JEECUP Group A Chemistry Sample Paper-13

Duration: 45 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **25** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**. No marks will be deducted for incorrect answers. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. According to the Bohr theory of the hydrogen atom, if an electron transitions from an arbitrary initial energy level n_2 to the first excited state ($n = 2$), the frequency of the emitted photon is found to be exactly 6.16×10^{14} Hz. Calculate the numerical value of the initial quantum level n_2. [Take Rydberg constant $R_H = 3.29 \times 10^{15}$ Hz].

(A) 3

(B) 4

(C) 5

(D) 6

Q2. The first ionization energy of atomic sodium is 496 kJ/mol. Calculate the maximum wavelength (λ_{max}) of electromagnetic radiation capable of ionizing a single ground-state sodium atom in the gas phase. [Take $h = 6.626 \times 10^{-34}$ J · s, $c = 3 \times 10^8$ m/s, and $N_A = 6.022 \times 10^{23}$ mol^{-1}].

(A) 241 nm

(B) 482 nm

(C) 120 nm

(D) 362 nm

Q3. Based on Molecular Orbital Theory (MOT), what is the correct molecular orbital configuration and resulting bond order for the heteronuclear nitric oxide molecule (NO)?

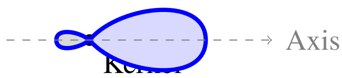
(A) Bond order = 2.0, Diamagnetic

(B) Bond order = 2.5, Paramagnetic

(C) Bond order = 3.0, Diamagnetic

(D) Bond order = 1.5, Paramagnetic

Q4. An advanced electron density profiling instrument maps the probability density of a specific valence hybrid orbital. Based on the asymmetric alignment along a single coordinate direction containing a minor rear node and a major forward directional lobe as visualized below, identify the hybrid state of the central atomic kernel:



(A) Pure unhybridized p_x orbital

(B) Pure unhybridized d_{z^2} orbital

(C) Directional sp^n hybrid orbital directional profile

(D) Spherical s orbital profile

Q5. The fundamental electronegativity difference ($\Delta\chi$) values across a bonded pair regulate its percentage ionic character. According to Hannay-Smith empirical calculations, if a compound $A - B$ exhibits an electronegativity difference of exactly $\Delta\chi = 1.9$, the evaluated percentage ionic character of this single covalent bond is closest to:

(A) 50%

(B) 43%

(C) 35%

(D) 62%

Q6. Deduce the true systematic position (Group and Period boundaries) inside the Modern Periodic Table corresponding to the heavy transition element possessing the atomic number $Z = 74$:

(A) Group 4, Period 6

(B) Group 6, Period 5

(C) Group 6, Period 6

(D) Group 14, Period 6

Q7. Identify the correct increasing sequence of the second ionization energies (IE_2) among the selected first-row transition series metallic elements listed below:

(A) V < Cr < Mn < Fe

(B) V < Mn < Fe < Cr

(C) Cr < V < Mn < Fe

(D) Fe < Mn < V < Cr

Q8. Isolate the correct tracking indices for the stoichiometric variables x, y, and z required to fully balance the complex redox equation in alkaline conditions: $x\,Cl_2 + y\,OH^- \rightarrow z\,Cl^- + 1\,ClO_3^- + 3\,H_2O$

(A) $x = 3, y = 6, z = 5$

(B) $x = 2, y = 4, z = 3$

(C) $x = 3, y = 6, z = 3$

(D) $x = 5, y = 10, z = 9$

Q9. A rigid multi-chamber container holds a mixture of 4 g of Deuterium gas (D_2, $M = 4$) and 14 g of Nitrogen gas (N_2, $M = 28$). If the aggregate total internal pressure tracking across the container manifold reads exactly 12 atm, compute the partial pressure component belonging to the deuterium fraction.

(A) 4 atm

(B) 8 atm

(C) 6 atm

(D) 3 atm

Q10. A volatile hydrocarbon compound contains 80% carbon and 20% hydrogen by mass. If exactly 1.12 liters of this gaseous hydrocarbon measured at STP conditions weighs exactly 1.5 grams, determine its true molecular formula.

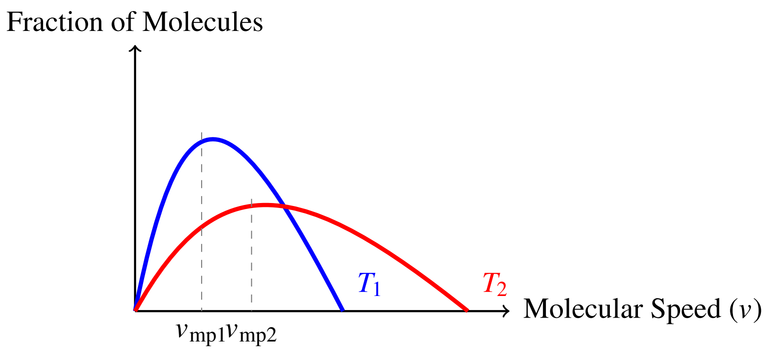
(A) CH_4

(B) C_2H_4

(C) C_2H_6

(D) C_3H_8

Q11. An industrial engineering workstation maps out the Maxwell-Boltzmann molecular speed distribution profiles for an ideal gas sample at two discrete operational temperatures. Based on the probability curves plotted below, identify the correct configuration option matching the temperature properties and molecular velocity points labeled:



(A) $T_1 > T_2$, and the most probable velocity increases as temperature falls

(B) $T_2 > T_1$, and the most probable velocity increases as temperature rises

(C) $T_1 = T_2$, showing no change in speed distributions

(D) $T_2 > T_1$, but the total fraction of high-speed molecules decreases

Q12. An industrial chemist dilutes exactly 100 mL of an aqueous 12 M HCl stock solution with pure distilled water to produce a large standard batch volume of exactly 3.0 liters. Calculate the final resulting molar concentration (M) of the diluted acid solution.

