

# JELET Chemistry Sample Paper-3

Duration: 25 Minutes

Maximum Marks: 25

## Instructions

- This paper contains **20** Multiple Choice Questions divided into **2 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.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

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

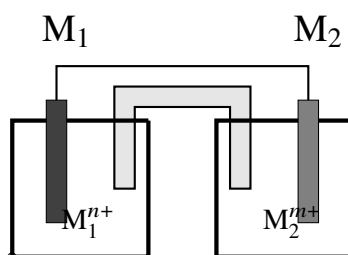
- Q1.** According to the Bohr-Sommerfeld relativistic model and advanced quantum numbers, consider a hydrogen-like atom of atomic number  $Z$ . If an electron is residing in an orbit with principal quantum number  $n = 4$  and azimuthal quantum number  $l = 2$ , the total number of fine-structure relativistic sub-states generated due to spin-orbit coupling ( $j - j$  coupling) is:
- (A) 2  
(B) 3  
(C) 5  
(D) 6
- Q2.** At a specific high industrial operating temperature  $T$ , a closed rigid vessel contains an equilibrium mixture according to the reaction:  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$  with an equilibrium constant  $K_c$ . If the volume of the reaction chamber is compressed suddenly to exactly half of its initial volume while maintaining



temperature constant, the new equilibrium constant  $K'_c$  will satisfy which relationship?

- (A)  $K'_c = 2K_c$
- (B)  $K'_c = \frac{1}{2}K_c$
- (C)  $K'_c = K_c$
- (D)  $K'_c = 4K_c$

**Q3.** An advanced galvanic cell assembly utilizes a highly concentrated redox chemical system diagrammed below. A constant current density is passed through the cell, initiating competitive migration. Identify the correct mathematical relation governing the net cell potential  $E_{\text{cell}}$  at  $25^\circ\text{C}$  based on the dynamic shifting parameters:



- (A)  $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{nm} \log \frac{[M_1^{n+}]^m}{[M_2^{m+}]^n}$
- (B)  $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{n+m} \log \frac{[M_1^{n+}]}{[M_2^{m+}]}$
- (C)  $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{nm} \log \frac{[M_2^{m+}]^n}{[M_1^{n+}]^m}$
- (D)  $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{n} \log \frac{[M_1^{n+}]}{[M_2^{m+}]}$

**Q4.** During the extractive metallurgy of ultra-pure copper from copper pyrites ( $\text{CuFeS}_2$ ) in a Bessemer converter, a self-reduction chemical reaction cascade occurs in the final stages. The exact chemical balanced reaction representing this spontaneous self-reduction phase is:

- (A)  $\text{Cu}_2\text{S} + 2\text{CuO} \rightarrow 4\text{Cu} + \text{SO}_2$
- (B)  $\text{Cu}_2\text{S} + 2\text{Cu}_2\text{O} \rightarrow 6\text{Cu} + \text{SO}_2$
- (C)  $2\text{FeS} + 3\text{O}_2 \rightarrow 2\text{FeO} + 2\text{SO}_2$







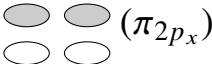

**Q5.** An organic polyfunctional hydrocarbon matrix displays a complex branching profile. Evaluate the correct IUPAC nomenclature designation for an alkene derivative containing an alkoxy grouping:  $\text{CH}_3 - \text{CH}(\text{OCH}_3) - \text{C}(\text{CH}_3) = \text{CH} - \text{CH}_2 - \text{COOH}$ :

- (A) 5-Methoxy-4-methylhex-3-enoic acid  
 (B) 2-Methoxy-3-methylhex-3-en-6-oic acid  
 (C) 5-Methoxy-4-methylhex-2-enoic acid  
 (D) 4-Methyl-5-methoxyhex-3-enoic acid

**Q6.** In the upper stratosphere, the catalytic destruction cycle of the protective ozone layer ( $\text{O}_3$ ) by chlorofluorocarbons (CFCs) is highly efficient. Which specific free radical intermediate species acts as the primary regenerative propagation catalyst in this cycle?

- (A)  $\text{CF}_2\text{Cl}^\bullet$   
 (B)  $\text{Cl}^\bullet$   
 (C)  $\text{ClO}^\bullet$   
 (D)  $\text{O}^\bullet$

**Q7.** Select the correct spatial orientation representing the Highest Occupied Molecular Orbital (HOMO) boundary surface profile for the dinitrogen ( $\text{N}_2$ ) molecule in its ground electronic state configuration among the options drafted below:

- (A)  ( $\pi_{2p}^*$ )  
 (B)  ( $\sigma_{2p_z}$ )  
 (C)  ( $\pi_{2p_x}$ )  
 (D)  ( $\sigma_{2p_z}^*$ )

**Q8.** A high-precision buffer solution formulation is compiled by mixing 100 mL of 0.2 M weak monoprotic acid HA ( $K_a = 2.0 \times 10^{-5}$ ) with 50 mL of 0.2 M strong



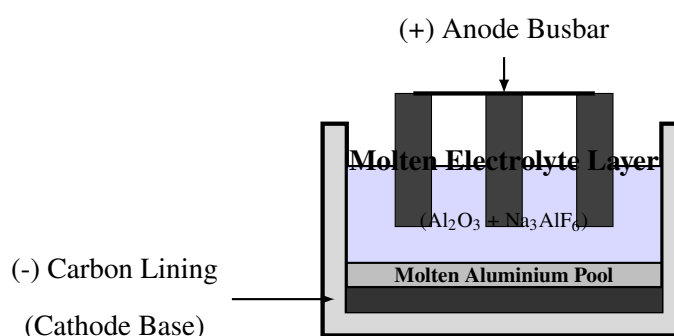
base NaOH. The final exact operating pH value of this industrial buffer matrix at standard room reference temperature is given by:

