to clear the activation energy barrier, thus accelerating both forward (k_f) and reverse (k_b) rate constants without lowering the structural barrier (E_a) itself.

Solution:

Step 1: Evaluate statement A using thermodynamics. Since $\Delta H^\circ > 0$ for an endothermic process, the mathematical derivative of $\ln K_{eq}$ with respect to temperature is positive. Consequently, an increase in system temperature yields a larger equilibrium constant (K_{eq}). Thus, statement A is correct.

Step 2: Evaluate statement B using activation energy principles. The activation energy (E_a) is an intrinsic mechanistic barrier determined solely by the transition state configuration; it remains constant regardless of kinetic temperature changes. Thus, statement B is incorrect.

Step 3: Evaluate statement C using kinetic theory. In the Arrhenius expression, increasing T diminishes the magnitude of the exponent $-\frac{E_a}{RT}$, which mathematically increases the exponential factor. This accelerates both the forward rate (k_f) and backward rate (k_b). Thus, statement C is correct.

Step 4: Evaluate statement D using enthalpy definitions. The reaction enthalpy (ΔH°) depends slightly on temperature based on heat capacities via Kirchhoff's law, but a moderate temperature change cannot invert its absolute thermodynamic sign. Thus, statement D is incorrect.

Final Answer: $\boxed{\text{A and C are correct options}}$

Answer: (A, C)

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Q17.

Solution

Concept:
Electronic configuration and atomic behavior are governed by fundamental laws. Pauli's Exclusion Principle states that no two electrons in an atom can have identical quantum numbers. Hund's Rule states that degenerate orbitals must be singly occupied with parallel spins before pairing. Bohr's postulates state that orbital angular momentum (L) is quantized as $L = \frac{nh}{2\pi}$. The Aufbau Principle dictates that subshells fill in order of increasing energy, following the path of increasing $(n+l)$ values.

Solution:
Step 1: Evaluate statement A. This accurately reflects Pauli's exclusion principle. Because each orbital holds at most two electrons with opposing spin magnetic quantum numbers ($m_s = \pm 1/2$), statement A is correct.

Step 2: Evaluate statement B. This matches Hund's rule of maximum multiplicity. Singly filling degenerate orbitals minimizes inter-electronic coulomb repulsions before pairing. Thus, statement B is correct.

Step 3: Evaluate statement C. This is Bohr's fundamental quantization condition for stationary state circular electronic orbits. Thus, statement C is correct.

Step 4: Evaluate statement D. The Aufbau principle specifies that orbital filling progresses by increasing $(n + l)$ values, not decreasing. Thus, statement D is completely false.

Final Answer: $\boxed{\text{A, B, and C are correct options}}$

$\boxed{\textbf{Answer: (A, B, C)}}$

Go Back to Question 17

Q18.

Solution

Concept:
In a galvanic cell, the half-cell with the larger standard reduction potential (E°) acts as the cathode (reduction), while the lower acts as the anode (oxidation). The net cell potential is:

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

Standard reduction potential is an intensive property; multiplying stoichiometric coefficients by a scalar factor to balance electrons does not alter its value.

Solution:
Step 1: Identify cathode and anode roles from the given half-cell reduction values.

$$E^\circ_{\text{Fe}^{3+}/\text{Fe}^{2+}} = +0.77\text{ V}, \quad E^\circ_{\text{MnO}_4^-/\text{Mn}^{2+}} = +1.51\text{ V}$$

Since $+1.51\text{ V} > +0.77\text{ V}$, the permanganell system is the cathode and the iron system is the anode.

Step 2: Compute the standard EMF value of the combined chemical cell.

$$E^\circ_{\text{cell}} = +1.51\text{ V} - (+0.77\text{ V}) = +0.74\text{ V} \quad \text{(Statement A is correct)}$$

Step 3: Identify the oxidizing agent. The cathode species $\text{MnO}_4^-(aq)$ undergoes reduction, acting as the oxidizing agent. Thus, statement B is correct.

Step 4: Check stoichiometric dependencies. Multiplying the iron half-reaction by 5 leaves E° unchanged at $+0.77$ V. Thus, statement C is incorrect.

Step 5: Determine spontaneous species pathways. Since the iron half-cell acts as the anode, Fe^{2+} undergoes oxidation to Fe^{3+}. Thus, statement D is correct.

Final Answer: $\boxed{\text{A, B, and D are correct options}}$

$\boxed{\textbf{Answer: (A, B, D)}}$

Go Back to Question 18

Q19.

