JELET Chemistry Sample Paper-10

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. Which of the following sets of quantum numbers is not permissible for an electron in an atom?

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

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

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

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

Q2. If the equilibrium constant for the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is K_c, what will be the equilibrium constant for the reaction $\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$ at the same temperature?

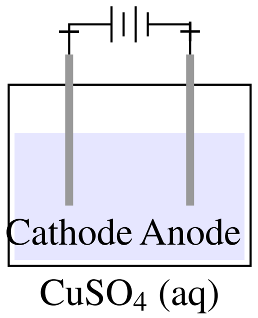
(A) K_c

(B) $\sqrt{K_c}$

(C) K_c^2

(D) $\frac{1}{K_c}$

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



(A) Copper at cathode, Oxygen gas at anode

(B) Hydrogen gas at cathode, Oxygen gas at anode

(C) Copper at cathode, Chlorine gas at anode

(D) Sulfur dioxide at cathode, Copper at anode

Q4. Temporary hardness of water is primarily caused by the presence of which of the following salts?

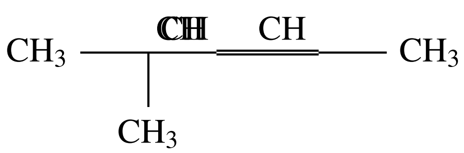
(A) Calcium chloride and Magnesium sulfate

(B) Calcium bicarbonate and Magnesium bicarbonate

(C) Magnesium chloride and Calcium sulfate

(D) Sodium carbonate and Potassium bicarbonate

Q5. What is the correct IUPAC name of the compound given by the chemical structure below?



(A) 2-Methylpent-3-ene

(B) 4-Methylpent-2-ene

(C) 1,1-Dimethylbut-2-ene

(D) Isohexene

Q6. Which historical catalytic process is industrially used to produce nitric acid by the oxidation of ammonia?

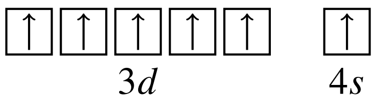
(A) Haber's Process

(B) Contact Process

(C) Ostwald's Process

(D) Solvay Process

Q7. In the ground state of a chromium atom ($Z = 24$), how many unpaired electrons are present in total?



(A) 4

(B) 5

(C) 6

(D) 3

Q8. Which chemical species is responsible for the destructive depletion of the ozone layer in the stratosphere via a free radical chain mechanism?

(A) CO_2

(B) CF_2Cl_2

(C) SO_2

(D) O_3

Q9. What is the pH of a 1.0×10^{-8} M aqueous solution of hydrochloric acid (HCl) at 25°C?

(A) 8.00

(B) 6.00

(C) 6.98

(D) 7.02

Q10. How many moles of electrons are required to fully reduce 1 mole of MnO_4^- ions to Mn^{2+} ions in an acidic medium as shown in the transformation below?

$$MnO_4^- + 8H^+ + ne^- \longrightarrow Mn^{2+} + 4H_2O$$

(A) 2 moles

(B) 3 moles

(C) 5 moles

(D) 7 moles

Q11. Which primary air pollutant undergoes photochemical reactions in the presence of solar radiation and hydrocarbons to form photochemical smog?

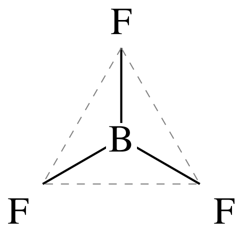
(A) Carbon monoxide (CO)

(B) Oxides of nitrogen (NO_x)

(C) Sulfur dioxide (SO_2)

(D) Carbon dioxide (CO_2)

Q12. What type of hybridization is exhibited by the central boron atom in a boron trifluoride (BF_3) molecule?



(A) sp

(B) sp^2

(C) sp^3

(D) sp^3d

Q13. In the blast furnace during the extraction of iron from hematite ore, what chemical species acts as the primary reducing agent in the upper lower-temperature zone?

(A) Carbon (C)

(B) Carbon monoxide (CO)

(C) Carbon dioxide (CO_2)

(D) Calcium silicate ($CaSiO_3$)

Q14. What is the correct conjugate base of the amphiprotic bicarbonate ion (HCO_3^-)?