- (A) 4.70
- (B) 5.00
- (C) 4.30
- (D) 3.70

**Q9.** During the electrolytic refining of an industrial copper slab, a constant current of  $I = 5.0 \text{ A}$  is sustained through an acidic copper sulfate ( $\text{CuSO}_4$ ) electrolyte bath for exactly  $t = 9650$  seconds. Assuming an operational Faradaic current efficiency of 96%, what is the exact net mass yield of pure copper (At. Wt. = 63.5 g/mol) deposited onto the cathode plate?

- (A) 15.875 g
- (B) 7.937 g
- (C) 7.620 g
- (D) 15.240 g

**Q10.** An industrial aluminum smelting plant utilizes the Hall-Héroult electrolytic cell configuration sketched below to reduce purified alumina ( $\text{Al}_2\text{O}_3$ ) dissolved in a molten bath of cryolite ( $\text{Na}_3\text{AlF}_6$ ). Identify the specific electrochemical half-cell reaction occurring at the carbon-lined internal hearth surface (Cathode) of this reactor:

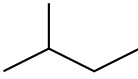
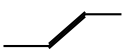
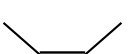
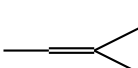


- (A)  $\text{Al}^{3+}(\text{melt}) + 3e^- \rightarrow \text{Al}(\text{l})$
- (B)  $\text{C}(\text{s}) + 2\text{O}^{2-}(\text{melt}) \rightarrow \text{CO}_2(\text{g}) + 4e^-$



- (C)  $\text{Al(l)} \rightarrow \text{Al}^{3+}(\text{melt}) + 3e^{-}$   
(D)  $2\text{Al}_2\text{O}_3 + 3\text{C(s)} \rightarrow 4\text{Al(l)} + 3\text{CO}_2(\text{g})$

**Q11.** Among the primary isomeric configuration structures derived for the molecular formula  $\text{C}_4\text{H}_8$ , select the structure that possesses the highest thermodynamic stability profile (lowest heat of hydrogenation values):

- (A)   
(B)   
(C)   
(D) 

**Q12.** The biochemical oxygen demand ( $\text{BOD}_5$ ) assay configuration of an industrial wastewater discharge sample registers an initial dissolved oxygen (DO) level of 9.0 mg/L. After a standard 5-day incubation tracking phase at  $20^\circ\text{C}$  inside a 1 : 50 dilution flask ratio, the final residual DO reading drops to 3.0 mg/L. The baseline absolute BOD rating of the wastewater sample is:

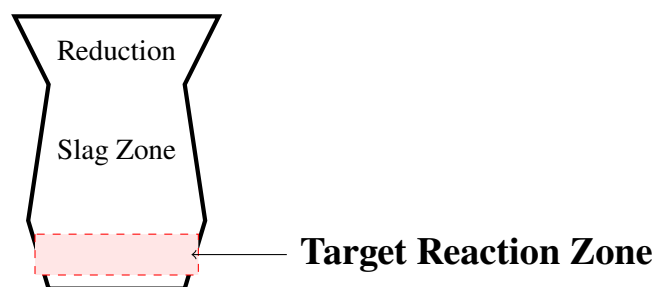
- (A) 150 mg/L  
(B) 300 mg/L  
(C) 450 mg/L  
(D) 600 mg/L

**Q13.** The steric number and geometry of the interhalogen atomic compound species iodine heptafluoride ( $\text{IF}_7$ ) is evaluated based on the Valence Shell Electron Pair Repulsion (VSEPR) model. The hybridization state of the central iodine nucleus and its spatial orientation configuration is:

- (A)  $sp^3d^2$ , Octahedral  
(B)  $sp^3d^3$ , Pentagonal Bipyramidal  
(C)  $sp^3d$ , Trigonal Bipyramidal  
(D)  $d^2sp^3$ , Distorted Octahedral



- Q14.** The solubility product constant of a sparingly soluble ternary salt system  $M(OH)_2$  at a baseline temperature is evaluated to be  $K_{sp} = 4.0 \times 10^{-12}$ . What is the exact equilibrium pH of a saturated aqueous solution of this salt composition?
- (A) 10.30  
(B) 11.00  
(C) 9.70  
(D) 11.30
- Q15.** The high-temperature reduction profiles inside an industrial iron-producing blast furnace assembly are tracked systematically. Identify the specific balanced chemical equation operating efficiently within the highest thermal zone (Lower Combustion Zone,  $1500^\circ\text{C} - 2000^\circ\text{C}$ ) near the air tuyeres section highlighted below:



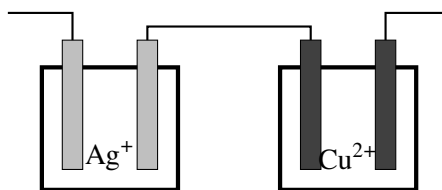
- (A)  $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$   
(B)  $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$   
(C)  $\text{CO}_2 + \text{C} \rightarrow 2\text{CO}$   
(D)  $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$

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

- Q16.** A highly technical multi-electrolyte electrochemical deposition array is analyzed below. Two cells containing aqueous silver nitrate ( $\text{AgNO}_3$ ) and copper(II) sulfate ( $\text{CuSO}_4$ ) solutions are arranged in series connectivity configuration under



a constant galvanic current load. Select all the correct declarations from the choices provided:



- (A) The mass of silver deposited is exactly double the mass of copper deposited if equal moles of electrons pass through the circuit loop.
- (B) The ratio of equivalents of silver deposited to copper deposited is strictly 1 : 1.
- (C) If 1 Faraday of charge passes through the cells, 107.8 g of Ag and 31.75 g of Cu are deposited.
- (D) Oxidation reactions occur exclusively at the anodes of both interconnected cell loops.