(A) 0.40 M

(B) 0.25 M

(C) 0.12 M

(D) 0.04 M

Q13. An analytical sample solution is prepared by dissolving 0.56 grams of pure Potassium Hydroxide (KOH, $M = 56$) into water to achieve a final target volume of 100 mL at 298 K. Calculate the exact pH value tracking this base matrix solution.

(A) 1.00

(B) 13.00

(C) 12.00

(D) 11.00

Q14. According to the Bronsted-Lowry definition, select the correct formula matching the conjugate acid of the weak dihydrogen phosphate ion ($H_2PO_4^-$):

(A) HPO_4^{2-}

(B) PO_4^{3-}

(C) H_3PO_4

(D) $H_4PO_4^+$

Q15. A buffer mixture contains 0.15 M Sodium Acetate (CH_3COONa) and 0.05 M Acetic Acid (CH_3COOH). If the basic dissociation property parameter defines a pK_a value of 4.75 for acetic acid, determine the exact operational pH tracking this active system. [Given: $\log_{10}(3) = 0.477$].

(A) 5.23

(B) 4.27

(C) 4.75

(D) 3.75

Q16. Which of the following structured white crystalline mineral compound complexes represents the true chemical composition of standard commercial Baking Powder, blending sodium bicarbonate with a stabilizing solid acid component?

(A) Sodium Hydrogen Carbonate and Potassium Hydrogen Tartrate

(B) Sodium Hydrogen Carbonate and Calcium Sulfate

(C) Sodium Carbonate Decahydrate and Citric Acid

(D) Ammonium Carbonate and Sodium Chloride

Q17. During the pyrometallurgical smelting operation of copper inside a blast furnace, the primary molten matte layer tapped from the hearth separation channel consists of an optimized high-temperature mixture of which specific components?

(A) CuO and FeS

(B) Cu_2S and FeS

(C) Cu_2O and Fe_2O_3

(D) Cu_2S and $FeSO_4$

Q18. When elemental Silicon (Si), a critical semiconductor non-metal metalloid, is treated with hot concentrated aqueous Sodium Hydroxide (NaOH), it reacts to form water-soluble sodium silicate along with which byproduct gas?

(A) Oxygen gas (O_2)

(B) Hydrogen gas (H_2)

(C) Silicon hydride (SiH_4)

(D) Carbon dioxide (CO_2)

Q19. The structural formulation profile of the high-strength industrial non-ferrous alloy known as German Silver consists of which composition mixture matrix?

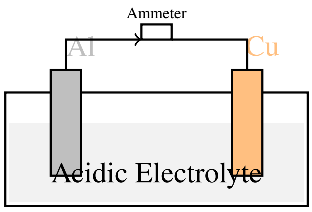
(A) Copper, Zinc, and Silver

(B) Copper, Zinc, and Nickel

(C) Copper, Tin, and Lead

(D) Nickel, Iron, and Chromium

Q20. A metallurgical corrosion analysis setup links an aluminum plate and a copper plate through an external circuit loop submerged in an acidic electrolyte. Based on the galvanic potential flow schematic outlined below, identify the true reaction properties and chemical path transformations occurring at the Aluminum anode:



(A) Aluminum is reduced, gaining electrons to form Al(s)

(B) Aluminum is oxidized, dissolving into the solution as Al^{3+}(aq) ions

(C) Oxygen gas bubbles evolve along the aluminum plate boundary

(D) Copper ions migrate and deposit onto the aluminum anode surface

Q21. Determine the exact counts of localized sigma (σ) bonds and pi (π) bonds running across a single molecule of the aliphatic hydrocarbon compound Penta-1,2-diene:

(A) 10 σ and 2 π

(B) 11 σ and 2 π

(C) 12 σ and 2 π

(D) 9 σ and 3 π

Q22. When an organic synthesis stream converts an alkyne compound via a hydroboration-oxidation sequence, it forms key carbonyl materials. If Propyne ($CH_3 - C \equiv CH$) undergoes anti-Markovnikov hydration using B_2H_6 followed by alkaline H_2O_2, identify the principal organic product generated:

(A) Propan-2-one (Acetone)

(B) Propanal

(C) Propan-1-ol

(D) Propanoic acid

Q23. The clean industrial fuel resource known as Liquefied Petroleum Gas (LPG) supplied for residential and commercial heating manifolds consists primarily of a highly pressurized liquid mixture of which hydrocarbon structures?

