

JELET Chemistry Sample Paper-9

Duration: 45 Minutes

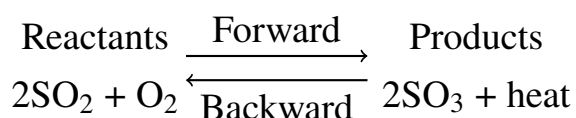
Maximum Marks: 50

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.

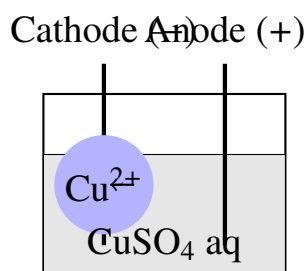
Section–A — 15 Questions × 1 Mark Each
(Negative Marking: –0.25) [Single Correct]

- Q1.** An electron in an atom has a magnetic quantum number $m_l = -2$. What is the minimum possible value of the principal quantum number n for this electron?
- (A) 1
(B) 2
(C) 3
(D) 4
- Q2.** For the reversible reaction $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) + \text{heat}$, which of the following conditions will shift the equilibrium state toward the forward direction?



- (A) Increasing the temperature and decreasing the pressure
- (B) Decreasing the temperature and increasing the pressure
- (C) Decreasing the concentration of SO_2
- (D) Adding an inert gas at constant volume

Q3. During the electrolysis of an aqueous solution of CuSO_4 using inert platinum electrodes, what are the primary products liberated at the cathode and anode respectively?



- (A) Cu at cathode and O_2 at anode
- (B) H_2 at cathode and O_2 at anode
- (C) Cu at cathode and SO_2 at anode
- (D) H_2 at cathode and Cu at anode

Q4. Permanent hardness of water due to the presence of magnesium sulfate (MgSO_4) can be effectively removed by adding which of the following reagents?

- (A) $\text{Ca}(\text{OH})_2$ (Slaked lime)
- (B) Na_2CO_3 (Washing soda)
- (C) $\text{Ca}(\text{HCO}_3)_2$
- (D) Boiling alone

Q5. What is the correct IUPAC name of the compound $\text{CH}_3 - \text{CH}(\text{CH}_3) - \text{C} \equiv \text{C} - \text{CH}_3$?

- (A) 2-Methylpent-3-yne
- (B) 4-Methylpent-2-yne
- (C) 4-Methylpent-3-yne



(D) 2-Methylpent-2-yne

Q6. Which of the following chemical species is primarily responsible for the classic dynamic depletion of the stratospheric ozone layer via a catalytic chain reaction cycle?

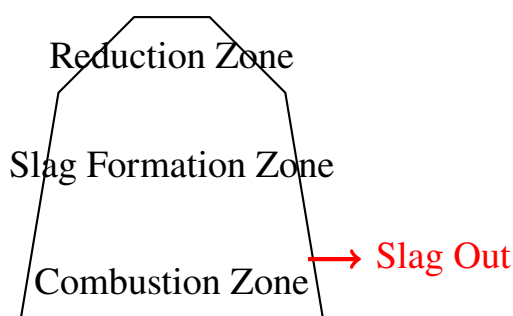
(A) Carbon dioxide (CO_2)

(B) Chlorine free radicals (Cl^\bullet)

(C) Sulfur dioxide (SO_2)

(D) Particulate matter (PM 2.5)

Q7. In the extraction of Iron (Fe) in the blast furnace, what is the chemical composition of the slag removed from the lower-middle zone?



(A) FeSiO_3

(B) CaSiO_3

(C) $\text{Al}_2(\text{SiO}_3)_3$

(D) $\text{Ca}_3(\text{PO}_4)_2$

Q8. What is the pH of a buffer solution prepared by mixing equal volumes of 0.2 M acetic acid (CH_3COOH) and 0.02 M sodium acetate (CH_3COONa)? (Given K_a of $\text{CH}_3\text{COOH} = 1.8 \times 10^{-5}$)

(A) 4.74

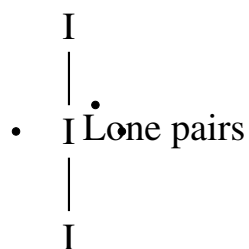
(B) 3.74

(C) 5.74

(D) 2.74



Q9. In which of the following molecules or ions does the central atom exhibit sp^3d hybridization with a linear spatial geometry?



- (A) SF_4
- (B) ClF_3
- (C) I_3^-
- (D) PCl_5

Q10. How many Faradays of electricity are required to completely reduce 1 mole of $\text{Cr}_2\text{O}_7^{2-}$ ions to Cr^{3+} ions in an acidic medium?

- (A) 1 F
- (B) 3 F
- (C) 6 F
- (D) 12 F

Q11. According to the molecular orbital theory (MOT), which of the following diatomic species is expected to be paramagnetic and have a fractional bond order?