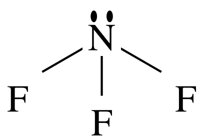
(A) H_2CO_3

(B) CO_3^{2-}

(C) OH^-

(D) CO_2

Q15. Which of the following molecules has a non-zero, permanent net dipole moment vector $\vec{\mu}$?



(A) CCl_4

(B) CO_2

(C) NF_3

(D) BF_3

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

Q16. Which of the following organic compounds exhibit structural or geometrical isomerism?

(A) But-2-ene

(B) Propan-1-ol

(C) Ethane

(D) 2-Methylpropane

Q17. Which of the following statements are correct regarding an aqueous buffer solution prepared from a weak acid (HA) and its conjugate salt (MA)?

(A) The pH change is resisted when small amounts of an acid or a base are added.

(B) The buffer capacity is maximum when the concentration of the weak acid equals the concentration of its conjugate base.

(C) Diluting the buffer solution significantly alters its pH value.

(D) Its pH can be calculated using the relation $\text{pH} = \text{p}K_a + \log \frac{[\text{Salt}]}{[\text{Acid}]}$.

Q18. According to Bohr's model of the hydrogen atom, which properties of the electron are inversely proportional to the principal quantum number (n)?

(A) Radius of the orbit

(B) Velocity of the electron in the orbit

(C) Kinetic energy of the electron

(D) Magnitude of the potential energy of the electron

Q19. Which of the following processes or reactions take place during the industrial extraction of copper from copper pyrites ($CuFeS_2$)?

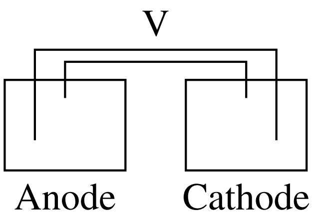
(A) Roasting of the ore to remove volatile impurities and convert sulfides to oxides.

(B) Smelting in a blast furnace where iron oxide combines with silica (SiO_2) to form a fusible slag ($FeSiO_3$).

(C) Self-reduction of copper oxide by copper sulfide in a Bessemer converter.

(D) Electrolytic refining using an anode of pure copper and a cathode of impure blister copper.

Q20. Which of the following standard electrochemical cells will experience an increase in its electromotive force (EMF) when the concentration of Cu^{2+} ions is increased at 25°C?



(A) $Zn(s) \mid Zn^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$

(B) $Cu(s) \mid Cu^{2+}(aq) \parallel Ag^{+}(aq) \mid Ag(s)$

(C) $Fe(s) \mid Fe^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$

(D) $Pt(s) \mid H_2(g) \mid H^{+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$

Detailed Solutions

Q1.

Solution

Concept: The state of an electron in an atom is defined by four quantum numbers: principal (n), azimuthal (l), magnetic (m_l), and spin (m_s). The rules governing these are: n must be a positive integer $(1, 2, 3, \dots)$, l can range from 0 to $n-1$, m_l can take integer values from $-l$ to $+l$, and m_s must be either $+\frac{1}{2}$ or $-\frac{1}{2}$.

Solution: Step 1: Analyze option (A) where $n = 3, l = 2, m_l = -2, m_s = +\frac{1}{2}$. Here, $l = 2$ is valid since $2 \leq 3 - 1$. The value $m_l = -2$ lies within the permitted range of -2 to $+2$. Thus, this set is valid.

Step 2: Analyze option (B) where $n = 4, l = 0, m_l = 0, m_s = -\frac{1}{2}$. Here, $l = 0$ is valid since $0 \leq 4 - 1$. The value $m_l = 0$ is correct for $l = 0$. Thus, this set is valid.

Step 3: Analyze option (C) where $n = 3, l = 3, m_l = -1, m_s = +\frac{1}{2}$. For any given value of n, the maximum possible value of the azimuthal quantum number l is $n - 1$. For $n = 3$, the allowed values for l are 0, 1, and 2. Therefore, $l = 3$ is strictly forbidden.

Step 4: Analyze option (D) where $n = 2, l = 1, m_l = 0, m_s = -\frac{1}{2}$. Here, $l = 1$ is valid since $1 \leq 2 - 1$. The value $m_l = 0$ lies within the permitted range of -1 to $+1$. Thus, this set is valid.