(A) Methane and Ethane

(B) Propane and Butane

(C) Ethane and Propane

(D) Butane and Pentane

Q24. The specialized industrial process where heavy high-boiling petroleum fractions are broken down into lower-boiling lighter hydrocarbons suitable for motor fuels by heating under high pressure in the presence of a zeolite catalyst is called:

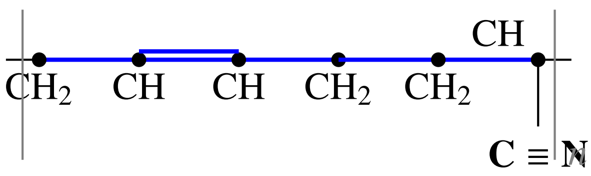
(A) Isomerization

(B) Catalytic Cracking (Pyrolysis)

(C) Fractional Distillation

(D) Polymerization

Q25. An industrial polymer engineering laboratory runs quality control tests on a synthetic elastomer praised for its exceptional resistance to oils, petroleum hydrocarbons, and high mechanical abrasion. Based on the chemical structure of the repeating copolymer unit illustrated below, deduce the correct systematic IUPAC names of the two distinct monomer fragments used to synthesize this high-strength material (commercially known as Buna-N):



(A) Buta-1,3-diene and Styrene

(B) Buta-1,3-diene and Prop-2-enalthiol

(C) Buta-1,3-diene and Prop-2-enenitrile (Acrylonitrile)

(D) 2-Chlorobuta-1,3-diene and Ethene

Detailed Solutions

Q1.

Solution

Concept:

According to the Bohr model of the hydrogen atom, the frequency (ν) of a photon emitted during an electronic transition from an initial higher energy level (n_2) to a final lower energy level (n_1) is given by the formula:

$$\nu = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

where R_H is the Rydberg constant expressed in frequency units (Hz).

Solution:

Substitute the given values into the Bohr frequency equation ($n_1 = 2$ for the first excited state, $\nu = 6.16 \times 10^{14}$ Hz, and $R_H = 3.29 \times 10^{15}$ Hz):

$$6.16 \times 10^{14} = 3.29 \times 10^{15} \left(\frac{1}{2^2} - \frac{1}{n_2^2} \right)$$

Divide both sides by 3.29×10^{15}:

$$\frac{6.16 \times 10^{14}}{3.29 \times 10^{15}} = \frac{1}{4} - \frac{1}{n_2^2} \implies 0.1872 = 0.25 - \frac{1}{n_2^2}$$

Isolate the term containing n_2:

$$\frac{1}{n_2^2} = 0.25 - 0.1872 = 0.0628$$

$$n_2^2 = \frac{1}{0.0628} \approx 15.92 \implies n_2 = \sqrt{15.92} \approx 4$$

Thus, the initial principal quantum level is $n_2 = 4$.

The configuration matches Option (B).

Final Answer: $\boxed{4}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:

The ionization energy provided (ΔH_{ion}) represents the energy required to remove an electron from one mole of gaseous sodium atoms. To find the energy threshold (E) required to ionize a single sodium atom, divide the molar value by Avogadro's number (N_A):

$$E = \frac{\Delta H_{ion}}{N_A}$$

The maximum wavelength (λ_{max}) capable of supplying this ionization threshold energy is calculated using Planck's relation:

$$E = \frac{hc}{\lambda_{max}} \implies \lambda_{max} = \frac{hc \cdot N_A}{\Delta H_{ion}}$$

Solution:

Convert the ionization energy from kilojoules to joules: $\Delta H_{ion} = 496$ kJ/mol $= 4.96 \times 10^5$ J/mol. Substitute the remaining standard constants ($h = 6.626 \times 10^{-34}$ J · s, $c = 3 \times 10^8$ m/s, and $N_A = 6.022 \times 10^{23}$ mol^{-1}) into the wavelength equation:

$$\lambda_{max} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s}) \times (3 \times 10^8 \text{ m/s}) \times (6.022 \times 10^{23} \text{ mol}^{-1})}{4.96 \times 10^5 \text{ J/mol}}$$

Multiply the numerator components:

$$\lambda_{max} = \frac{1.197 \times 10^{-1}}{4.96 \times 10^5} = 2.413 \times 10^{-7} \text{ m}$$

Convert meters into nanometers (1 nm $= 10^{-9}$ m):

$$\lambda_{max} = 241.3 \text{ nm} \approx 241 \text{ nm}$$

The configuration matches Option (A).

Final Answer: 241 nm

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept:

According to Molecular Orbital Theory (MOT), heteronuclear diatomic molecules like nitric oxide (NO) fill their combined molecular orbitals sequentially based on their total electron count. The bond order is calculated from the number of bonding electrons (N_b) and antibonding electrons (N_a):

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

If a configuration contains unpaired electrons, the molecule is paramagnetic; if all electrons are completely paired, it is diamagnetic.

Solution:

Determine the total electron count for an NO molecule:

$$\text{Total Electrons} = 7 \text{ (from N)} + 8 \text{ (from O)} = 15 \text{ electrons}$$

Fill the molecular orbitals in order of increasing energy:

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

Count the total number of bonding and antibonding valence electrons:

- Bonding electrons (N_b) = 10 (from $\sigma_{1s}, \sigma_{2s}, \sigma_{2p_z}, \pi_{2p_x}, \pi_{2p_y}$)
- Antibonding electrons (N_a) = 5 (from $\sigma_{1s}^*, \sigma_{2s}^*, \pi_{2p_x}^*$)

Calculate the resulting bond order:

$$\text{Bond Order} = \frac{10 - 5}{2} = 2.5$$

Because there is one unpaired electron residing within the partially filled $\pi_{2p_x}^*$ antibonding orbital, nitric oxide is classified as a paramagnetic molecule.