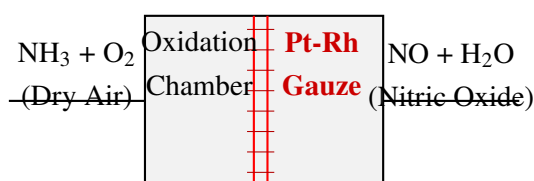
- (A) O_2
- (B) N_2^+
- (C) CO
- (D) F_2

Q12. Which of the following standard chemical components is the principal contributor to the phenomenon of “Photochemical Smog” observed in congested urban atmospheres?



- (A) Oxides of sulfur (SO_x)
- (B) Oxides of nitrogen (NO_x) and unburnt hydrocarbons
- (C) Carbon monoxide and chlorofluorocarbons
- (D) Carbon dioxide and water vapour

Q13. In the industrial manufacture of Nitric Acid (HNO_3) by Ostwald's process, what chemical catalyst and operating temperature are typically utilized during the initial catalytic oxidation stage of ammonia?



- (A) Finely divided Iron at 450°C
- (B) Platinized asbestos or Platinum-Rhodium gauze at 800°C
- (C) Vanadium pentoxide (V_2O_5) at 450°C
- (D) Nickel powder at 200°C

Q14. What is the specific state of hybridization of the carbon atoms involved in the single bond of the hydrocarbon molecule But-1-en-3-yne ($\text{CH}_2 = \text{CH} - \text{C} \equiv \text{CH}$)?

- (A) $sp^2 - sp^2$
- (B) $sp^2 - sp$
- (C) $sp^3 - sp$
- (D) $sp - sp$

Q15. Consider the aqueous salt solution of Ammonium Acetate ($\text{CH}_3\text{COONH}_4$). If the dissociation constants of the weak acid and weak base are identical ($K_a = K_b$), the nature of the solution and its pH behavior upon dilution will be:

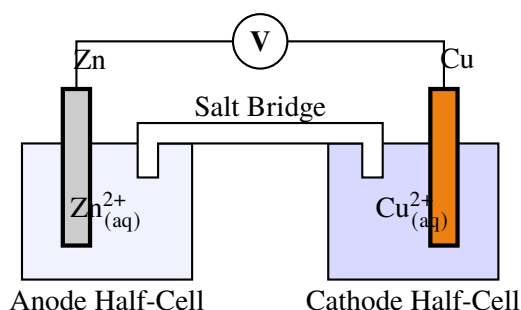
- (A) Strongly acidic; pH changes rapidly
- (B) Neutral; pH remains independent of concentration



- (C) Strongly alkaline; pH increases steadily
 (D) Weakly acidic; pH drops progressively

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

- Q16.** Which of the following statements regarding the quantum numbers, electronic configurations, and orbital principles are fundamentally correct?
- (A) No two electrons in a single atom can have an identical set of all four quantum numbers.
 (B) The electronic configuration of Chromium (Cr, $Z = 24$) violates the Aufbau principle to achieve extra stability through a half-filled d-subshell.
 (C) The azimuthal quantum number (l) dictates the absolute orientation of an orbital in three-dimensional space.
 (D) For an orbital with $l = 3$, the maximum possible number of electrons accommodated is 14.
- Q17.** For a standard Galvanic cell constructed using the half-cells Zn^{2+}/Zn ($E^\circ = -0.76 \text{ V}$) and Cu^{2+}/Cu ($E^\circ = +0.34 \text{ V}$), which of the following modifications or assertions will cause an increase in the measured cell potential (E_{cell}) at 298 K?



- (A) Increasing the concentration of Cu^{2+} ions in the cathode compartment
 (B) Increasing the concentration of Zn^{2+} ions in the anode compartment
 (C) Decreasing the concentration of Zn^{2+} ions in the anode compartment



(D) Increasing the physical size or surface area of the zinc electrode

Q18. Which of the following chemical processes, reactions, or extraction methods are correctly paired with their true industrial functions?

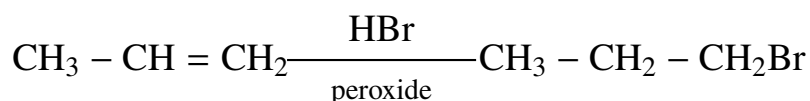
(A) Contact Process: Industrial manufacture of high-purity Sulfuric Acid (H_2SO_4)

(B) Hall-Héroult Process: Electrolytic reduction of alumina (Al_2O_3) to extract molten Aluminum

(C) Froth Flotation Process: Generally used for the concentration of oxide ores of Copper and Iron

(D) Haber-Bosch Process: Synthesis of Ammonia gas (NH_3) under high pressure and optimum temperature

Q19. Identify the organic reactions or structural trends that correctly state the behavioral patterns of hydrocarbons:



(A) Propene reacts with HBr in the presence of organic peroxides to yield 1-bromopropane as the major product.

(B) The carbon-carbon bond length decreases in the progressive order: Ethane > Ethene > Ethyne.