Final Answer: $\boxed{n = 3, l = 3, m_l = -1, m_s = +\frac{1}{2}}$

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept: When a reversible chemical reaction is multiplied or divided by a stoichiometric factor, the new equilibrium constant changes exponentially. If an equilibrium reaction is multiplied by a coefficient n, the new equilibrium constant K' relates to the original equilibrium constant K as $K' = K^n$.

Solution: Step 1: Write down the given chemical equilibrium equation and its corresponding equilibrium constant:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \text{with} \quad K_1 = K_c$$

Step 2: Identify the relationship between the target reaction and the original reaction. The target reaction is:

$$\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$$

Step 3: Notice that the target equation is obtained by multiplying the entire original chemical equation by a stoichiometric factor of $n = \frac{1}{2}$.

Step 4: Apply the exponential rule for equilibrium constants. The new equilibrium constant K_2 is equal to the original equilibrium constant raised to the power of the scaling factor:

$$K_2 = (K_1)^{\frac{1}{2}} = (K_c)^{\frac{1}{2}} = \sqrt{K_c}$$

Final Answer: $\boxed{\sqrt{K_c}}$

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: During the electrolysis of an aqueous solution, preferential discharge takes place at the electrodes based on the standard reduction potentials of the competing chemical species. At the cathode, the cation with the higher reduction potential is reduced. At the anode, the anion or species with the lower standard reduction potential is oxidized.

Solution: Step 1: Identify all ionic and molecular species present in the aqueous $CuSO_4$ solution: Cu^{2+}, SO_4^{2-}, H^+, and OH^- from water molecules.
Step 2: Analyze the reduction competitive reactions taking place at the negative electrode (cathode). The ions present are Cu^{2+} and H^+. The standard reduction potential of copper ($E^\circ = +0.34$ V) is significantly higher than that of hydrogen ($E^\circ = 0.00$ V). Therefore, Cu^{2+} ions are preferentially discharged to form solid copper metal:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

Step 3: Analyze the oxidation competitive reactions taking place at the positive electrode (anode). The species present are SO_4^{2-} and H_2O or OH^-. The oxidation of sulfate requires a very high potential, so water molecules are preferentially oxidized to liberate oxygen gas:

$$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$$

Final Answer: Copper at cathode, Oxygen gas at anode

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: Hardness of water is categorized into temporary hardness and permanent hardness. Temporary hardness is due to minerals that can be easily precipitated out of solution by simple boiling, whereas permanent hardness is caused by salts that cannot be removed by boiling alone and require chemical treatment.

Solution: Step 1: Define the chemical cause of temporary hardness. It is caused by the presence of dissolved bicarbonate salts of alkaline earth metals, specifically calcium and magnesium. These salts are soluble in water at room temperature.
Step 2: Understand the behavior of these salts upon boiling. When water containing calcium bicarbonate and magnesium bicarbonate is boiled, these soluble salts decompose into insoluble carbonates and hydroxides, which precipitate out of the water:

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3(s) + CO_2(g) + H_2O(l)$$

$$Mg(HCO_3)_2 \xrightarrow{\Delta} Mg(OH)_2(s) + 2CO_2(g)$$

Step 3: Differentiate this from permanent hardness, which is caused by the presence of chloride and sulfate salts of calcium and magnesium ($CaCl_2$, $MgCl_2$, $CaSO_4$, $MgSO_4$). These remain stable and fully dissolved upon boiling.

Final Answer: Calcium bicarbonate and Magnesium bicarbonate

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: According to IUPAC nomenclature for unsaturated hydrocarbons, the longest continuous carbon chain containing the principal functional group (the carbon-carbon double bond) must be selected as the parent principal chain. Numbering must be carried out from the end that gives the lower locant position number to the double bond.

Solution: Step 1: Analyze the given structural formula: $CH_3 - CH(CH_3) - CH = CH - CH_3$. Find the longest continuous carbon chain that contains the double bond. The longest chain contains 5 carbon atoms, making the parent alkene name "pentene".
Step 2: Number the parent continuous chain. We have two directions: left-to-right or right-to-left.
Path A (Left-to-right): The double bond starts at position carbon-3, and the methyl substituent group is located at position carbon-2.
Path B (Right-to-left): The double bond starts at position carbon-2, and the methyl substituent group is located at position carbon-4.
Step 3: Compare priorities. The principal double bond has a higher nomenclature priority than the alkyl methyl substituent. Therefore, Path B is the correct choice because it assigns the lower locant value (2) to the double bond instead of (3).
Step 4: Assemble the complete name. At carbon-4, there is a methyl group, and the main 5-carbon chain has a double bond starting at carbon-2. This yields 4-methylpent-2-ene.

