# Rajasthan JET Chemistry Sample Paper-10

**Duration: 40 Minutes** **Maximum Marks: 160**

## Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 marks**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

**Q1.** An organic compound contains 40% carbon, 6.7% hydrogen, and 53.3% oxygen by mass. If the vapour density of the compound is 30, what is its molecular formula?

(A) CH2O

(B) C2H4O2

(C) C3H6O3

(D) C4H8O4

**Q2.** The work function for a certain metal surface is 4.2 eV. If light of wavelength 200 nm is incident on this metal surface, what will be the maximum kinetic energy of the emitted photoelectrons? (Take hc = 1240 eV-nm)

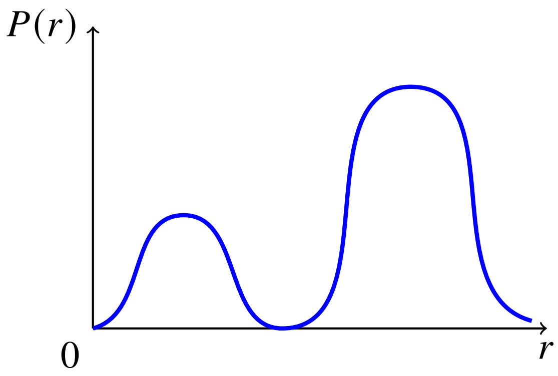
(A) 2.0 eV

(B) 6.2 eV

(C) 8.4 eV

(D) 4.2 eV

**Q3.** Consider the following radial probability distribution curve for an orbital of the hydrogen atom:



(A) 1s

(B) 2s

(C) 2p

(D) 3p

**Q4.** Which of the following elements has the highest negative electron gain enthalpy value?

(A) Fluorine

(B) Chlorine

(C) Bromine

(D) Oxygen

**Q5.** The correct increasing order of ionic radii for the isoelectronic species is:

(A) Ca2+ < K+ < Cl- < S2-

(B) S2- < Cl- < K+ < Ca2+

(C) N3- < O2- < F- < Na+

(D) K+ < Ca2+ < S2- < Cl-

**Q6.** What is the molecular geometry and the number of lone pairs on the central atom in a molecule of ClF3?

(A) Trigonal planar, 0 lone pairs

(B) T-shaped, 2 lone pairs

(C) Trigonal bipyramidal, 1 lone pair

(D) See-saw, 2 lone pairs

**Q7.** According to Molecular Orbital Theory, which of the following species is diamagnetic and has a bond order equal to 3?

(A) O2

(B) N2

(C) O22-

(D) C2

**Q8.** In the balanced chemical reaction: x MnO4- + y C2O42- + z H+ -> x Mn2+ + 2y CO2 + (z/2) H2O The coefficients x, y, and z are respectively:

(A) 2, 5, 16

(B) 5, 2, 16

(C) 2, 5, 8

(D) 1, 5, 8

**Q9.** The oxidation number of sulfur in peroxodisulfuric acid (H2S2O8) is:

(A) +7

(B) +6

(C) +8

(D) +4

**Q10.** For a first-order reaction, the time required for 99.9% completion is approximately how many times the half-life (t1/2) of the reaction?

(A) 2 times

(B) 4 times

(C) 10 times

(D) 100 times

**Q11.** For a reversible gaseous reaction, the relation between the equilibrium constants $K_p$ and $K_c$ is given by $K_p = K_c(RT)^{\Delta n}$. For which of the following reactions is $K_p$ equal to $K_c$?

(A) PCl5(g) <=> PCl3(g) + Cl2(g)

(B) N2(g) + 3H2(g) <=> 2NH3(g)

(C) H2(g) + I2(g) <=> 2HI(g)

(D) 2SO2(g) + O2(g) <=> 2SO3(g)

**Q12.** The specific conductance of a 0.01 M solution of an electrolyte is 0.002 S $\text{cm}^{-1}$. What is its molar conductance ($\Lambda_m$) in S $\text{cm}^2$ $\text{mol}^{-1}$?