(C) Acidic character of terminal alkynes is due to the high *s*-character (50%) of the *sp*-hybridized carbon atom.

(D) Alkanes readily undergo electrophilic addition reactions under standard ambient laboratory conditions.

Q20. Which of the following solutions or chemical systems qualify as true buffer solutions capable of resisting drastic variations in pH upon minor additions of strong acids or bases?

(A) A mixture of Sodium Chloride (NaCl) and Hydrochloric Acid (HCl)



- (B) A mixture of Ammonium Chloride (NH_4Cl) and Ammonium Hydroxide (NH_4OH)
- (C) A solution prepared by mixing 100 mL of 0.1 M CH_3COOH with 50 mL of 0.1 M NaOH
- (D) A solution prepared by mixing 50 mL of 0.1 M CH_3COOH with 100 mL of 0.1 M NaOH



Detailed Solutions

Q1.

Solution

Concept:

The principal quantum number n defines the primary electron shell or energy level of an atom. The azimuthal quantum number l represents the subshell and ranges from 0 to $n - 1$. The magnetic quantum number m_l specifies the spatial orientation of the orbital and can take integer values from $-l$ to $+l$. Therefore, for a given m_l , the absolute value of l must be at least equal to $|m_l|$, and the value of n must be strictly greater than l .

Solution:

Step 1: Identify the given quantum number from the problem statement:

$$m_l = -2$$

Step 2: Determine the restriction on the azimuthal quantum number l . Since m_l ranges from $-l$ to $+l$, the minimum possible value of l that can accommodate an orbital with $m_l = -2$ is:

$$l = 2$$

Step 3: Relate the azimuthal quantum number l to the principal quantum number n . According to quantum mechanics rules, the permissible values for l given a specific shell n are bounded by:

$$l \leq n - 1 \implies n \geq l + 1$$

Step 4: Substitute the minimum value of $l = 2$ into the inequality to solve for the lowest possible energy level n :

$$n_{\min} = 2 + 1 = 3$$

Step 5: Conclude that an electron with a magnetic quantum number of -2 must belong to at least the third principal energy shell ($n = 3$, corresponding to a d -subshell).

Final Answer:

Answer: (C)

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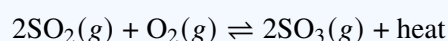
Q2.

Solution**Concept:**

Le Chatelier's Principle states that if a dynamic equilibrium system is subjected to a change in temperature, pressure, or concentration of reacting species, the system will shift its equilibrium position in a direction that counteracts the applied change. For an exothermic reaction, heat is treated as a product, so lowering the temperature shifts the reaction forward. Increasing pressure shifts the equilibrium toward the side with fewer gas moles.

Solution:

Step 1: Analyze the stoichiometry and nature of the given reversible gaseous reaction:



Step 2: Count the total number of moles of gaseous reactants and products. The total moles of gaseous reactants is $2 + 1 = 3$, whereas the total moles of gaseous products is 2.

$$\Delta n_g = 2 - 3 = -1$$

Step 3: Evaluate the effect of pressure. Since the forward direction leads to a reduction in the number of gaseous moles (from 3 moles to 2 moles), increasing the total pressure will shift the system toward the side with fewer moles to relieve the pressure, thus moving it in the forward direction.

Step 4: Evaluate the effect of temperature. The reaction is explicitly marked as exothermic (+ heat on the product side). According to thermodynamic principles, lowering the temperature removes heat from the system, prompting it to favor the exothermic forward pathway to generate more heat.

Step 5: Combine both conditions to establish that decreasing the temperature and simultaneously increasing the total pressure will maximize the forward yield of sulfur trioxide.

Final Answer:

Answer: (B)

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Q3.

Solution**Concept:**

During the electrolysis of an aqueous solution using inert electrodes, multiple ions compete for discharge at the surfaces of the cathode and anode. At the cathode, reduction occurs, and the species with the higher standard reduction potential is preferentially discharged. At the anode, oxidation takes place, and the chemical species with the lower standard reduction potential (or lower discharge potential) loses electrons.

Solution:

Step 1: Enumerate all the chemical ions present in an aqueous solution of copper(II) sulfate (CuSO_4):

From salt dissociation: Cu^{2+} and SO_4^{2-}

From water self-ionization: H^+ and OH^-

Step 2: Analyze the competitive reduction processes occurring at the negative electrode (cathode). The ions attracted are Cu^{2+} and H^+ . Compare their standard reduction potentials:

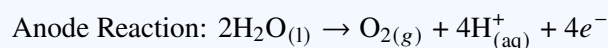
$$E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34 \text{ V}$$

$$E^\circ(\text{H}^+/\text{H}_2) = 0.00 \text{ V}$$

Step 3: Since copper has a significantly higher reduction potential, Cu^{2+} ions are preferentially reduced to metallic copper on the cathode surface, preventing hydrogen evolution:



Step 4: Analyze the competitive oxidation processes occurring at the positive electrode (anode). The chemical ions attracted are SO_4^{2-} and OH^- . Sulfate ions are highly stable and possess an exceptionally high discharge potential. Therefore, water molecules or hydroxyl ions undergo oxidation preferentially to release oxygen gas:



Step 5: Conclude that the primary chemical products collected at the electrodes are solid copper metal at the cathode and gaseous oxygen at the anode.