Final Answer: 4-Methylpent-2-ene

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: Industrial manufacturing methods for heavy chemical commodities utilize specific heterogeneous catalytic oxidation pathways. Each major chemical industrial product is associated with a named historical scientific process and specialized chemical reactors.

Solution: Step 1: Analyze the chemical transformations of the Ostwald process. This industrial method manufactures nitric acid (HNO_3) from ammonia (NH_3). It occurs in three sequential chemical chemical steps.
Step 2: In the first step, ammonia is catalytic oxidized by oxygen from air in the presence of a platinum-rhodium gauge catalyst at high temperatures to yield nitric oxide: $4NH_3(g) + 5O_2(g) \xrightarrow{\text{Pt/Rh}} 4NO(g) + 6H_2O(g)$
Step 3: In the second step, the nitric oxide gas is further reacted with oxygen to produce nitrogen dioxide gas: $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
Step 4: In the final step, the nitrogen dioxide gas is absorbed in water to generate the desired product nitric acid: $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$
Step 5: Differentiate options. Haber's process is used for synthesising ammonia, the Contact process produces sulfuric acid, and the Solvay process yields sodium carbonate.

Final Answer: Ostwald's Process

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept: The electronic configuration of elements generally follows the Aufbau principle, Hund's rule of maximum multiplicity, and Pauli's exclusion principle. However, half-filled (d^5) and fully-filled (d^{10}) subshells possess exceptional thermodynamic stability due to symmetrical distribution of charge and high exchange energy.

Solution: Step 1: Determine the regular expected configuration of chromium ($Z = 24$) using the core Aufbau ordering. The expected regular electronic configuration would be $[Ar]3d^4 4s^2$.
Step 2: Apply the stabilization rule for half-filled shells. An electron from the lower-lying $4s$ orbital shifts into the $3d$ orbital subshell to establish a stable half-filled configuration. This results in the correct electronic configuration:

$$\text{Cr } (Z = 24) = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1 \quad \text{or} \quad [\text{Ar}]3d^5 4s^1$$

Step 3: Count the total number of unpaired individual valence electrons in the stabilized orbitals. The $3d$ subshell has five degenerate sub-orbitals, each containing one electron according to Hund's rule, yielding 5 unpaired electrons. The $4s$ orbital contains 1 unpaired electron.
Step 4: Sum the single electrons: 5 (from $3d$) + 1 (from $4s$) = 6 unpaired electrons.

Final Answer: 6

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept: Stratospheric ozone depletion is caused by synthetic halogenated volatile organic compounds known as chlorofluorocarbons (CFCs). In the upper atmosphere, these stable chemical compounds undergo photochemical breakdown to generate reactive free radicals that catalyze the breakdown of ozone molecules.

Solution: Step 1: Identify the compound in the options that belongs to the class of chlorofluorocarbons. Freon-12, chemically represented by the molecular formula CF_2Cl_2, is a widely used refrigerant and propellant compound.

Step 2: Understand the photochemical decomposition step. When CF_2Cl_2 molecules migrate up into the stratosphere, they are exposed to high-energy short-wave ultraviolet (UV) radiation, breaking a carbon-chlorine covalent bond:

$$CF_2Cl_2 \xrightarrow{h\nu} CF_2Cl^{\bullet} + Cl^{\bullet}$$

Step 3: Analyze the catalytic breakdown cycle. The free chlorine radical ($Cl^{\bullet}$) is highly reactive and attacks stratospheric ozone molecules (O_3), forming a chlorine monoxide radical and oxygen:

$$Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$$

$$ClO^{\bullet} + O \rightarrow Cl^{\bullet} + O_2$$

Since the chlorine atom radical is continuously regenerated, a single CFC molecule can decompose thousands of ozone molecules.