The configuration matches Option (B).

Final Answer: $\boxed{\text{Bond order} = 2.5,\ \text{Paramagnetic}}$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:

Atomic orbital hybridization mixes atomic orbitals (s, p, d) of similar energies to form new, highly directional hybrid orbitals. The resulting spatial boundary profiles are distinct from pure unhybridized shapes:

- A pure unhybridized p orbital is a symmetric dumbbell with two identical lobes separated by a planar node passing directly through the nucleus.
- An sp^n hybrid orbital exhibits an asymmetric directional distribution. Due to constructive and destructive wave interference, the electron density shifts predominantly to one side, forming a large forward directional lobe and a small minor rear lobe behind the atomic kernel.

Solution:

Analyzing the asymmetry in the provided profiling diagram:

(a) The distribution along the coordinate reference axis is highly unbalanced around the origin.

(b) It features a single major forward-pointing directional lobe on the right side and a highly compressed minor node lobe on the left.

This combination of a large directional lobe and a small rear lobe is the characteristic spatial profile of an sp, sp^2, or sp^3 directional hybrid orbital, allowing for effective head-on overlap during covalent σ-bond formations.

The configuration matches Option (C).

Final Answer: Directional sp^n hybrid orbital directional profile

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept:

The partial ionic character of a single heteronuclear covalent bond can be estimated from the electronegativity difference ($\Delta\chi$) between the two bonded atoms. According to the empirical relation formulated by Hannay and Smith, the percentage of ionic character is given by the formula:

$$\%\text{ Ionic Character} = 16(\Delta\chi) + 3.5(\Delta\chi)^2$$

Solution:

Substitute the given electronegativity difference ($\Delta\chi = 1.9$) directly into the Hannay-Smith empirical equation:

$$\%\text{ Ionic Character} = 16(1.9) + 3.5(1.9)^2$$

Calculate each term:

$$16 \times 1.9 = 30.4$$

$$3.5 \times (1.9)^2 = 3.5 \times 3.61 = 12.635$$

Sum the values to find the total percentage ionic character:

$$\%\text{ Ionic Character} = 30.4 + 12.635 = 43.035\% \approx 43\%$$

Thus, the ionic character of this covalent bond is closest to 43%.

The configuration matches Option (B).

Final Answer: $\boxed{43\%}$

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:

To locate a heavy transition element inside the modern periodic table, determine its complete ground state electron configuration by following the Aufbau principle relative to the nearest preceding noble gas core (Xe, $Z = 54$):

- **Period Number:** Determined by the highest principal quantum number (n) in the configuration.
- **Group Number:** For a d-block element, the group equals the sum of the outer s and underlying $(n-1)d$ electrons:

$$\text{Group} = \text{number of } ns \text{ electrons} + \text{number of } (n-1)d \text{ electrons}$$

Solution:

Write the electronic configuration for the element with atomic number $Z = 74$:

$$Z = 74 \implies [\text{Xe}]4f^{14}5d^4 6s^2$$

Identify the location parameters from this configuration:

- The maximum principal quantum number is $n = 6$, which places the element in **Period 6**.
- The differentiating electrons enter the $5d$ subshell, confirming it is a d-block transition metal.
- Calculate the group position:

$$\text{Group} = 2 \text{ (from } 6s) + 4 \text{ (from } 5d) = 6$$

The parameters yield Group 6, Period 6, which identifies the heavy transition metal Tungsten (W). The configuration matches Option (C).

Final Answer: Group 6, Period 6

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept:

The second ionization energy (IE_2) is the energy required to remove an electron from a univalent gaseous cation ($M^+ \rightarrow M^{2+} + e^-$). Its value depends heavily on the electron configuration of the M^+ ion:

- Removing an electron from exceptionally stable half-filled (d^5) or completely filled (d^{10}) subshells requires significantly more energy, resulting in an anomalously high IE_2.
- Generally, across a transition series, IE_2 increases due to an increase in effective nuclear charge (Z_{eff}), provided there are no stabilization anomalies.

Solution:

Determine the electron configuration for the monovalent cations (M^+) of each given element:

- **Vanadium (V, $Z = 23$):** $V = [Ar]3d^3 4s^2 \implies V^+ = [Ar]3d^4$
- **Chromium (Cr, $Z = 24$):** $Cr = [Ar]3d^5 4s^1 \implies Cr^+ = [Ar]3d^5$ (**Stable half-filled configuration**)
- **Manganese (Mn, $Z = 25$):** $Mn = [Ar]3d^5 4s^2 \implies Mn^+ = [Ar]3d^5 4s^1$
- **Iron (Fe, $Z = 26$):** $Fe = [Ar]3d^6 4s^2 \implies Fe^+ = [Ar]3d^6 4s^1$

Analyze the relative ease of electron removal to establish the trend:

- Cr^+ has a highly stable $3d^5$ half-filled subshell. Removing an electron disrupts this exchange-stabilized state, giving Chromium an exceptionally high IE_2 value that outpaces the surrounding elements.
- For the remaining ions (V^+, Mn^+, Fe^+), the electron is removed from a $4s$ or $3d$ orbital where the energy standard increases regularly with effective nuclear charge: $V^+ < Mn^+ < Fe^+$.