Final Answer:

Answer: (A)

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Q4.

Solution**Concept:**

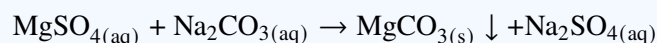
Water hardness is categorized into temporary hardness and permanent hardness. Temporary hardness is due to dissolved calcium and magnesium bicarbonates and can be removed by simple boiling. Permanent hardness is caused by the presence of soluble sulfate and chloride salts of calcium and magnesium. Removing permanent hardness requires chemical reagents that can react with these soluble salts to form insoluble precipitates.

Solution:

Step 1: Identify the nature of the hardness described in the problem. The presence of magnesium sulfate (MgSO_4) constitutes permanent hardness, which cannot be broken down or precipitated out by boiling alone.

Step 2: Evaluate the action of adding washing soda, which is sodium carbonate (Na_2CO_3). This reagent provides a high concentration of carbonate ions (CO_3^{2-}) in solution.

Step 3: Formulate the double displacement chemical reaction that takes place when sodium carbonate is introduced into water containing dissolved magnesium sulfate:



Step 4: Observe that the magnesium ions (Mg^{2+}) are successfully precipitated out of the water as solid, insoluble magnesium carbonate (MgCO_3), while the harmless sodium sulfate remains dissolved.

Step 5: Conclude that sodium carbonate (washing soda) is the highly effective reagent for eliminating permanent hardness from water supplies.

Final Answer:

Answer: (B)

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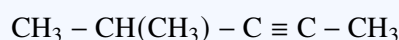
Q5.

Solution**Concept:**

According to the systematic IUPAC nomenclature rules for unsaturated hydrocarbons, the longest continuous carbon chain containing the principal functional group (the carbon-carbon triple bond) must be selected as the parent chain. Numbering of the main carbon chain must be carried out from the end that gives the lower locant numbers to the triple bond, prioritizing its position over alkyl substituents.

Solution:

Step 1: Write down the structural formula of the given organic compound and identify its skeletal chain:



Step 2: Find the longest continuous carbon chain containing both alkynyl carbons. The chain consists of 5 continuous carbon atoms, establishing the root name as "pent".

Step 3: Number the parent chain from both directions to compare the locants assigned to the triple bond:

Left-to-right numbering: Alkynes start at Carbon-3, Methyl substituent is at Carbon-2.

Right-to-left numbering: Alkynes start at Carbon-2, Methyl substituent is at Carbon-4.

Step 4: Apply the IUPAC priority rule which states that lowest locants must be assigned strictly to the carbon-carbon triple bond before considering alkyl branches. The right-to-left numbering scheme gives the triple bond a locant of 2, which is lower than 3. Thus, right-to-left numbering is chosen.

Step 5: Assemble the complete systematic name by listing the substituent alphabetically with its position followed by the parent alkene name: 4-methylpent-2-yne.

Final Answer:

Answer: (B)

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Q6.

Solution**Concept:**

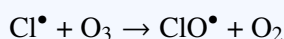
The destruction of the stratospheric ozone layer (O_3) is catalyzed heavily by halogen radicals. Chlorofluorocarbons (CFCs) released from anthropogenic sources migrate into the upper stratosphere, where they undergo homolytic cleavage by high-energy ultraviolet (UV) radiation to produce highly reactive, uncharged chlorine free radicals (Cl^\bullet). These free radicals initiate a destructive cyclic chain reaction.

Solution:

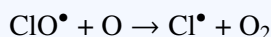
Step 1: Understand the atmospheric chemistry of chlorofluorocarbons when exposed to short-wavelength solar radiation in the stratosphere:



Step 2: Examine the propagation steps of the catalytic cycle. The generated atomic chlorine free radical attacks an ozone molecule, converting it into oxygen:



Step 3: Analyze the subsequent stage where the chlorine monoxide radical (ClO^\bullet) reacts with a naturally occurring free oxygen atom to regenerate the original chlorine catalyst:



Step 4: Notice that the chlorine radical emerges completely unchanged from the net chemical reaction, allowing a single radical to continuously destroy thousands of ozone molecules before termination.

Step 5: Conclude that chlorine free radicals are the primary reactive intermediates responsible for driving the dynamic depletion of the protective ozone layer.

Final Answer: Chlorine free radicals (Cl^\bullet)

Answer: (B)

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Q7.