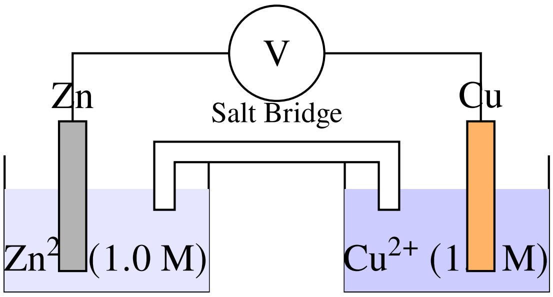
(A) 20

(B) 200

(C) 2000

(D) 0.2

**Q13.** Consider the following galvanic cell diagram representing standard conditions:



If $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76$ V and $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34$ V, what is the standard cell potential ($E^\circ_{\text{cell}}$) measured?

(A) +0.42 V

(B) -1.10 V

(C) +1.10 V

(D) -0.42 V

**Q14.** Which of the following aqueous solutions will exhibit the highest boiling point elevation? (Assume complete dissociation of salts)

(A) 0.1 M Glucose

(B) 0.1 M NaCl

(C) 0.1 M CaCl2

(D) 0.1 M Al2(SO4)3

**Q15.** For a spontaneous process at all temperatures, the thermodynamic conditions that must be satisfied are:

(A) $\Delta H < 0 and \Delta S > 0$

(A) $\Delta H > 0 and \Delta S > 0$

(A) $\Delta H < 0 and \Delta S < 0$

(A) $\Delta H > 0 and \Delta S < 0$

**Q16.** The pH of a buffer solution containing 0.1 M acetic acid ($K_a = 1.8 \times 10^{-5}$) and 0.1 M sodium acetate is approximately:

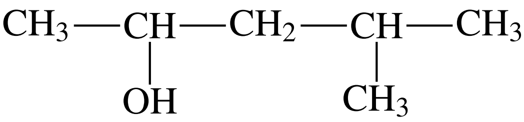
(A) 2.74

(B) 4.74

(C) 7.00

(D) 9.26

**Q17.** According to IUPAC nomenclature rules, what is the correct systematic name of the given compound?



$$CH_3-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$$

(A) 2-Methylpentan-4-ol

(B) 4-Methylpentan-2-ol

(C) 2,4-Dimethylbutan-1-ol

(D) Isohexanol

**Q18.** Which of the following carbocations is the most stable due to maximum hyperconjugation and inductive effect?

(A) +CH3

(B) CH3-+CH2

(C) (CH3)2+CH

(D) (CH3)3+C

**Q19.** When propyne is treated with dilute $H_2SO_4$ in the presence of $Hg^{2+}$ catalyst, the major organic product formed is:

(A) Propanal

(B) Propanone

(C) Propan-1-ol

(D) Propanoic acid

**Q20.** Identify the major product 'X' obtained in the following chemical transformation:

$$CH3 - CH2 - CH(Br) - CH3 + AlcoholicKOH- > [\Delta]'X'(MajorProduct)$$

(A) Butan-2-ol

(B) But-1-ene

(C) trans-But-2-ene

(D) cis-But-2-ene

**Q21.** What is the correct IUPAC name of the coordination compound [Co(NH3)5Cl]Cl2?

(A) Pentamminemonochlorocobalt(II) chloride

(B) Pentamlinechlorocobalt(III) chloride

(C) Pentaamminechloridocobalt(III) chloride

(D) Cobalt(III) pentaaminechloride

**Q22.** The magnetic behavior of $[Ni(CN)_4]^{2-}$ and $[NiCl_4]^{2-}$ complexes are respectively:

(A) Both are paramagnetic

(B) Both are diamagnetic

(C) Paramagnetic and Diamagnetic

(D) Diamagnetic and Paramagnetic

**Q23.** Which type of isomerism is shown by the pair of coordination compounds [Co(NH3)5(SO4)]Br and [Co(NH3)5Br]SO4?

(A) Linkage isomerism

(B) Ionization isomerism

(C) Coordination isomerism

(D) Hydrate isomerism

**Q24.** What is the correct order of field strength of ligands in the spectrochemical series?

(A) $I^- < Cl^- < F^- < H_2O < NH_3 < CN^-$

(B) $CN^- < NH_3 < H_2O < F^- < Cl^- < I^-$

(C) $H_2O < I^- < Cl^- < F^- < CN^- < NH_3$

(D) $F^- < Cl^- < I^- < H_2O < NH_3 < CN^-$

**Q25.** Which component of soil is primarily responsible for its high Cation Exchange Capacity (CEC)?

(A) Quartz sand particles

(B) Organic matter (humus) and silicate clay minerals

(C) Calcium carbonate deposits

(D) Free iron oxides

**Q26.** Which type of soil clay mineral exhibits a 2:1 expanding crystal lattice structure type?

(A) Kaolinite

(B) Montmorillonite

(C) Illite

(D) Gibbsite

**Q27.** The reclamation of alkaline (sodic) soils in agricultural fields is most commonly carried out by adding which of the following soil amendments?

(A) Calcium carbonate (Lime)

(B) Calcium sulfate dihydrate (Gypsum)

(C) Sodium carbonate

(D) Ammonium chloride

**Q28.** Which essential plant nutrient is an integral structural constituent of chlorophyll molecules?

(A) Iron (Fe)

(B) Magnesium (Mg)

(C) Manganese (Mn)

(D) Phosphorus (P)

**Q29.** Which of the following fertilizers is chemically classified as an organic nitrogenous fertilizer?

(A) Ammonium sulfate

(B) Urea

(C) Calcium ammonium nitrate (CAN)

(D) Potassium nitrate

**Q30.** What is the ideal pH range for most agricultural crops to ensure optimal availability of primary plant nutrients in the soil solution?

(A) 4.0 - 5.0

(B) 6.5 - 7.5

(C) 8.5 - 9.5

(D) 3.0 - 4.0

**Q31.** An element has the electronic configuration [Ar] 3d10 4s1. To which group and period of the modern periodic table does it belong?

(A) Group 1, Period 4

(B) Group 11, Period 4

(C) Group 11, Period 3

(D) Group 1, Period 3

**Q32.** How many $\sigma$ and $\pi$ bonds are present in a molecule of benzene?

(A) 6 $\sigma$ and 3 $\pi$

(B) 12 $\sigma$ and 3 $\pi$

(C) 9 $\sigma$ and 3 $\pi$

(D) 12 $\sigma$ and 6 $\pi$

**Q33.** For the reaction mechanism: Step 1: A + B -> C (Slow) Step 2: C + B -> D (Fast) The overall molecularity and rate law for the formation of D are respectively:

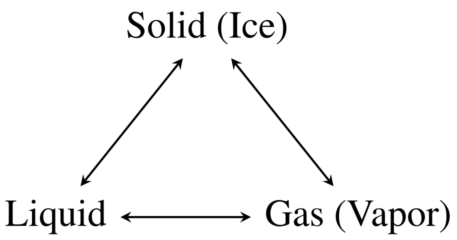
(A) Molecularity = 3, Rate = k[A][B]$^2$

(A) Molecularity = 2, Rate = k[A][B]

(B) Molecularity cannot be defined overall, Rate = k[A][B]

(C) Molecularity cannot be defined overall, Rate = k[A][B][C]

**Q34.** Consider the following phase transition layout of water:



At the triple point of water, the number of degrees of freedom ($F$) calculated using Gibbs Phase Rule ($F = C - P + 2$) is equal to:

(A) 0

(B) 1

(C) 2

(D) 3

**Q35.** The major component of biogas produced during anaerobic digestion of agricultural cattle waste is:

(A) Carbon monoxide

(B) Methane

(C) Hydrogen sulfide

(D) Ethane

**Q36.** Which functional group is characterized by a strong, sharp absorption band around 1700-1750 cm-1 in Infrared (IR) spectroscopy?