**Q17.** The Contact Process layout represents the core chemical engineering methodology utilized for the mass manufacture of high-strength industrial sulfuric acid ( $\text{H}_2\text{SO}_4$ ). Which of the following optimization parameters or reaction constraints are scientifically true regarding this industrial mechanism?

- (A) The conversion of  $\text{SO}_2$  to  $\text{SO}_3$  is catalyzed using porous vanadium pentoxide ( $\text{V}_2\text{O}_5$ ) pellets.
- (B) The oxidation phase of sulfur dioxide is highly endothermic, requiring continuous external thermal heating updates.
- (C) High pressure values (100 – 200 atm) are mandatory to ensure the initial survival of the  $\text{SO}_3$  yield configuration.
- (D) Absorption of  $\text{SO}_3$  gas is safely conducted in concentrated  $\text{H}_2\text{SO}_4$  to form oleum ( $\text{H}_2\text{S}_2\text{O}_7$ ) rather than directly in pure water water.

**Q18.** Consider the chemical reaction dynamics and kinetic mechanism configuration of a sterically hindered alkyl halide undergoing a substitution pathway under strongly nucleophilic conditions. Choose all the correct mechanistic interpretations from below:



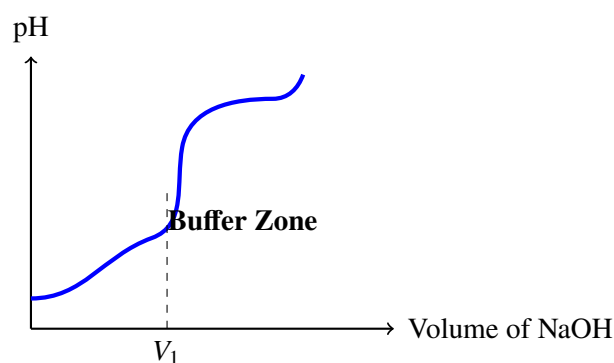
- (A) An  $S_N1$  substitution mechanism follows a two-step path involving a planar, carbocation intermediate configuration.
- (B) The rate-determining step of an  $S_N2$  mechanism relies exclusively on the starting concentration profile of the incoming nucleophile.
- (C) Polar protic solvent formulations significantly accelerate the step-rate performance of  $S_N1$  ionization pathways.
- (D) Complete inversion of stereochemical configuration (Walden Inversion) is the hallmark signature of an  $S_N2$  mechanism.

**Q19.** Which of the given quantum mechanical assertions or tracking metrics regarding the distribution profiles of electron configurations within multielectronic systems are structurally valid?

- (A) Hund's rule of maximum multiplicity asserts that pairing of electrons within degenerate shell levels cannot occur until all subshells contain at least one electron.
- (B) The total number of radial nodes generated within an atomic orbital boundary is mathematically defined as  $n - l - 1$ .
- (C) No two electrons residing inside the same atomic confinement field can share an identical set of all four principal quantum numbers.
- (D) The magnetic spin quantum number ( $m_s$ ) is a direct spatial derivative of the principal solution vectors of Schrödinger's wave equation.

**Q20.** The pH neutralization profile of a complex polyprotic acid sample titrated with a standard aqueous solution of sodium hydroxide (NaOH) is systematically mapped below. Evaluate the structural layout data and choose all the correct chemical interpretations:





- (A) The titration curve showcases a single distinct inflection endpoint, characterizing a typical weak monoprotic acid template.
- (B) At the half-neutralization threshold volume point ( $V_1/2$ ), the pH value of the matrix matches the numeric value of the  $pK_a$  parameter.
- (C) The sharp vertical jump configuration near volume point  $V_1$  indicates complete neutralization of the first acidic proton.
- (D) The chemical buffering capacity reaches its maximum performance limits when the pH of the system equals the operating pOH matrix.



## Detailed Solutions

Q1.

## Solution

**Concept:** Under the Bohr-Sommerfeld relativistic model and advanced quantum theory, spin-orbit coupling ( $j - j$  coupling) splits an orbital state characterized by a given azimuthal quantum number  $l$  into fine-structure sub-states. The total angular momentum quantum number  $j$  can take values from  $|l - s|$  to  $l + s$ , where the electron spin is  $s = \frac{1}{2}$ .

**Solution:**

Given quantum numbers:  $n = 4$  and  $l = 2$ . The spin of a single electron is always  $s = \frac{1}{2}$ .

The allowable values for the total angular momentum quantum number  $j$  are:

$$j = l \pm s = 2 \pm \frac{1}{2}$$

This yields two distinct possible values for  $j$ :

$$j_1 = 2 - \frac{1}{2} = \frac{3}{2}$$

$$j_2 = 2 + \frac{1}{2} = \frac{5}{2}$$

Each distinct value of  $j$  corresponds to a unique relativistic fine-structure sub-state (represented spectroscopically as  $^2D_{3/2}$  and  $^2D_{5/2}$ ). Therefore, the total number of fine-structure relativistic sub-states generated is exactly 2.