Solution**Concept:**

Metallurgical extraction of iron in a blast furnace involves the reduction of iron oxides alongside the removal of acidic impurities using a fluxing agent. Limestone (CaCO_3) is added to the furnace as a flux. At high temperatures, it undergoes thermal decomposition to generate a basic oxide, which subsequently reacts with the primary acidic impurity (silicon dioxide, SiO_2) to form an easily fusible liquid mass called slag.

Solution:

Step 1: Identify the main impurities embedded within the hematite iron ore. The dominant gangue or impurity present is silicon dioxide (SiO_2), which exhibits an acidic chemical nature.

Step 2: Track the thermal breakdown of the added limestone flux (CaCO_3) inside the moderate-temperature zone (slag formation zone, around 800°C to 1000°C):



Step 3: Analyze the neutralization reaction between the newly formed basic flux, calcium oxide (CaO), and the acidic sand impurities present in the molten iron mix:



Step 4: The chemical product formed is calcium silicate (CaSiO_3), which has a lower density than molten iron and floats on top of it, protecting the iron from re-oxidation.

Step 5: Confirm that the composition of the slag removed from the furnace is calcium silicate.

Final Answer:

Answer: (B)

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Q8.

Solution**Concept:**

An acidic buffer solution consists of a mixture of a weak acid and its conjugate base salt. The pH of such a buffer system can be quantitatively determined using the Henderson-Hasselbalch equation:

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

where $\text{p}K_a = -\log_{10}(K_a)$, and the concentrations are the final molarities within the total mixed volume.

Solution:

Step 1: Calculate the value of $\text{p}K_a$ for acetic acid using the provided value of $K_a = 1.8 \times 10^{-5}$:

$$\text{p}K_a = -\log_{10}(1.8 \times 10^{-5}) = 5 - \log_{10}(1.8) \approx 4.74$$

Step 2: Account for the volume expansion when equal volumes of the two solutions are mixed together. Let the volume of each solution be V . The total volume of the mixture becomes $2V$.

Step 3: Determine the final concentrations of the weak acid and its salt in the combined solution:

$$[\text{Acid}] = \frac{0.2 \text{ M} \times V}{2V} = 0.1 \text{ M}$$

$$[\text{Salt}] = \frac{0.02 \text{ M} \times V}{2V} = 0.01 \text{ M}$$

Step 4: Substitute the values calculated into the Henderson-Hasselbalch equation:

$$\text{pH} = 4.74 + \log_{10} \left(\frac{0.01}{0.1} \right)$$

Step 5: Simplify the logarithmic term to find the final pH value:

$$\text{pH} = 4.74 + \log_{10}(0.1) = 4.74 + (-1) = 3.74$$

Final Answer:

Answer: (B)

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Q9.

Solution**Concept:**

The steric number rule in Valence Shell Electron Pair Repulsion (VSEPR) theory dictates the hybridization state and geometry of a central atom. The steric number is calculated by summing the number of bonded atoms (σ -bonds) and the number of lone pairs on that central atom. A steric number of 5 corresponds to sp^3d hybridization, which typically generates a trigonal bipyramidal electronic geometry. The specific spatial layout of the atoms depends on the placement of the lone pairs.

Solution:

Step 1: Determine the valence electrons and steric details for the triiodide ion (I_3^-). The central iodine atom belongs to Group 17 and possesses 7 valence electrons plus 1 negative charge, totaling 8 electrons.

Step 2: Count the bonding and non-bonding electron pairs around the central iodine atom. It forms 2 single covalent bonds with the two surrounding iodine atoms, consuming 2 electrons. The remaining 6 electrons form 3 separate lone pairs:

$$\text{Steric Number} = 2 (\sigma\text{-bonds}) + 3 (\text{lone pairs}) = 5$$

Step 3: Assign the hybridization state corresponding to a steric number of 5, which is sp^3d .

Step 4: Apply VSEPR principles to position the 3 lone pairs. To minimize strong electron-pair repulsions, all three lone pairs occupy the equatorial positions of the trigonal bipyramid at 120° angles relative to one another.

Step 5: Observe the positions of the remaining two bonding iodine atoms, which occupy the axial vertices directly opposite one another. This orientation results in a linear molecular shape with an I – I – I bond angle of exactly 180° .

Final Answer:

Answer: (C)

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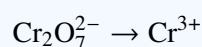
Q10.

Solution**Concept:**

Faraday's laws of electrolysis establish a direct relationship between the quantity of electric charge passed through an electrolyte and the chemical equivalents of substance undergoing reduction or oxidation. The total number of Faradays (F) required for a redox half-reaction corresponds directly to the total moles of electrons transferred per mole of the reacting chemical species in the balanced ionic equation.

Solution:

Step 1: Write down the unbalanced chemical reduction half-reaction for the dichromate ion converting into chromium ions in an acidic environment:



Step 2: Assign formal oxidation states to the chromium atoms on both sides of the expression. In the reactant $\text{Cr}_2\text{O}_7^{2-}$, let the oxidation state of Cr be x :

$$2x + 7(-2) = -2 \implies 2x - 14 = -2 \implies 2x = +12 \implies x = +6$$

The oxidation state of chromium in the product Cr^{3+} is simply +3.