Final Answer: CF_2Cl_2

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept: When calculating the pH of extremely dilute solutions of strong acids ($< 1.0 \times 10^{-6}$ M), the auto-ionization of water cannot be ignored. Water contributes a baseline concentration of hydronium ions equal to 1.0×10^{-7} M at equilibrium, which must be systematically combined with the acid's concentration.

Solution: Step 1: Set up the total hydronium concentration expression. Let x be the concentration of H^+ ions contributed by the self-ionization of water molecules:

$$[H^+]_{\text{total}} = [H^+]_{\text{acid}} + [H^+]_{\text{water}} = 1.0 \times 10^{-8} + x$$

The concentration of hydroxide ions $[OH^-]$ from water will also be equal to x.
Step 2: Utilize the water ion-product constant expression (K_w) at 25°C:

$$K_w = [H^+]_{\text{total}} \times [OH^-] = (1.0 \times 10^{-8} + x) \cdot x = 1.0 \times 10^{-14}$$

$$x^2 + 1.0 \times 10^{-8}x - 1.0 \times 10^{-14} = 0$$

Step 3: Solve the quadratic algebraic equation using the quadratic formula:

$$x = \frac{-1.0 \times 10^{-8} + \sqrt{(1.0 \times 10^{-8})^2 - 4(1)(-1.0 \times 10^{-14})}}{2} \approx 9.5 \times 10^{-8} \text{ M}$$

Step 4: Calculate the absolute total value of the hydronium ion concentration:

$$[H^+]_{\text{total}} = 1.0 \times 10^{-8} + 9.5 \times 10^{-8} = 1.05 \times 10^{-7} \text{ M}$$

Step 5: Determine the pH by taking the negative common logarithm of $[H^+]_{\text{total}}$:

$$\text{pH} = -\log_{10}(1.05 \times 10^{-7}) \approx 7 - 0.02 = 6.98$$

Final Answer: 6.98

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept: The number of moles of electrons participating in an electrochemical redox reaction is determined by evaluating the absolute shift in the oxidation state of the chemical element undergoing reduction or oxidation. The total balance of electronic charge must satisfy the conservation of mass and electrical charge.

Solution: Step 1: Determine the initial chemical oxidation state of manganese in the polyatomic permanganate ion (MnO_4^-). Let x represent the unknown oxidation state of the central manganese atom. Oxygen always has an oxidation state of -2 in these compounds:

$$x + 4(-2) = -1 \implies x - 8 = -1 \implies x = +7$$

Thus, manganese begins in the +7 oxidation state.

Step 2: Determine the final oxidation state of the reduction product. The resulting species is a monoatomic manganese ion, Mn^{2+}, which has an oxidation state equal to its ionic charge, +2.

Step 3: Calculate the change (Δ) in oxidation state, which corresponds directly to the number of electrons captured by each atom of manganese:

$$\text{Change in oxidation number} = (+7) - (+2) = 5$$

Step 4: Deduce the balanced partial ionic reduction equation for the half-reaction:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

One mole of permanganate ions requires exactly 5 moles of electrons.

Final Answer: 5 moles

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept: Photochemical smog is a modern atmospheric pollution phenomenon that develops in urban areas. It is formed through complex primary reactions driven by solar ultraviolet radiation acting upon specific primary auto-exhaust gases and unburnt volatile organic hydrocarbons.

Solution: Step 1: Define the primary precursor elements of photochemical smog. The critical chemical components required to initiate the reaction are hydrocarbons and nitrogen oxides (NO_x), mainly nitric oxide (NO) and nitrogen dioxide (NO_2).
Step 2: Understand the chemical pathway. In the presence of sunlight, nitrogen dioxide undergoes photolysis to yield highly reactive oxygen atoms:

$$NO_2 + h\nu \rightarrow NO + O$$

Step 3: The atomic oxygen rapidly combines with molecular oxygen to generate ozone (O_3):

$$O + O_2 \rightarrow O_3$$

Step 4: The ozone and nitrogen oxides then react further with ambient unburnt volatile organic compounds (hydrocarbons) to form irritating secondary pollutants like peroxyacetyl nitrate (PAN) and acrolein. Thus, oxides of nitrogen are the vital primary pollutants that drive this process.