Combining these observations gives the correct increasing sequence of second ionization energies: $V < Mn < Fe < Cr$.

The configuration matches Option (B).

Final Answer: $\boxed{V < Mn < Fe < Cr}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

A disproportionation reaction is a redox process where the same chemical species is simultaneously oxidized and reduced. To balance the equation in alkaline conditions, determine the electron transfers using oxidation numbers, then balance the net charge using hydroxide ions (OH^-).

Solution:

Analyze the changing oxidation states of Chlorine in the given skeleton reaction:

$$x\,Cl_2 + y\,OH^- \rightarrow z\,Cl^- + 1\,ClO_3^- + 3\,H_2O$$

- **Reduction Half-Reaction:** Elemental chlorine (Cl_2^0) is reduced to chloride ions (Cl^-):

$$Cl_2 + 2e^- \rightarrow 2Cl^-$$

- **Oxidation Half-Reaction:** Elemental chlorine (Cl_2^0) is oxidized to chlorate ions (ClO_3^-) where Chlorine has a +5 oxidation state:

$$Cl_2 \rightarrow 2ClO_3^- + 10e^-$$

To balance the electrons transferred, multiply the reduction half-reaction by 5 and add it to the oxidation half-reaction:

$$5Cl_2 + Cl_2 \rightarrow 10Cl^- + 2ClO_3^- \implies 6Cl_2 \rightarrow 10Cl^- + 2ClO_3^-$$

Divide the entire equation by 2 to obtain the simplest whole-number ratio:

$$3Cl_2 \rightarrow 5Cl^- + 1ClO_3^-$$

Now, balance the net negative charge on the right side (which equals $-5 + (-1) = -6$) by adding 6 hydroxide ions (OH^-) to the left side:

$$3Cl_2 + 6OH^- \rightarrow 5Cl^- + 1ClO_3^- + 3H_2O$$

Matching this balanced equation to the stoichiometric coefficients gives $x = 3, y = 6, z = 5$.

The configuration matches Option (A).

Final Answer: $\boxed{x = 3, y = 6, z = 5}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:

According to Dalton's Law of Partial Pressures, the partial pressure exerted by an individual component gas (P_i) within a non-reactive mixture is equal to the product of its mole fraction (X_i) and the total system pressure (P_{total}):

$$P_i = X_i \cdot P_{\text{total}} = \left(\frac{n_i}{n_{\text{total}}}\right) P_{\text{total}}$$

Solution:

Calculate the number of moles of each gas using their mass and molar mass (M):

- Moles of Deuterium gas (n_{D_2}):

$$n_{D_2} = \frac{4 \text{ g}}{4 \text{ g/mol}} = 1.0 \text{ mole}$$

- Moles of Nitrogen gas (n_{N_2}):

$$n_{N_2} = \frac{14 \text{ g}}{28 \text{ g/mol}} = 0.5 \text{ mole}$$

Calculate the total moles of gas in the mixture:

$$n_{\text{total}} = n_{D_2} + n_{N_2} = 1.0 + 0.5 = 1.5 \text{ moles}$$

Determine the mole fraction of Deuterium (X_{D_2}):

$$X_{D_2} = \frac{1.0 \text{ mole}}{1.5 \text{ moles}} = \frac{2}{3}$$

Multiply the mole fraction by the total pressure ($P_{\text{total}} = 12$ atm) to find the partial pressure of deuterium:

$$P_{D_2} = X_{D_2} \cdot P_{\text{total}} = \frac{2}{3} \times 12 \text{ atm} = 8 \text{ atm}$$

The configuration matches Option (B).

Final Answer: 8 atm

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:

The empirical formula represents the simplest whole-number ratio of the atoms present in a compound, while the molecular formula shows the actual number of each atom per molecule. The molecular mass (M) can be calculated from the volume and mass of the gas at standard temperature and pressure (STP) using the fact that one mole of an ideal gas occupies 22.4 liters.

Solution:

Step 1: Determine the empirical formula from the mass percentages:

- Moles of Carbon: $\frac{80\text{ g}}{12\text{ g/mol}} = 6.67$ moles
- Moles of Hydrogen: $\frac{20\text{ g}}{1\text{ g/mol}} = 20.00$ moles

Find the simplest ratio by dividing by the smallest value (6.67):

$$C = \frac{6.67}{6.67} = 1, \quad H = \frac{20.00}{6.67} = 3 \implies \text{Empirical Formula} = CH_3$$

The mass of this empirical formula unit is $12 + (3 \times 1) = 15$ g/mol.

Step 2: Calculate the true molecular weight (M) using the STP volume data:

$$M = 1.5\text{ grams} \times \left(\frac{22.4\text{ liters}}{1.12\text{ liters}}\right) = 1.5 \times 20 = 30\text{ g/mol}$$

Step 3: Determine the molecular formula multiplier (n):

$$n = \frac{\text{Molecular Mass}}{\text{Empirical Formula Mass}} = \frac{30}{15} = 2$$

Multiply the empirical formula subscripts by 2: Molecular Formula = $(CH_3)_2 = C_2H_6$ (Ethane). The configuration matches Option (C).