Step 3: Calculate the change in oxidation number for a single atom of chromium during the reduction process:

$$\Delta\text{Oxidation State} = +6 - (+3) = 3 \text{ electrons per Cr atom}$$

Step 4: Account for the total number of chromium atoms contained within a single mole of dichromate reactant ions. Since each $\text{Cr}_2\text{O}_7^{2-}$ ion contains 2 chromium atoms, the total number of moles of electrons required per mole of dichromate is:

$$\text{Total electrons} = 2 \text{ atoms} \times 3 \text{ electrons/atom} = 6 \text{ moles of electrons}$$

Step 5: Equate the moles of electrons directly to Faradays of electricity. Since 1 mole of electrons carries a charge of 1 F, exactly 6 F of electricity are consumed.

Final Answer:

Answer: (C)

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Q11.

Solution**Concept:**

Molecular Orbital Theory (MOT) describes the electronic structure of molecules by assigning electrons to molecular orbitals that span the entire molecule. The chemical stability and bond strength are characterized by the bond order, defined as:

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

where N_b is the number of bonding electrons and N_a is the number of antibonding electrons. A molecule is paramagnetic if it contains one or more unpaired electrons.

Solution:

Step 1: Determine the total electron count for the homonuclear diatomic cation N_2^+ . A neutral nitrogen atom has 7 electrons, so an N_2 molecule has 14 electrons. Removing one electron yields 13 total electrons for N_2^+ :

$$\text{Total electrons for } \text{N}_2^+ = 14 - 1 = 13$$

Step 2: Fill the molecular orbitals according to the energy ordering rules for lighter diatomic molecules ($Z \leq 7$):

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

Step 3: Count the total number of bonding electrons (N_b) and antibonding electrons (N_a) from the configuration:

$$N_b = 2 \text{ (from } \sigma_{1s}) + 2 \text{ (from } \sigma_{2s}) + 4 \text{ (from } \pi_{2p}) + 1 \text{ (from } \sigma_{2p_z}) = 9$$

$$N_a = 2 \text{ (from } \sigma_{1s}^*) + 2 \text{ (from } \sigma_{2s}^*) = 4$$

Step 4: Calculate the bond order of the N_2^+ molecular ion using the mathematical formula:

$$\text{Bond Order} = \frac{9 - 4}{2} = 2.5$$

Since 2.5 is a non-integer value, it qualifies as a fractional bond order.

Step 5: Inspect the configuration for unpaired electrons. The highest occupied molecular orbital (σ_{2p_z}) contains a single, unpaired electron. The presence of this unpaired electron makes the species paramagnetic.

Final Answer:

Answer: (B)

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Q12.

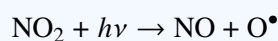
Solution**Concept:**

Photochemical smog is a modern atmospheric pollution phenomenon that develops in warm, dry, and sunny urban environments. Unlike classical reducing sulfur smog, photochemical smog is oxidizing in nature. It forms through solar-driven secondary chemical transformations involving primary automotive exhaust pollutants, namely nitrogen oxides (NO_x) and volatile unburnt hydrocarbons.

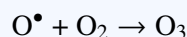
Solution:

Step 1: Identify the primary pollutants emitted by internal combustion engines into urban air spaces. These include nitric oxide (NO) and various fragmented, unburnt hydrocarbon molecules.

Step 2: Analyze the initiation step under sunlight. Nitric oxide reacts with atmospheric oxygen to yield nitrogen dioxide (NO_2), which absorbs ultraviolet sunlight and undergoes photodissociation:



Step 3: Track the formation of highly reactive secondary pollutants. The atomic oxygen radical (O^\bullet) combines with molecular oxygen to generate ozone (O_3):



Step 4: Understand the interaction with organic fractions. Ozone and nitrogen oxides react with the airborne unburnt hydrocarbons to form toxic compounds such as peroxyacetyl nitrate (PAN), acrolein, and formaldehyde.

Step 5: Conclude that the combination of nitrogen oxides (NO_x) and unburnt hydrocarbons, activated by solar UV radiation, forms the primary chemical foundation of photochemical smog.

Final Answer: Oxides of nitrogen (NO_x) and unburnt hydrocarbons

Answer: (B)

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Q13.

Solution**Concept:**

Ostwald's process is a major industrial method used to manufacture nitric acid (HNO_3) via the controlled catalytic oxidation of ammonia. The initial stage involves a highly exothermic gas-phase reaction where ammonia gas is blended with atmospheric oxygen and passed over a metallic catalyst at elevated temperatures to yield nitric oxide gas.

Solution:

Step 1: Examine the chemical equation representing the initial oxidation stage within Ostwald's process:



Step 2: Analyze the catalyst requirements. To achieve a selective conversion of ammonia into nitric oxide rather than element nitrogen, a highly active and selective catalyst is required. Industrial setups use a platinum-rhodium (Pt-Rh) alloy gauze network.