Final Answer: Oxides of nitrogen (NO_x)

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The hybridization state and spatial geometry of a molecule can be determined using the Valence Shell Electron Pair Repulsion (VSEPR) theory and the steric number formula. The steric number is calculated as: Steric Number = $\frac{1}{2}[V + M - C + A]$, where V is valence electrons, M is monovalent atoms, C is cation charge, and A is anion charge.

Solution: Step 1: Identify the central atom and its valence configuration. In boron trifluoride (BF_3), the central atom is Boron ($Z = 5$), which belongs to Group 13 and has $V = 3$ valence electrons.
Step 2: Count the surrounding monovalent atoms. There are 3 fluorine atoms attached to the central boron atom, so $M = 3$. The molecule is neutral, so $C = 0$ and $A = 0$.
Step 3: Calculate the steric number:

$$\text{Steric Number} = \frac{1}{2}[3 + 3 - 0 + 0] = \frac{6}{2} = 3$$

Step 4: Associate the steric number with the corresponding hybridization orbital configuration. A steric number of 3 corresponds to sp^2 hybridization, which creates a trigonal planar molecular geometry with ideal bond angles of 120°.

Final Answer: $\boxed{sp^2}$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: The industrial pyrometallurgical reduction of iron ore inside a vertical blast furnace involves distinct thermal zones. Different reduction reactions occur as the material descends through these zones, depending on the local temperature profile.

Solution: Step 1: Identify the temperature profile of the blast furnace. The top section of the furnace is the lowest temperature zone (500 K – 800 K), while the bottom combustion zone reaches up to 2200 K.
Step 2: Understand the source of the reducing gases. At the hot base, coke reacts with oxygen to form carbon dioxide, which is then reduced by excess coke to produce carbon monoxide gas (CO):

$$C + O_2 \rightarrow CO_2 \quad \text{and} \quad CO_2 + C \rightarrow 2CO$$

Step 3: Analyze the reduction reactions occurring in the cooler upper zone. As the carbon monoxide gas rises, it acts as the primary reducing agent for the descending iron oxides, converting them into spongy metallic iron:

$$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$$

$$Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$$

$$FeO + CO \rightarrow Fe + CO_2$$

Thus, gaseous carbon monoxide is the operational reducing agent in this upper region.

Final Answer: Carbon monoxide (CO)

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: According to the Brønsted-Lowry acid-base theory, an acid is a chemical species that donates a proton (H^+), while a base is a species that accepts a proton. A conjugate base is formed when a Brønsted-Lowry acid loses one proton from its molecular structure.

Solution: Step 1: Understand the amphiprotic nature of the bicarbonate ion (HCO_3^-). An amphiprotic species can act as either a proton donor or a proton acceptor depending on the reaction conditions.
Step 2: To find the conjugate base of any given chemical species, treat the initial species as a Brønsted-Lowry acid and remove exactly one proton (H^+) from it.
Step 3: Formulate the proton loss chemical equation for the bicarbonate ion:

$$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)$$

Step 4: Evaluate the remaining species. Removing H^+ from HCO_3^- decreases both the number of hydrogen atoms by one and the net electric charge by one unit (from -1 to -2). The resulting species is the carbonate divalent anion (CO_3^{2-}).

Final Answer: CO_3^{2-}

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: The net molecular dipole moment ($\vec{\mu}$) of a polyatomic molecule is the vector sum of its individual polar covalent bond dipoles and lone pair moments. A molecule will have a net permanent dipole moment ($\vec{\mu} \neq 0$) if its spatial geometry is asymmetrical, preventing the individual bond dipoles from canceling one another out.

Solution: Step 1: Evaluate option (A), CCl_4. It has a symmetrical tetrahedral geometry (sp^3). The four polar carbon-chlorine bond dipoles cancel out perfectly due to its highly symmetrical shape, resulting in $\vec{\mu} = 0$.

Step 2: Evaluate option (B), CO_2. This is a linear molecule (sp). The two carbon-oxygen double bond dipoles point in opposite directions at an angle of 180°, completely canceling each other out ($\vec{\mu} = 0$).

Step 3: Evaluate option (C), NF_3. The central nitrogen atom has sp^3 hybridization with three bond pairs and one lone pair, giving it a trigonal pyramidal geometry. The polar nitrogen-fluorine bonds point downward, while the lone pair dipole points upward. Because the lone pair moment and the bond dipoles differ in magnitude, they do not cancel out, leaving a net permanent dipole moment ($\vec{\mu} \neq 0$).