Final Answer: $\boxed{C_2H_6}$

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept:
The Maxwell-Boltzmann distribution describes the thermal speeds of molecules in an ideal gas. The peak of each probability curve corresponds to the most probable velocity (v_{mp}), which is given by:

$$v_{mp} = \sqrt{\frac{2RT}{M}}$$

As the temperature increases:

- The most probable velocity shifts to a higher value (v_{mp} increases).
- The curve flattens and broadens because a larger fraction of molecules acquire higher kinetic energies, which lowers the peak height (the maximum fraction of molecules at v_{mp} decreases).

Solution:
Analyze the given probability curves:

(a) Curve T_1 has a narrower, taller peak at a lower speed coordinate (v_{mp1}). This corresponds to the lower operational temperature.

(b) Curve T_2 is broader and flatter, shifting its peak to a higher speed coordinate ($v_{mp2} > v_{mp1}$). This corresponds to the higher operational temperature.

Therefore, $T_2 > T_1$, and the most probable velocity increases as the temperature rises.
The configuration matches Option (B).
Final Answer: $\boxed{T_2 > T_1\text{, and the most probable velocity increases as temperature rises}}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:

During a chemical dilution, the total number of moles of solute remains constant because only pure solvent is added to the system. The relationship between concentrations and volumes before and after dilution is given by the dilution equation:

$$M_1V_1 = M_2V_2$$

Solution:

Identify the initial and final parameters from the problem:

- Initial Stock Molarity (M_1) = 12 M
- Initial Stock Volume (V_1) = 100 mL = 0.1 liters
- Final Diluted Volume (V_2) = 3.0 liters

Substitute these values into the dilution equation to solve for the final molarity (M_2):

$$12\text{ M} \times 0.1\text{ liters} = M_2 \times 3.0\text{ liters}$$

$$1.2 = 3.0 \cdot M_2 \implies M_2 = \frac{1.2}{3.0} = 0.40\text{ M}$$

Thus, the final molar concentration of the diluted acid solution is 0.40 M.
The configuration matches Option (A).
Final Answer: $\boxed{0.40\text{ M}}$

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept:

Potassium Hydroxide (KOH) is a strong, fully dissociating monacidic base. The concentration of hydroxide ions ($[OH^-]$) in the solution is equal to the molarity of the dissolved base. The pH is found from the hydroxide ion concentration using the following water relationships at 298 K:

$$\text{pOH} = -\log_{10}[\text{OH}^-] \quad \text{and} \quad \text{pH} = 14 - \text{pOH}$$

Solution:

First, calculate the molarity of the KOH solution:

- Moles of KOH: $\frac{0.56 \text{ grams}}{56 \text{ g/mol}} = 0.01$ moles
- Volume of solution in liters: 100 mL = 0.1 liters
- Concentration (M): $\frac{0.01 \text{ moles}}{0.1 \text{ liters}} = 0.1 \text{ M} = 10^{-1} \text{ M}$

Since KOH dissociates completely, $[\text{OH}^-] = 10^{-1}$ M. Now, calculate pOH and pH:

$$\text{pOH} = -\log_{10}(10^{-1}) = 1.00$$

$$\text{pH} = 14.00 - \text{pOH} = 14.00 - 1.00 = 13.00$$

The configuration matches Option (B).

Final Answer: 13.00

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:

According to the Brønsted-Lowry acid-base theory, a conjugate acid is formed when a base accepts a single proton (H^+). Therefore, to find the formula of a conjugate acid, add one hydrogen atom (H) and increase the net chemical charge by +1:

$$\text{Conjugate Acid} = \text{Base} + H^+$$

Solution:

The given starting species is the dihydrogen phosphate ion ($H_2PO_4^-$). To find its conjugate acid, add a proton (H^+) to the formula:

$$H_2PO_4^- + H^+ \longrightarrow H_3PO_4$$

The resulting neutral compound is Phosphoric Acid (H_3PO_4). Conversely, losing a proton would yield its conjugate base, HPO_4^{2-}.

The configuration matches Option (C).

Final Answer: $\boxed{H_3PO_4}$

Answer: (C)

Go Back to Question 14

Q15.

Solution

Concept:

An acidic buffer solution consists of a weak acid paired with its conjugate base salt. The operational pH of an acidic buffer system is calculated using the Henderson-Hasselbalch equation:

$$pH = pK_a + \log_{10}\left(\frac{[\text{Conjugate Base Salt}]}{[\text{Weak Acid}]}\right)$$

Solution:

Identify the concentrations provided in the problem:

- Concentration of weak acid ($[CH_3COOH]$) = 0.05 M
- Concentration of conjugate base salt ($[CH_3COONa]$) = 0.15 M
- Weak acid dissociation constant (pK_a) = 4.75

Substitute these values into the Henderson-Hasselbalch equation:

$$pH = 4.75 + \log_{10}\left(\frac{0.15}{0.05}\right)$$

Simplify the concentration ratio inside the logarithm:

$$\frac{0.15}{0.05} = 3 \implies pH = 4.75 + \log_{10}(3)$$

Using the given value $\log_{10}(3) = 0.477$:

$$pH = 4.75 + 0.477 = 5.227 \approx 5.23$$

The configuration matches Option (A).