Step 3: Analyze the temperature requirements. Although the oxidation reaction is inherently exothermic, a high initial temperature is required to overcome the activation energy barrier and ensure rapid gas flow through the catalyst gauze.

Step 4: Match the standard industrial operating parameters for this step, which require maintaining the catalyst chamber at a temperature of approximately 500 K to 1200 K (commonly optimized around 800°C to 900°C).

Step 5: Verify that using platinum-rhodium gauze at 800°C aligns with the established chemical engineering standards for Ostwald's process.

Final Answer: Platinized asbestos or Platinum-Rhodium gauze at 800°C

Answer: (B)

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Q14.

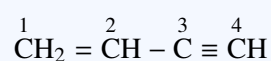
Solution

Concept:

The hybridization state of a carbon atom in a hydrocarbon molecule is determined by counting the total number of localized σ -bonds it forms. A carbon atom forming 4 σ -bonds is sp^3 hybridized, one forming 3 σ -bonds is sp^2 hybridized, and one forming 2 σ -bonds is sp hybridized. Alternatively, carbon atoms involved only in single bonds are sp^3 , those with one double bond are sp^2 , and those participating in a triple bond are sp hybridized.

Solution:

Step 1: Draw the structural formula of the given hydrocarbon molecule, But-1-en-3-yne, showing all its multiple bonds explicitly:



Step 2: Identify the single bond connecting two carbon atoms within this structure. The single bond is located between Carbon-2 and Carbon-3.



Step 3: Evaluate the hybridization of Carbon-2 (C_2). This carbon atom is involved in a double bond with Carbon-1 ($\text{C}_1 = \text{C}_2$). Because it forms 3 σ -bonds in total, its hybridization state is sp^2 .

Step 4: Evaluate the hybridization of Carbon-3 (C_3). This carbon atom is involved in a triple bond with Carbon-4 ($\text{C}_3 \equiv \text{C}_4$). Because it forms 2 σ -bonds in total, its hybridization state is sp .

Step 5: Combine these results to determine the orbital hybridization of the two carbons flanking the single bond, which is $sp^2 - sp$.

Final Answer: $sp^2 - sp$

Answer: (B)

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Q15.

Solution**Concept:**

Ammonium acetate ($\text{CH}_3\text{COONH}_4$) is a salt formed from a weak acid (acetic acid, CH_3COOH) and a weak base (ammonia, NH_3). The pH of a salt solution derived from a weak acid and a weak base is governed by the following mathematical expression:

$$\text{pH} = 7 + \frac{1}{2}(\text{p}K_a - \text{p}K_b)$$

This relationship shows that the pH depends solely on the relative strengths of the constituent weak acid and base, and is independent of the overall concentration of the salt solution.

Solution:

Step 1: Identify the given condition from the problem statement: the dissociation constants are perfectly identical:

$$K_a = K_b$$

Step 2: Convert the dissociation constants into their respective logarithmic forms:

$$\text{p}K_a = -\log_{10}(K_a) \text{ and } \text{p}K_b = -\log_{10}(K_b)$$

Since $K_a = K_b$, it follows that $\text{p}K_a = \text{p}K_b$.

Step 3: Substitute this equality into the weak acid-weak base salt pH formula:

$$\text{pH} = 7 + \frac{1}{2}(0) = 7$$

Step 4: Analyze the effect of dilution on the solution. Because the concentration term (c) does not appear anywhere in this pH equation, diluting the salt solution with pure water will not alter its pH value. The solution remains neutral.

Step 5: Conclude that the salt solution is neutral, and its pH remains fixed at 7 regardless of dilution.

Final Answer: Neutral; pH remains independent of concentration

Answer: (B)

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Q16.

Solution

Concept: The characteristics of electronic configurations and orbital properties are governed by fundamental quantum mechanical principles, specifically the Pauli Exclusion Principle, the definitions of quantum numbers, and subshell electronic capacities.

Solution: Step 1: Analyze statement (A). The Pauli Exclusion Principle states that no two electrons within a single atom can have identical values for all four quantum numbers (n, l, m_l, m_s), making this statement correct.

Step 2: Analyze statement (B). The expected Aufbau configuration for Chromium ($Z = 24$) is $[\text{Ar}]4s^23d^4$. However, it adopts a $[\text{Ar}]4s^13d^5$ configuration. This deliberate shift maximizes exchange energy and subshell symmetry, deliberately violating the basic Aufbau rule for enhanced thermodynamic stability. Thus, this statement is correct.

Step 3: Analyze statement (C). The azimuthal quantum number (l) defines the geometric shape of an orbital, whereas the magnetic quantum number (m_l) dictates its absolute orientation in space. Therefore, this statement is incorrect.