**Final Answer:**

**Answer: (A)**

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Q2.

**Solution**

**Concept:** The chemical equilibrium constant ( $K_c$  or  $K_p$ ) for a given balanced reaction depends strictly and exclusively on the absolute operating temperature  $T$ .

**Solution:**

According to the van 't Hoff equation and fundamental thermodynamic laws, changing the concentration, partial pressure, or total volume of a closed system shifts the position of equilibrium in accordance with Le Chatelier's Principle to counteract the perturbation.

However, because the temperature  $T$  is held completely constant during the sudden volume compression, the intrinsic thermodynamic equilibrium constant remains unaltered. Thus, the new equilibrium constant  $K'_c$  relates to the initial value as:

$$K'_c = K_c$$

**Final Answer:**  $K'_c = K_c$

**Answer: (C)**

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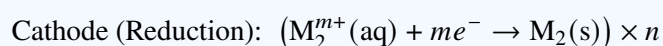
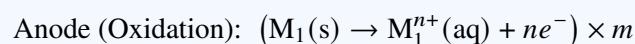
Q3.

**Solution**

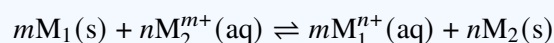
**Concept:** The instantaneous net potential  $E_{\text{cell}}$  of an electrochemical galvanic cell assembly at  $25^\circ\text{C}$  is derived via the Nernst Equation:  $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{z} \log Q$ , where  $z$  is the total number of moles of electrons transferred in the balanced net redox equation and  $Q$  is the reaction quotient.

**Solution:**

1. Formulate the half-cell reactions and determine the overall balanced cell reaction:



2. Summing these half-reactions yields the overall balanced redox process:



3. The total number of transferred electrons is  $z = n \times m$ . The reaction quotient  $Q$  ignoring pure solids is:

$$Q = \frac{[M_1^{n+}]^m}{[M_2^{m+}]^n}$$

4. Substituting these terms into the Nernst equation at  $25^\circ\text{C}$ :

$$E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{nm} \log \frac{[M_1^{n+}]^m}{[M_2^{m+}]^n}$$

**Final Answer:**  $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{nm} \log \frac{[M_1^{n+}]^m}{[M_2^{m+}]^n}$

**Answer: (A)**

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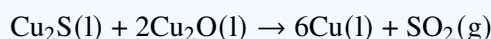
Q4.

**Solution**

**Concept:** During the final blister copper formation stages inside a Bessemer converter, no external reducing agent is added. Instead, a portion of the unreacted copper(I) sulfide ( $\text{Cu}_2\text{S}$ ) undergoes a spontaneous self-reduction reaction with the copper(I) oxide ( $\text{Cu}_2\text{O}$ ) formed during preliminary partial roasting.

**Solution:**

The self-reduction chemistry cascade is characterized by the reaction between copper(I) sulfide and copper(I) oxide to yield pure liquid metallic copper and sulfur dioxide gas:



Let us review the given choices: \* Option (A) utilizes  $\text{CuO}$  (copper(II) oxide) which is incorrect. \* Option (B) correctly represents the balanced self-reduction phase matching copper in its +1 oxidation state. \* Option (C) represents the slag-formation phase of iron impurities. \* Option (D) represents standard carbon monoxide reduction.

**Final Answer:**  $\text{Cu}_2\text{S} + 2\text{Cu}_2\text{O} \rightarrow 6\text{Cu} + \text{SO}_2$

**Answer: (B)**

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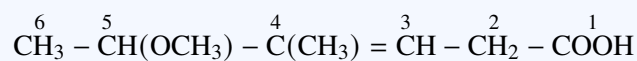
Q5.

**Solution**

**Concept:** According to standard IUPAC nomenclature rule sets for polyfunctional organic compounds, principal functional groups take numbering priority. The carboxylic acid group ( $-\text{COOH}$ ) has the highest priority over alkenes, alkyl branches, and alkoxy substituents, and its carbon is designated as C – 1.

**Solution:**

1. Identify and number the longest continuous carbon chain starting at the  $-\text{COOH}$  carbon:



The principal chain contains 6 carbons, giving the parent name **hexanoic acid**.

2. Identify the position of the unsaturation (double bond): The alkene double bond starts at position C – 3, which updates the stem to **hex-3-enoic acid**.

3. Arrange alphabetical prefixes for the remaining groups attached to the chain: \* At C – 4: a methyl group ( $-\text{CH}_3$ ) \* At C – 5: a methoxy group ( $-\text{OCH}_3$ )

4. Assemble the full name alphabetically (Methoxy precedes Methyl): **5-Methoxy-4-methylhex-3-enoic acid**

**Final Answer:**  $5\text{-Methoxy-4-methylhex-3-enoic acid}$

**Answer: (A)**

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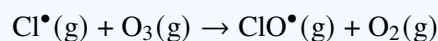
Q6.

**Solution**

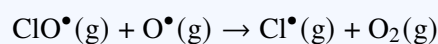
**Concept:** Chlorofluorocarbons (CFCs) broken down by intense solar ultraviolet radiation release highly reactive chlorine free radicals ( $\text{Cl}^\bullet$ ). These radicals initiate a catalytic chain reaction loop that breaks down ozone molecules ( $\text{O}_3$ ).