Final Answer: 5.23

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept:
Commercial baking powder is a dry leavening mixture used in baking. It contains an alkaline base, a solid acid salt, and an inert starch. When mixed with moisture, the acid reacts with the base to release carbon dioxide gas bubbles, causing dough to rise.
Solution:
Let us identify the components of standard baking powder:

(a) **Alkaline Base:** Sodium Hydrogen Carbonate (Sodium Bicarbonate, $NaHCO_3$), which releases carbon dioxide gas when neutralized.

(b) **Solid Acid Component:** Potassium Hydrogen Tartrate (Cream of Tartar, $KHC_4H_4O_6$), which dissolves in water to slowly neutralize the bicarbonate salt.

Pure sodium bicarbonate alone is baking soda; adding the stabilizing hydrogen tartrate acid salt converts it into commercial baking powder.
The configuration matches Option (A).
Final Answer: Sodium Hydrogen Carbonate and Potassium Hydrogen Tartrate

Answer: (A)
Go Back to Question 16

Q17.

Solution

Concept:
During the pyrometallurgical smelting of copper sulfide ores (like chalcopyrite, $CuFeS_2$), the roasted ore is heated with silica (SiO_2) and coke in a blast furnace. Iron has a higher affinity for oxygen than copper, so it is preferentially oxidized to form an iron silicate slag ($FeSiO_3$), which floats to the top. The denser copper-rich sulfide layer settles to the bottom as a molten mixture known as matte.
Solution:
Copper matte is the molten sulfide layer tapped from the lower hearth channel of the smelting furnace. It consists primarily of:

- **Copper(I) sulfide (Cu_2S):** $\sim$ 80% to 90%
- **Iron(II) sulfide (FeS):** $\sim$ 10% to 20%

This matte is subsequently transferred to a Bessemer converter, where air is blown through it to oxidize the remaining iron sulfide and reduce the copper sulfide to crude blister copper metal.
The configuration matches Option (B).
Final Answer: Cu_2S and FeS

Answer: (B)
Go Back to Question 17

Q18.

Solution

Concept:
Silicon (Si) is a metalloid element that dissolves in hot, concentrated aqueous alkali solutions. In this reaction, silicon is oxidized, displacing hydrogen from water to release a flammable elemental byproduct gas.

Solution:
Write the balanced chemical equation for elemental silicon reacting with hot, concentrated sodium hydroxide (NaOH):

$$Si(s) + 2NaOH(aq) + H_2O(l) \longrightarrow Na_2SiO_3(aq) + 2H_2(g) \uparrow$$

The products of this reaction are:

(a) **Sodium silicate (Na_2SiO_3):** A water-soluble salt.

(b) **Hydrogen gas (H_2):** Released as a flammable byproduct gas.

The configuration matches Option (B).

Final Answer: Hydrogen gas (H_2)

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:
German Silver is an industrial non-ferrous alloy known for its silvery-white metallic appearance, high corrosion resistance, and mechanical strength. Despite its common name, it contains no elemental silver.

Solution:
German silver belongs to the copper-nickel alloy family. Its standard industrial composition includes:

- **Copper (Cu):** $\sim 50\% - 60\%$
- **Zinc (Zn):** $\sim 20\% - 30\%$
- **Nickel (Ni):** $\sim 15\% - 30\%$

Because it contains no precious silver, its common name refers only to its silver-like color, which is produced by the dissolved nickel content.

The configuration matches Option (B).

Final Answer: Copper, Zinc, and Nickel

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept:
In a galvanic or corrosion cell, the direction of spontaneous electron flow is determined by the standard reduction potentials (E°) of the participating metals:

- The metal with the lower (more negative) reduction potential acts as the **Anode** and undergoes oxidation (losing electrons and dissolving into solution).
- The metal with the higher (more positive) reduction potential acts as the **Cathode** and undergoes reduction.

Solution:
Compare the standard reduction potentials for the aluminum-copper galvanic couple:

$$E^\circ_{Al^{3+}/Al} = -1.66\text{ V} \quad \text{and} \quad E^\circ_{Cu^{2+}/Cu} = +0.34\text{ V}$$

- Because aluminum has a significantly more negative reduction potential, it acts as the anode in this acidic electrolyte solution.
- At the anode, metallic aluminum undergoes oxidation, losing electrons and dissolving into the electrolyte as trivalent ions:

$$\text{Anode Reaction (Oxidation): } Al(s) \longrightarrow Al^{3+}(aq) + 3e^-$$

As a result, the aluminum plate corrodes and dissolves over time, while electrons flow through the external circuit to the copper cathode.
The configuration matches Option (B).
Final Answer: Aluminum is oxidized, dissolving into the solution as Al^{3+}(aq) ions

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept:

In an aliphatic hydrocarbon molecule, every single covalent connection represents a σ (sigma) bond. A double bond consists of one σ bond and one π (pi) bond. To find the total number of sigma bonds, sum all carbon-carbon ($C-C$) bonds and all carbon-hydrogen ($C-H$) bonds.