Solution

Concept:

The industrial extraction of copper from copper pyrites ($CuFeS_2$) involves partial roasting, smelting in a blast furnace, and self-reduction in a Bessemer converter. During smelting, the ore is converted into a molten mixture called copper matte. This matte contains iron sulfide (FeS) impurities that must be removed. This is achieved by adding silica (SiO_2), a flux that reacts with iron oxides to form a fusible slag. The remaining copper sulfide undergoes self-reduction to produce blister copper, which is then purified using electrolytic refining.

Solution:

Step 1: Evaluate statement A. Copper matte is the molten product obtained after smelting in the blast furnace. It consists of copper(I) sulfide (Cu_2S) and iron(II) sulfide (FeS), with small amounts of remaining oxides. Thus, statement A is correct.

Step 2: Evaluate statement B. In the Bessemer converter, iron sulfide is first oxidized to iron oxide (FeO). Acidic silica (SiO_2) flux is added to react with this basic oxide, forming a molten iron silicate slag ($FeSiO_3$) that can be easily poured off:

$$\mathrm{FeO} + \mathrm{SiO_2} \rightarrow \mathrm{FeSiO_3}\ (\text{slag})$$

Thus, statement B is correct.

Step 3: Evaluate statement C. Blister copper is the solidified metal obtained from the converter. It gets its characteristic blistered appearance from bubbles of sulfur dioxide (SO_2) gas escaping as the metal cools, not carbon dioxide (CO_2). Thus, statement C is false.

Step 4: Evaluate statement D. During the electrolytic refining of copper, blocks of impure blister copper are placed at the anode, where copper dissolves into solution ($\mathrm{Cu} \rightarrow \mathrm{Cu}^{2+} + 2e^-$). A thin sheet of pure copper is placed at the cathode, where pure copper ions from the electrolyte deposit onto it ($\mathrm{Cu}^{2+} + 2e^- \rightarrow \mathrm{Cu}$). Thus, statement D is correct.
In conclusion, statements A, B, and D are correct.

Final Answer: $\boxed{\text{A, B, and D are correct options}}$

$\boxed{\textbf{Answer: (A, B, D)}}$

Go Back to Question 19

Q20.

Solution

Concept:

The geometric shapes of covalent molecules can be predicted using Valence Shell Electron Pair Repulsion (VSEPR) theory. According to VSEPR, the geometry of a molecule depends on the total number of bonding pairs and lone pairs around the central atom. These electron pairs position themselves as far apart as possible to minimize electrostatic repulsions. Lone pairs occupy more space than bonding pairs, which causes deviations from ideal structural angles.

Solution:

Step 1: Analyze sulfur tetrafluoride (SF_4). The central sulfur atom has 6 valence electrons and forms 4 single bonds with fluorine atoms, leaving 1 lone pair (Steric number = 5). The electron pair geometry is trigonal bipyramidal. To minimize repulsion, the lone pair occupies an equatorial position, resulting in a distorted tetrahedral or "see-saw" molecular geometry. Thus, statement A is correct.

Step 2: Analyze xenon tetrafluoride (XeF_4). The central xenon atom has 8 valence electrons and forms 4 single bonds with fluorine atoms, leaving 2 lone pairs (Steric number = 6). The electron pair geometry is octahedral. To minimize lone pair-lone pair repulsions, the two lone pairs position themselves as far apart as possible in trans axial positions (180° apart), resulting in a square planar molecular geometry. Thus, statement B is correct.

Step 3: Analyze chlorine trifluoride (ClF_3). The central chlorine atom has 7 valence electrons and forms 3 single bonds with fluorine atoms, leaving 2 lone pairs (Steric number = 5). The electron pair geometry is trigonal bipyramidal. Both lone pairs occupy equatorial positions to minimize repulsion, resulting in a distorted T-shaped molecular geometry. Thus, statement C is correct.

Step 4: Analyze water (H_2O). The central oxygen atom has 6 valence electrons and forms 2 single bonds with hydrogen atoms, leaving 2 lone pairs (Steric number = 4). The electron pair geometry is tetrahedral, resulting in a bent or V-shaped molecular geometry. The two lone pairs are oriented at a tetrahedral angle of approximately 109.5° (compressed to 104.5° by repulsion), not 180°. Thus, statement D is false.
In conclusion, statements A, B, and C are correct.

Final Answer: $\boxed{\text{A, B, and C are correct options}}$

$\boxed{\textbf{Answer: (A, B, C)}}$

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	B	3	A	4	A	5	B
6	B	7	B	8	A	9	B	10	C
11	A	12	A	13	B	14	B	15	C
16	A, C	17	A, B, C	18	A, B, D	19	A, B, D	20	A, B, C