**Solution:**

The catalytic mechanism occurs via the following elementary propagation steps: 1. Attack on ozone by the chlorine radical:



2. Reaction of the chlorine monoxide radical with stratospheric atomic oxygen:



Adding these steps gives the net reaction:  $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$ . Since the atomic chlorine radical ( $\text{Cl}^\bullet$ ) is consumed in step 1 and regenerated intact in step 2, it serves as the primary regenerative propagation catalyst.

**Final Answer:**  $\text{Cl}^\bullet$

**Answer: (B)**

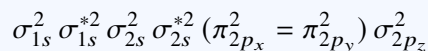
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Q7.

### Solution

**Concept:** According to Molecular Orbital (MO) Theory, the ground-state electronic configuration of a dinitrogen ( $N_2$ ) molecule (containing 14 electrons) is written as:



**Solution:**

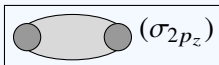
1. **Identify the Highest Occupied Molecular Orbital (HOMO):** Looking at the ground-state filling order for  $N_2$ , the orbital of highest energy that contains electrons is the bonding  $\sigma_{2p_z}$  molecular orbital.

2. **Analyze the Geometry and Symmetry of  $\sigma_{2p_z}$ :** \* A bonding  $\sigma$  molecular orbital is formed by the head-on ( $z$ -axis) constructive overlap of two  $2p_z$  atomic orbitals. \* This results in a continuous build-up of electron density concentrated directly along the internuclear axis between the two nuclei, accompanied by smaller outer lobes on both ends.

3. **Evaluate the Boundary Surface Profiles:**

- **Option A ( $\pi_{2p}^*$ ):** Shows side-by-side out-of-phase destructive overlap (an anti-bonding  $\pi$  profile with a vertical nodal plane).
- **Option B ( $\sigma_{2p_z}$ ):** Shows a large central, continuous elliptical electron cloud containing the internal nuclear positions, flanked by two outer lobes. This perfectly maps the constructive bonding distribution of a  $\sigma_{2p_z}$  orbital.
- **Option C ( $\pi_{2p_x}$ ):** Shows parallel, side-by-side constructive overlap with an electron density cloud above and below the internuclear axis.
- **Option D ( $\sigma_{2p_z}^*$ ):** Shows an anti-bonding  $\sigma$  profile with a central nodal plane separating the lobes due to out-of-phase axial overlap.

Therefore, the diagram corresponding to option (B) represents the correct boundary profile of the HOMO ( $\sigma_{2p_z}$ ) orbital.

**Final Answer:**  ( $\sigma_{2p_z}$ )

**Answer: (B)**

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Q8.

**Solution**

**Concept:** Mixing a weak acid (HA) with a limiting amount of a strong base (NaOH) results in partial neutralization, forming a classic acidic buffer solution containing unreacted weak acid HA and its conjugate base salt  $A^-$ . The operating pH is calculated using the Henderson-Hasselbalch equation:  $pH = pK_a + \log \frac{[A^-]}{[HA]}$ .

**Solution:**

1. Calculate initial millimoles (mmol) of the reactants:

$$\text{Initial mmol of HA} = 100 \text{ mL} \times 0.2 \text{ M} = 20 \text{ mmol}$$

$$\text{Initial mmol of NaOH} = 50 \text{ mL} \times 0.2 \text{ M} = 10 \text{ mmol}$$

2. Determine the composition after the neutralization reaction ( $HA + OH^- \rightarrow A^- + H_2O$ ):

$$\text{Remaining mmol of HA} = 20 - 10 = 10 \text{ mmol}$$

$$\text{Formed mmol of } A^- = 10 \text{ mmol}$$

3. Compute  $pK_a$  from  $K_a = 2.0 \times 10^{-5}$ :

$$pK_a = -\log(2.0 \times 10^{-5}) = 5 - \log 2 = 5 - 0.3010 = 4.699 \approx 4.70$$

4. Apply the Henderson-Hasselbalch equation:

$$pH = pK_a + \log \frac{10 \text{ mmol}}{10 \text{ mmol}} = 4.70 + \log(1) = 4.70$$

**Final Answer:**

**Answer:** (A)

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Q9.

**Solution**

**Concept:** Faraday's laws of electrolysis state that the mass of a substance deposited at an electrode is given by  $m = \frac{I \cdot t \cdot M}{z \cdot F} \times \text{Efficiency}$ , where  $I$  is current,  $t$  is time,  $M$  is the molar mass,  $z$  is the valence factor, and  $F = 96500 \text{ C/mol}$ .

**Solution:**

1. Identify parameters for the deposition of copper from a  $\text{CuSO}_4$  bath ( $\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu(s)}$ ):  
\* Current  $I = 5.0 \text{ A}$  \* Time  $t = 9650 \text{ s}$  \* Valence factor  $z = 2$  \* Molar mass  $M = 63.5 \text{ g/mol}$  \* Faradaic efficiency =  $96\% = 0.96$
2. Calculate total theoretical charge passed  $Q$ :

$$Q = I \times t = 5.0 \times 9650 = 48250 \text{ C}$$

3. Calculate the theoretical mass yield:

$$m_{\text{theoretical}} = \frac{48250}{96500} \times \frac{63.5}{2} = 0.5 \times 31.75 = 15.875 \text{ g}$$

4. Adjust for the operational Faradaic efficiency profile:

$$m_{\text{actual}} = m_{\text{theoretical}} \times 0.96 = 15.875 \times 0.96 = 15.240 \text{ g}$$

**Final Answer:**

**Answer: (D)**

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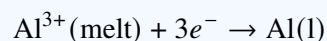
Q10.