Solution:

Write the structural formula for Penta-1,2-diene (C_5H_8):

$$CH_2 = C = CH - CH_2 - CH_3$$

This molecule is an allene derivative containing two adjacent double bonds. Let us count the individual bonds:

- **Sigma (σ) bonds:**
  - $C - C$ links along the backbone = 4
  - $C - H$ bonds attached to the carbons = 8
  - Total σ bonds = $4 + 8 = 12$
- **Pi (π) bonds:**
  - Each of the two adjacent double bonds contains one π bond.
  - Total π bonds = 2

Thus, a single molecule of penta-1,2-diene contains exactly 12 σ bonds and 2 π bonds.
The configuration matches Option (C).

Final Answer: $\boxed{12\,\sigma \text{ and } 2\,\pi}$

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept:

The hydroboration-oxidation of alkynes is a two-step reaction sequence that results in the net anti-Markovnikov addition of water across a triple bond:

(a) Diborane (B_2H_6) adds across the terminal alkyne bond, placing the boron atom at the less hindered terminal position.

(b) Alkaline hydrogen peroxide (H_2O_2/OH^-) oxidizes the carbon-boron bond to form a temporary enol intermediate, which quickly tautomerizes to its more stable carbonyl form.

Solution:

Follow the reaction steps for Propyne ($CH_3 - C \equiv CH$):

- Hydroboration places the hydroxyl group at the terminal position, forming a terminal enol intermediate:

$$CH_3 - C \equiv CH \xrightarrow{B_2H_6} \xrightarrow{H_2O_2/OH^-} CH_3 - CH = CH\text{-}OH \quad \text{(Prop-1-en-1-ol)}$$

- This unstable terminal enol rapidly undergoes keto-enol tautomerization, shifting a proton to convert the alcohol into a terminal aldehyde:

$$CH_3 - CH = CH\text{-}OH \rightleftharpoons CH_3 - CH_2 - CH = O \quad \text{(Propanal)}$$

In contrast, standard acid-catalyzed hydration (using Hg^{2+}/H^+) follows Markovnikov's rule to produce Propan-2-one (acetone). Thus, the principal product of hydroboration-oxidation is propanal.

The configuration matches Option (B).

Final Answer: Propanal

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept:
Liquefied Petroleum Gas (LPG) is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. It is synthesized during the refining of petroleum crude oil or extracted from natural gas streams, and liquefies under moderate pressure at ambient temperatures.
Solution:
LPG consists primarily of short-chain aliphatic alkanes containing three or four carbon atoms. The principal components are:

- **Propane (C_3H_8):** $\sim 40\% - 50\%$
- **Butane (C_4H_{10}):** $\sim 50\% - 60\%$ (including both n-butane and isobutane)

Methane and ethane are much lighter gases that remain gaseous under these conditions and are the primary components of Compressed Natural Gas (CNG). Therefore, LPG consists primarily of propane and butane.
The configuration matches Option (B).
Final Answer: Propane and Butane

Answer: (B)
Go Back to Question 23

Q24.

Solution

Concept:
Petroleum refining uses several thermal and chemical processes to break down crude fractions:

- Fractional distillation separates hydrocarbon mixtures based on their boiling points without altering their molecular structures.
- Isomerization rearranges straight-chain hydrocarbons into branched isomers to boost octane ratings.
- Catalytic cracking (pyrolysis) breaks long-chain, high-boiling heavy oil fractions into shorter, lower-boiling hydrocarbons using high temperatures and a catalyst (such as a synthetic zeolite).

Solution:
The description explicitly defines a process where heavy, high-boiling oil fractions are broken down into smaller alkanes and alkenes suitable for motor fuels using a zeolite catalyst. This chemical cracking process is called catalytic cracking or pyrolysis.
The configuration matches Option (B).
Final Answer: Catalytic Cracking (Pyrolysis)

Answer: (B)
Go Back to Question 24

Q25.

Solution

Concept:
A copolymer is formed when two different types of monomer units link together in an alternating or random sequence along the polymer chain. The chemical structure of the original monomers can be deduced by breaking the continuous chain at the synthetic boundary linkages and restoring the original unsaturated double bonds.

Solution:
The provided diagram illustrates a repeating polymer chain segment for the synthetic rubber Buna-N. Let us break the structure into its two distinct monomer units:

(a) **Left Monomer Component:** Consists of a four-carbon chain section containing a central double bond:

$$-CH_2 - CH = CH - CH_2-$$

Restoring the outer double bonds reveals that the starting monomer is **Buta-1,3-diene** ($CH_2 = CH - CH = CH_2$).

(b) **Right Monomer Component:** Consists of a two-carbon chain section substituted with a cyano group (-C $\equiv$ N):

$$-CH_2 - CH(C \equiv N)-$$

Restoring the double bond reveals that the starting monomer is **Prop-2-enenitrile** ($CH_2 = CH - C \equiv N$), which is commonly known as Acrylonitrile.

Thus, the two monomers used to synthesize Buna-N are Buta-1,3-diene and Prop-2-enenitrile. The configuration matches Option (C).

Final Answer: Buta-1,3-diene and Prop-2-enenitrile (Acrylonitrile)

Answer: (C)

Go Back to Question 26

Answer Key

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