Step 4: Evaluate option (D), BF_3. It has a symmetrical trigonal planar geometry (sp^2). The three boron-fluorine bond dipoles point toward the corners of an equilateral triangle at 120° angles, canceling completely ($\vec{\mu} = 0$).

Final Answer: NF_3

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept: Isomerism occurs when compounds share identical molecular formulas but differ in their structural layout or spatial arrangement. Geometrical (cis/trans) isomerism requires restricted rotation about a double bond, with each carbon atom of the double bond attached to two distinct chemical groups.

Solution: Step 1: Evaluate statement option (A), But-2-ene ($CH_3 - CH = CH - CH_3$). The carbon-carbon double bond restricts rotation, and each alkene carbon is bonded to two different groups: a hydrogen atom and a methyl group. This allows it to form distinct cis and trans geometrical isomers. Thus, option (A) is correct.

Step 2: Evaluate statement option (B), Propan-1-ol ($CH_3 - CH_2 - CH_2 - OH$). It exhibits structural position isomerism because the hydroxyl functional group can shift to the second carbon atom to form the distinct isomer propan-2-ol. Thus, option (B) is correct.

Step 3: Evaluate statement option (C), Ethane ($CH_3 - CH_3$). Ethane is too simple to have structural isomers, and free rotation about its single bond prevents geometrical isomerism. Thus, option (C) is incorrect.

Step 4: Evaluate statement option (D), 2-Methylpropane ($CH(CH_3)_3$). This compound is a structural chain isomer of butane (C_4H_{10}), meaning it exhibits structural isomerism. Thus, option (D) is correct.

Final Answer: A, B, and D are correct options

Answer: (A, B, D)

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Q17.

Solution

Concept: An acidic buffer solution consists of a weak acid and its conjugate base salt. Its pH behavior is governed by the Henderson-Hasselbalch equation: $\text{pH} = \text{p}K_a + \log \frac{[\text{Substituent Conjugate Base}]}{[\text{Weak Acid}]}$. The buffer capacity measures a solution's resistance to pH changes when an acid or base is added.

Solution: Step 1: Evaluate statement (A). By definition, a buffer solution maintains a relatively stable pH when small amounts of strong acids or bases are added, as the weak acid and conjugate base neutralize the added H^+ or OH^- ions. Thus, statement (A) is correct.
Step 2: Evaluate statement (B). Buffer capacity is maximized when the concentrations of the weak acid and its conjugate base are equal ($[\text{Acid}] = [\text{Salt}]$). Under this condition, the solution can neutralize added acids and bases equally effectively. Thus, statement (B) is correct.
Step 3: Evaluate statement (C). Diluting a buffer solution changes the concentrations of both the acid and its conjugate base by the same ratio. Since the Henderson-Hasselbalch equation depends on the ratio of these concentrations rather than their absolute values, moderate dilution does not significantly alter the pH. Thus, statement (C) is incorrect.
Step 4: Evaluate statement (D). The Henderson-Hasselbalch equation is the standard mathematical model used to determine the pH of an acidic buffer solution. Thus, statement (D) is correct.

Final Answer: A, B, and D are correct options

Answer: (A, B, D)

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Q18.

Solution

Concept: Bohr's atomic model provides analytical expressions for the physical properties of an electron orbiting a hydrogen-like atom. These equations describe how properties like orbital radius (r), linear electronic velocity (v), kinetic energy (K), and potential energy (U) scale with the principal quantum number (n).

Solution: Step 1: State the relationship for the radius of the stable Bohr orbit. The radius scales with the principal quantum number as $r_n \propto n^2$. Since it is directly proportional to n^2, it is not inversely proportional to n. Thus, option (A) is incorrect.
Step 2: State the relationship for the linear velocity of the electron. The velocity in a given orbit scales as $v_n \propto \frac{1}{n}$. Because velocity is inversely proportional to n, option (B) is correct.
Step 3: State the relationship for the kinetic energy of the electron. Kinetic energy is given by $K_n = \frac{1}{2}mv_n^2$. Substituting the velocity relationship yields $K_n \propto \frac{1}{n^2}$. This means kinetic energy is inversely proportional to n^2, not n. Thus, option (C) is incorrect.
Step 4: State the relationship for the potential energy of the electron. The potential energy is given by $U_n = -\frac{Ze^2}{4\pi\epsilon_0 r_n}$, so its magnitude is $|U_n| \propto \frac{1}{n^2}$. Like kinetic energy, its magnitude is inversely proportional to n^2, not n. Thus, option (D) is incorrect.