**Solution**

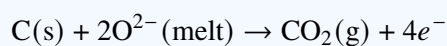
**Concept:** In the Hall-Héroult industrial process for smelting aluminum, electrolysis reduces alumina ( $\text{Al}_2\text{O}_3$ ) dissolved in molten cryolite. Reduction half-reactions (gain of electrons) take place exclusively at the negative electrode, which is the carbon-lined hearth base (Cathode).

**Solution:**

Let's analyze the options for reactions inside the cell: \* At the cathode (negative carbon lining), aluminum ions  $\text{Al}^{3+}$  from the molten electrolyte gain electrons to form liquid aluminum metal:



\* At the anode (positive carbon rods), oxide ions are oxidized, consuming the carbon rods to produce carbon dioxide gas:



Since the question explicitly asks for the half-cell reaction occurring at the cathode base, option (A) is the correct choice.

**Final Answer:**  $\text{Al}^{3+}(\text{melt}) + 3e^- \rightarrow \text{Al}(\text{l})$

**Answer:** (A)

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Q11.

**Solution**

**Concept:** The thermodynamic stability of alkene isomers is inversely proportional to their experimental heat of hydrogenation ( $\Delta H_{\text{hydro}}$ ) values. A lower release of heat during catalytic hydrogenation indicates a more stable, lower-energy starting ground state. Alkene stability increases with the degree of alkyl substitution around the  $sp^2$  carbon centers due to hyperconjugation and steric relief.

**Solution:**

Let us identify the four structures drawn in the TikZ options:

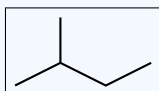
- (A) **Structure A:** Represents **2-methylpropene** (isobutylene). It is a disubstituted alkene with two methyl groups bound to the same carbon atom ( $\text{CH}_2 = \text{C}(\text{CH}_3)_2$ ).
- (B) **Structure B:** Represents **cis-but-2-ene**. It is a 1,2-disubstituted alkene where both methyl groups reside on the same side of the double bond, introducing mild steric strain.
- (C) **Structure C:** Represents **trans-but-2-ene**. It is a 1,2-disubstituted alkene where the methyl groups are situated on opposite sides, minimizing steric repulsion.
- (D) **Structure D:** Represents **but-1-ene**. It is a monosubstituted terminal alkene ( $\text{CH}_2 = \text{CH} - \text{CH}_2 - \text{CH}_3$ ).

Comparing the thermodynamic parameters for these structural isomers:

- Monosubstituted alkenes (but-1-ene) have fewer hyperconjugative pathways and are the least stable.
- Among the disubstituted options, the stability trend follows: **2-methylpropene > trans-but-2-ene > cis-but-2-ene**.
- 2-Methylpropene is an asymmetrically gem-disubstituted alkene. It possesses 6  $\alpha$ -hydrogens participating in hyperconjugation, and its unique charge distribution gives it a lower ground state energy profile ( $\Delta H_{\text{hydro}} \approx -115 \text{ kJ/mol}$ ) compared to trans-but-2-ene ( $\Delta H_{\text{hydro}} \approx -115.5 \text{ kJ/mol}$ ) and cis-but-2-ene ( $\Delta H_{\text{hydro}} \approx -119.7 \text{ kJ/mol}$ ).

Thus, 2-methylpropene is the most thermodynamically stable isomer and releases the lowest heat of hydrogenation.

**Final Answer:**



**Answer: (A)**

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Q12.

**Solution**

**Concept:** The biochemical oxygen demand ( $BOD_5$ ) of a wastewater sample measures the organic pollution load. It is calculated by multiplying the drop in dissolved oxygen (DO) during incubation by the dilution factor:  $BOD_5 = (DO_{initial} - DO_{final}) \times \text{Dilution Factor}$ .

**Solution:**

1. Extract the given parameters from the assay text: \*  $DO_{initial} = 9.0 \text{ mg/L}$  \*  $DO_{final} = 3.0 \text{ mg/L}$  \*  
Dilution ratio = 1 : 50  $\implies$  Dilution Factor = 50
2. Calculate the net oxygen consumption:

$$\Delta DO = 9.0 \text{ mg/L} - 3.0 \text{ mg/L} = 6.0 \text{ mg/L}$$

3. Multiply by the dilution factor to find the baseline absolute BOD rating:

$$BOD_5 = 6.0 \text{ mg/L} \times 50 = 300 \text{ mg/L}$$

**Final Answer:**

**Answer: (B)**

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Q13.

**Solution**

**Concept:** According to the VSEPR model, the steric number (SN) determines the hybridization state and electron-pair geometry of a central atom:  $SN = (\text{Valence electrons} + \text{Monovalent atoms} - \text{Charge})/2$ .

**Solution:**

1. For iodine heptafluoride ( $IF_7$ ), the central atom is Iodine (I): \* Number of valence electrons on I = 7 \* Number of surrounding monovalent fluorine atoms = 7

$$\text{Steric Number (SN)} = \frac{7 + 7}{2} = 7$$

2. A steric number of 7 corresponds to an  $sp^3d^3$  hybridization state.
3. With 7 bonding pairs and 0 lone pairs, the spatial molecular geometry matches a **Pentagonal Bipyramidal** distribution to minimize electron-pair repulsions.