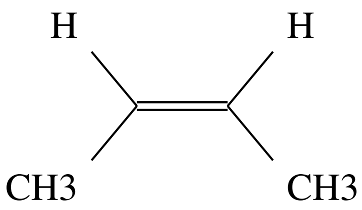
(A) Hydroxyl group (-OH)

(B) Carbonyl group (C=O)

(C) Amino group (-NH2)

(D) Alkyne triple bond (-C$\equiv C-$)

**Q37.** Consider the structure of the given molecule:



This compound is named:

(A) cis-But-2-ene

(B) trans-But-2-ene

(C) But-1-ene

(D) 2-Methylpropene

**Q38.** The concentration of a solute in an aqueous solution is expressed as mass percentage. If 22 g of benzene is dissolved in 122 g of carbon tetrachloride, what is the mass percentage of benzene?

(A) 15.28%

(B) 18.03%

(C) 84.72%

(D) 22.00%

**Q39.** The half-life of a radioactive isotope is 10 days. What fraction of the original sample will remain undecayed after 40 days?

(A) 1/4

(B) 1/8

(C) 1/16

(D) 1/32

**Q40.** Which type of soil micro-organism is mainly responsible for the biological oxidation of ammonia (NH3) to nitrite (NO2-) ions in the nitrification pathway?

(A) Nitrobacter

(B) Nitrosomonas

(C) Azotobacter

(D) Rhizobium

## Detailed Solutions

## Q1.

### Solution

**Concept:**
To find the molecular formula from mass percentages, calculate the empirical formula by converting masses to relative moles. The molecular mass is derived from vapour density using the relation Molecular Mass = 2 × Vapour Density.

**Solution:**

(a) Assume a 100 g sample. The moles of Carbon (C) = $40/12 = 3.33$, Hydrogen (H) = $6.7/1 = 6.7$, and Oxygen (O) = $53.3/16 = 3.33$.

(b) Divide by the smallest value (3.33) to get the simple molar ratio: C = 1, H = 2, O = 1. The empirical formula is $CH_2O$.

(c) The empirical formula mass is $12 + (2 \times 1) + 16 = 30$ g/mol.

(d) The given molecular mass is $2 \times$ Vapour Density $= 2 \times 30 = 60$ g/mol.

(e) The multiplier $n$ = Molecular Mass/Empirical Mass $= 60/30 = 2$. Multiplying the empirical formula by 2 gives $C_2H_4O_2$.

**Final Answer:** The molecular formula is $C_2H_4O_2$.

**Answer: (B)**

Go Back to Question 1

## Q2.

### Solution

**Concept:**
According to Einstein photoelectric equation, the maximum kinetic energy ($\text{KE}_{\text{max}}$) of emitted photoelectrons is given by $\text{KE}_{\text{max}} = E - \phi$, where $E$ is the energy of incident photon and $\phi$ is the work function of the metal surface.

**Solution:**

(a) Find the energy of the incident photon using the formula $E = hc/\lambda$.

(b) Given that $hc = 1240$ eV-nm and wavelength $\lambda = 200$ nm.

(c) Calculate energy $E = 1240/200 = 6.2$ eV.

(d) The work function ($\phi$) of the metal surface is given as 4.2 eV.

(e) Calculate maximum kinetic energy $\text{KE}_{\text{max}} = 6.2 \text{ eV} - 4.2 \text{ eV} = 2.0 \text{ eV}$.