Step 4: Analyze statement (D). For an orbital with $l = 3$ (f -subshell), the total number of orientations is given by $2l + 1 = 2(3) + 1 = 7$. Because every orbital can hold a maximum of 2 electrons, the total capacity is $7 \times 2 = 14$ electrons. This statement is correct.

Final Answer: (A), (B), (D)

Answer: (A, B, D)

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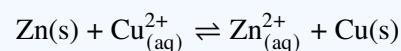


Q17.

Solution

Concept: The dependency of a Galvanic cell potential (E_{cell}) on the molar concentrations of its active aqueous ions is quantified by the Nernst equation at thermodynamic equilibrium.

Solution: Step 1: Write the net balanced redox reaction for the zinc-copper standard cell:



Step 2: Apply the Nernst equation to the system at a temperature of 298 K:

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{2} \log \left(\frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} \right)$$

Step 3: Evaluate concentration parameters. To increase the value of E_{cell} , the reaction quotient fraction must be minimized. This mathematically requires increasing the reactant concentration or reducing the product concentration.

Step 4: Increasing the concentration of Cu^{2+} ions decreases the log term, raising E_{cell} . Decreasing the concentration of Zn^{2+} ions similarly lowers the log term, raising E_{cell} . Changing the physical size of the solid zinc electrode has no impact on the thermodynamic cell potential.

Final Answer: (A), (C)

Answer: (A, C)

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Q18.

Solution

Concept: Industrial metallurgical and chemical manufacturing pathways are optimized around specific raw material inputs, thermodynamic principles, and targeted chemical separations.

Solution: Step 1: Evaluate statement (A). The Contact Process utilizes the catalytic oxidation of sulfur dioxide over a vanadium pentoxide catalyst to produce high-purity sulfuric acid (H_2SO_4). This statement is correct.

Step 2: Evaluate statement (B). The Hall-Héroult Process involves the electrolytic reduction of alumina (Al_2O_3) dissolved in a molten cryolite bath to produce pure liquid aluminum. This statement is correct.

Step 3: Evaluate statement (C). The Froth Flotation Process relies on preferential wetting to concentrate hydrophobic sulfide ores, such as chalcopyrite, rather than hydrophilic oxide ores of iron or copper. This statement is incorrect.

Step 4: Evaluate statement (D). The Haber-Bosch Process synthesizes ammonia gas (NH_3) directly from elemental nitrogen and hydrogen under high pressures and optimized temperatures. This statement is correct.

Final Answer: (A), (B), (D)

Answer: (A, B, D)

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Q19.

Solution

Concept: The physical dimensions and chemical properties of hydrocarbons depend on structural hybridization, bonding patterns, and specific mechanistic radical addition pathways.

Solution: Step 1: Evaluate statement (A). The addition of hydrogen bromide to propene in the presence of organic peroxides proceeds via a stable free-radical intermediate pathway, following the Anti-Markovnikov orientation to yield 1-bromopropane as the primary major product. This statement is correct.

Step 2: Evaluate statement (B). As the multiplicity of a carbon-carbon bond increases, the orbital overlap tightens, shortening the interatomic distance. The bond lengths follow the decreasing sequence: Ethane (sp^3) > Ethene (sp^2) > Ethyne (sp). This statement is correct.

Step 3: Evaluate statement (C). Terminal alkynes feature sp -hybridized carbon atoms containing 50% s -character. This high s -character keeps electrons tightly bound to the nucleus, enhancing electronegativity and facilitating proton release. This statement is correct.

Step 4: Evaluate statement (D). Alkanes are saturated molecules containing only robust σ -bonds, meaning they undergo substitution reactions rather than addition processes under normal ambient laboratory conditions. This statement is incorrect.

Final Answer: (A), (B), (C)

Answer: (A, B, C)

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Q20.

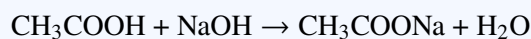
Solution

Concept: A functional chemical buffer system requires a conjugate pair consisting either of a weak acid combined with its conjugate base, or a weak base combined with its corresponding conjugate acid.

Solution: Step 1: Analyze system (A). Hydrochloric acid is a strong acid and sodium chloride is its neutral salt; strong acids cannot function as buffer systems.

Step 2: Analyze system (B). Ammonium hydroxide (NH₄OH) is a weak base, and ammonium chloride (NH₄Cl) supplies its conjugate acid. This classic combination constitutes a functional basic buffer.

Step 3: Analyze system (C). Mixing 10 mmol of CH₃COOH with 5 mmol of NaOH results in neutralization:



The base acts as the limiting reactant, leaving 5 mmol of unreacted weak acid alongside 5 mmol of its generated conjugate salt, producing a viable acidic buffer.

Step 4: Analyze system (D). Mixing 5 mmol of CH₃COOH with 10 mmol of NaOH entirely consumes the weak acid, leaving an excess of strong base, which prevents buffer formation.

Final Answer: (B), (C)

Answer: (B, C)

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Answer Key

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