**Final Answer:**

**Answer: (B)**

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Q14.

**Solution**

**Concept:** For a sparingly soluble ternary hydroxide salt  $M(OH)_2$ , dissolution establishes the equilibrium:  $M(OH)_2(s) \rightleftharpoons M^{2+}(aq) + 2OH^{-}(aq)$ . The solubility product expression is  $K_{sp} = [M^{2+}][OH^{-}]^2$ .

**Solution:**

1. Let the molar solubility of the salt be  $S$ . At equilibrium:

$$[M^{2+}] = S \quad \text{and} \quad [OH^{-}] = 2S$$

2. Substitute these terms into the  $K_{sp}$  expression:

$$K_{sp} = S \cdot (2S)^2 = 4S^3$$

3. Given  $K_{sp} = 4.0 \times 10^{-12}$ :

$$4S^3 = 4.0 \times 10^{-12} \implies S^3 = 1.0 \times 10^{-12} \implies S = 1.0 \times 10^{-4} \text{ M}$$

4. Determine the hydroxide ion concentration  $[OH^{-}]$ :

$$[OH^{-}] = 2S = 2 \times 10^{-4} \text{ M}$$

5. Compute pOH and pH:

$$\text{pOH} = -\log[OH^{-}] = -\log(2 \times 10^{-4}) = 4 - \log 2 \approx 4 - 0.30 = 3.70$$

$$\text{pH} = 14 - \text{pOH} = 14 - 3.70 = 10.30$$

**Final Answer:**

**Answer: (A)**

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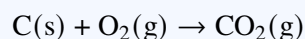
Q15.

**Solution**

**Concept:** The blast furnace layout exhibits distinct temperature zones. The lowermost combustion zone near the air tuyeres experiences the highest temperatures (1500°C – 2000°C), where coke burns intensely in incoming oxygen.

**Solution:**

In the lower combustion zone, coke (C) reacts directly with the hot oxygen air blast to produce carbon dioxide gas in a highly exothermic reaction that maintains the furnace's high operational temperatures:



Let's review the options: \* Option (A) occurs in the upper, cooler reduction zone (400°C – 700°C). \* Option (B) represents this primary combustion process occurring at the tuyere level. \* Option (C) represents the endothermic reduction of CO<sub>2</sub> to CO occurring slightly higher up in the furnace.

**Final Answer:**  $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$

**Answer: (B)**

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Q16.

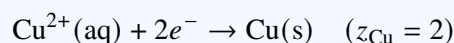
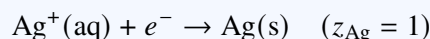
**Solution**

**Concept:** For electrochemical cells arranged in series, Faraday's Second Law of Electrolysis states that passing a constant galvanic current load through interconnected cell loops deposits masses of different ionic species in direct proportion to their chemical equivalent weights ( $E = \text{At. Wt.}/z$ ).

**Solution:**

Let us systematically evaluate each of the given declarations:

(A) **Mass of Silver vs. Copper:** The respective cathodic reduction half-reactions are:



If equal moles of electrons (1 mol  $e^-$ ) pass through the circuit, 1 mol of Ag (107.8 g) and 0.5 mol of Cu (31.75 g) are deposited. The mass ratio is  $107.8/31.75 \approx 3.4$ , not exactly double. Thus, Statement A is incorrect.

(B) **Ratio of Equivalent:** By definition, the passage of the exact same electric charge through cells connected in series deposits an equal number of chemical equivalents of each substance. Therefore, the ratio of equivalents deposited is strictly 1 : 1. This confirms Statement B is correct.

(C) **Deposition by 1 Faraday:** Passing 1 Faraday of charge (1 mol  $e^-$ ) yields exactly 1 equivalent weight of each metal:

$$\text{Mass of Ag} = 1 \times \frac{107.8 \text{ g/mol}}{1} = 107.8 \text{ g}$$

$$\text{Mass of Cu} = 1 \times \frac{63.5 \text{ g/mol}}{2} = 31.75 \text{ g}$$

This confirms Statement C is correct.

(D) **Reaction Site Conventions:** In any functioning multi-electrolyte electrochemical array or galvanic setup, oxidation reactions occur exclusively at the anodes, while reduction reactions occur at the cathodes. This confirms Statement D is correct.

**Final Answers:** B, C, and D

**Answer:** (B, C, D)

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Q17.

**Solution**

**Concept:** The Contact Process relies on chemical kinetics and thermodynamics to maximize the production efficiency of sulfur trioxide ( $\text{SO}_3$ ) intermediate gas for high-strength sulfuric acid synthesis.