Final Answer: Velocity of the electron in the orbit

Answer: (B)

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Q19.

Solution

Concept: The extraction of metallic copper from copper pyrites ore ($CuFeS_2$) involves several sequential pyrometallurgical steps: concentration, roasting, smelting, bessemerization, and electrolytic refining. Each step uses specific chemical reactions to separate iron and sulfur from the copper.

Solution: Step 1: Evaluate statement (A). During roasting, the concentrated sulfide ore is heated in excess air. This removes volatile impurities like arsenic and antimony as oxides and partially converts the metal sulfides into oxides:

$$2CuFeS_2 + 4O_2 \rightarrow Cu_2S + 2FeO + 3SO_2$$

Thus, statement (A) is correct.
Step 2: Evaluate statement (B). In the smelting furnace, the roasted ore is heated with silica (SiO_2). The iron oxide (FeO) impurity reacts with the silica flux to form a fusible liquid iron silicate slag ($FeSiO_3$), which floats on top of the copper matte and is easily removed:

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

Thus, statement (B) is correct.
Step 3: Evaluate statement (C). During bessemerization, air is blown through the molten matte. Part of the Cu_2S is oxidized to Cu_2O, which then reacts with the remaining Cu_2S via a self-reduction process to yield blister copper metal without requiring an external reducing agent:

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2 \quad \text{and} \quad 2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$$

Thus, statement (C) is correct.
Step 4: Evaluate statement (D). In electrolytic refining, the plates are arranged such that the thick, impure blister copper serves as the anode, while a thin sheet of pure copper serves as the cathode. The statement incorrectly reverses these electrode roles. Thus, statement (D) is incorrect.

Final Answer: A, B, and C are correct options

Answer: (A, B, C)

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Q20.

Solution

Concept: The dependence of an electrochemical cell's electromotive force (EMF) on ion concentrations is described by the Nernst equation: $E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{n}\log_{10} Q$, where Q is the reaction quotient. Increasing the concentration of a reactant shifts the equilibrium forward and increases E_{cell}, while increasing a product concentration decreases it.

Solution: Step 1: Analyze cell configuration (A): $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$. The Nernst equation is:

$$E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{2}\log_{10}\frac{[Zn^{2+}]}{[Cu^{2+}]}$$

Here, Cu^{2+} is a reactant. Increasing $[Cu^{2+}]$ decreases the value of the log term, which increases E_{cell}. Thus, option (A) is correct.

Step 2: Analyze cell configuration (B): $Cu(s) + 2Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$. The Nernst equation is:

$$E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{2}\log_{10}\frac{[Cu^{2+}]}{[Ag^{+}]^2}$$

Here, Cu^{2+} is a product. Increasing $[Cu^{2+}]$ increases the reaction quotient, which decreases E_{cell}. Thus, option (B) is incorrect.

Step 3: Analyze cell configuration (C): $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$. The Nernst equation is:

$$E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{2}\log_{10}\frac{[Fe^{2+}]}{[Cu^{2+}]}$$

Since Cu^{2+} serves as a reactant, increasing its concentration reduces the reaction quotient, increasing E_{cell}. Thus, option (C) is correct.

Step 4: Analyze cell configuration (D): $H_2(g) + Cu^{2+}(aq) \rightarrow 2H^{+}(aq) + Cu(s)$. The Nernst equation is:

$$E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{2}\log_{10}\frac{[H^{+}]^2}{P_{H_2}[Cu^{2+}]}$$

Since Cu^{2+} is a reactant, increasing its concentration increases E_{cell}. Thus, option (D) is correct.

Final Answer: A, C, and D are correct options

Answer: (A, C, D)

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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	C	7	C	8	B	9	C	10	C
11	B	12	B	13	B	14	B	15	C
16	A, B, D	17	A, B, D	18	B	19	A, B, C	20	A, C, D