**Solution:**

Let us evaluate each engineering optimization parameter and reaction constraint:

- (A) **Catalytic Conversion Phase:** The heterogeneous oxidation step  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$  has a high activation energy barrier. It is catalyzed efficiently using porous vanadium pentoxide ( $\text{V}_2\text{O}_5$ ) pellets. This confirms Statement A is correct.
- (B) **Reaction Enthalpy Profile:** The oxidation of sulfur dioxide is highly exothermic ( $\Delta H = -196.6 \text{ kJ/mol}$ ), releasing heat. It does not require continuous external thermal heating updates during operation. Thus, Statement B is incorrect.
- (C) **Pressure Constraints:** According to Le Chatelier's Principle, high pressure shifts the equilibrium towards the side with fewer gas moles ( $\text{SO}_3$ ). However, the conversion efficiency is already high ( $\sim 98\%$ ) at a nominal operating pressure of 1 – 2 atm. High pressures of 100 – 200 atm are not mandatory and are industrially impractical. Thus, Statement C is incorrect.
- (D) **Gas Absorption Mechanics:** Directly dissolving  $\text{SO}_3$  gas in water is highly exothermic and creates a dense mist of sulfuric acid droplets that is difficult to condense. Instead,  $\text{SO}_3$  is safely absorbed into concentrated  $\text{H}_2\text{SO}_4$  to form oleum ( $\text{H}_2\text{S}_2\text{O}_7$ ), which is subsequently diluted with water. This confirms Statement D is correct.

**Final Answers:**  A and  D

**Answer:** (A, D)

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Q18.

**Solution**

**Concept:** Nucleophilic substitution reactions ( $S_N1$  vs.  $S_N2$ ) of alkyl halides are governed by structural parameters, solvent polarity, and steric hindrance profiles.

**Solution:**

Let us test the validity of each mechanistic interpretation choice:

- (A)  **$S_N1$  Reaction Pathway:** A sterically hindered substrate undergoes substitution primarily via an  $S_N1$  mechanism. This is a two-step path whose rate-determining step involves the slow departure of the leaving group to form a stable, planar carbocation intermediate. This confirms Statement A is correct.
- (B)  **$S_N2$  Rate Law Dynamics:** The rate law for an  $S_N2$  mechanism relies simultaneously on both the concentration of the alkyl halide substrate and the incoming nucleophile ( $\text{Rate} = k[\text{R-X}][\text{Nu}^-]$ ). It does not depend exclusively on the nucleophile. Thus, Statement B is incorrect.
- (C) **Solvent Solvation Effects:** Polar protic solvents possess high dielectric constants and can form hydrogen bonds with leaving group anions. This stabilizes the ionic transition state and accelerates the ionization rate-determining step of  $S_N1$  pathways. This confirms Statement C is correct.
- (D) **Stereochemical Outcome:** The single-step, concerted mechanism of  $S_N2$  forces the nucleophile to attack from the back side opposite to the leaving group, causing a complete inversion of stereochemical configuration known as Walden Inversion. This confirms Statement D is correct.

**Final Answers:** A, C, and D

**Answer:** (A, C, D)

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Q19.

**Solution**

**Concept:** The configuration of electrons within multielectronic shells is governed by spatial wave mechanics and the restrictions imposed by fundamental quantum numbers.

**Solution:**

Let us assess each quantum mechanical assertion:

- (A) **Hund's Rule of Maximum Multiplicity:** This rule states that for a given electronic configuration, pairing of electrons within a set of degenerate orbitals cannot occur until all orbitals in that subshell contain at least one electron with parallel spins. This confirms Statement A is correct.
- (B) **Radial Node Math Formula:** The total number of nodes in an atomic wavefunction is  $n - 1$ . This is split into angular nodes ( $l$ ) and radial nodes. The remaining radial nodes are mathematically defined as  $n - l - 1$ . This confirms Statement B is correct.
- (C) **Pauli Exclusion Principle:** The Pauli Exclusion Principle dictates that no two electrons residing inside the same atomic confinement field can share an identical set of all four quantum numbers ( $n, l, m_l, m_s$ ). This confirms Statement C is correct.
- (D) **Origin of the Spin Quantum Number:** The principal ( $n$ ), azimuthal ( $l$ ), and magnetic ( $m_l$ ) quantum numbers are spatial coordinates obtained directly by solving Schrödinger's time-independent wave equation. The magnetic spin quantum number ( $m_s$ ) arises instead from relativistic quantum mechanics (the Dirac equation) and is not a spatial derivative of Schrödinger's equation. Thus, Statement D is incorrect.

**Final Answers:**

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Q20.

**Solution**

**Concept:** A pH neutralization profile for a polyprotic acid displays multiple distinct steps and inflection endpoints corresponding to the loss of individual acidic protons.

**Solution:**

Let us analyze the layout data from the provided titration curve graph:

- (A) **Acid Profile Classification:** The titration curve contains multiple inflection points and plateaus, which is characteristic of a polyprotic acid template. A weak monoprotic acid would exhibit only a single distinct inflection endpoint. Thus, Statement A is incorrect.
- (B) **Half-Neutralization Buffer Region:** At the half-neutralization threshold volume point ( $V_1/2$ ) of the first proton, the concentration of the unreacted weak acid exactly matches that of its conjugate base ( $[H_nA] = [H_{n-1}A^-]$ ). Applying the Henderson-Hasselbalch equation reveals that the pH value of the matrix matches the numeric value of the  $pK_{a1}$  parameter. This confirms Statement B is correct.
- (C) **First Equivalence Endpoint:** The sharp vertical jump configuration near the volume point  $V_1$  indicates the first equivalence point, marking the complete neutralization of the first acidic proton. This confirms Statement C is correct.
- (D) **Maximum Buffering Capacity:** An aqueous buffer system reaches its maximum efficiency limits when the concentrations of the conjugate acid-base pair are equal, which occurs when the pH equals the operating  $pK_a$ . It does not depend on the system pH being equal to the pOH of the matrix. Thus, Statement D is incorrect.

**Final Answers:** B and C

**Answer:** (B, C)

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## Answer Key

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