**Final Answer:** The maximum kinetic energy is 2.0 eV.

**Answer: (A)**

Go Back to Question 2

## Q3.

### Solution

**Concept:**
The radial probability distribution function is given by $4\pi r^2 R(r)^2$. The number of radial nodes for any given orbital is determined by the formula Radial Nodes = $n - l - 1$, where $n$ is principal quantum number and $l$ is azimuthal quantum number.

**Solution:**

(a) The radial probability graph touches the zero line at the origin and has intermediate points where the probability drops to zero before the boundary, representing radial nodes.

(b) Looking at the given graph, there is exactly one intermediate point where the curve touches the r-axis between the two peaks, indicating 1 radial node.

(c) Calculate radial nodes for the options: For 1s, $1 - 0 - 1 = 0$; for 2s, $2 - 0 - 1 = 1$; for 2p, $2 - 1 - 1 = 0$; for 3p, $3 - 1 - 1 = 1$.

(d) Both 2s and 3p have 1 radial node. However, p-orbitals have zero probability at the nucleus ($r = 0$), whereas s-orbitals start rising with a finite value in wavefunctions, but the radial distribution function always starts at 0 due to the $r^2$ term.

(e) For a 3p orbital, the first peak is much smaller, and it matches the typical structural distribution shown in standard hydrogenic plots with one small and one large peak.

**Final Answer:** The orbital represented by this graph is 3p.

**Answer: (D)**

Go Back to Question 3

## Q4.

### Solution

**Concept:**
Electron gain enthalpy generally becomes more negative across a period and less negative down a group. However, there is an exception between the second and third-period elements of the same group due to electron-electron repulsion.

**Solution:**

(a) Halogens have highly negative electron gain enthalpies because they achieve a stable noble gas configuration by gaining one single electron.

(b) When comparing Fluorine and Chlorine, Fluorine has a very small atomic size.

(c) The incoming electron experiences significant inter-electronic repulsion within the compact 2p subshell of Fluorine.

(d) Chlorine has a larger 3p subshell, which accommodates the incoming electron easily with much less electron-electron repulsion.

(e) Consequently, energy released is greater for Chlorine, making its electron gain enthalpy value the highest negative among all periodic elements.

**Final Answer:** The element with the highest negative electron gain enthalpy is Chlorine.

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

**Go Back to Question 4**

## Q5.

### Solution

**Concept:**

Isoelectronic species contain the exact same number of total electrons. For these species, the ionic radius decreases as the effective nuclear charge increases because a larger number of protons attracts the same number of electrons more strongly.

**Solution:**

(a) Identify total electrons: $Ca^{2+}$ $(20 - 2 = 18)$, $K^+$ $(19 - 1 = 18)$, $Cl^-$ $(17 + 1 = 18)$, and $S^{2-}$ $(16 + 2 = 18)$. All are isoelectronic.

(b) Count nuclear charges (number of protons): Ca = 20, K = 19, Cl = 17, S = 16.

(c) Higher nuclear charge exerts a stronger pull on electrons, making the ionic size smaller.

(d) Therefore, $Ca^{2+}$ has the smallest radius because it has the maximum protons pulling the 18 electrons.

(e) Arranging from smallest to largest size based on decreasing nuclear charge gives the trend: $Ca^{2+} < K^+ < Cl^- < S^{2-}$.

**Final Answer:** The correct increasing order of ionic radii is $Ca^{2+} < K^+ < Cl^- < S^{2-}$.

**Answer: (A)**

Go Back to Question 5

## Q6.

### Solution

**Concept:**

According to Valence Shell Electron Pair Repulsion (VSEPR) theory, the molecular geometry is determined by calculating the steric number, which is the sum of sigma bonds and lone pairs on the central atom.

**Solution:**

(a) Chlorine (Cl) is the central atom and belongs to group 17, possessing 7 valence electrons.

(b) It forms three single covalent sigma bonds with three Fluorine atoms, consuming 3 valence electrons.

(c) The remaining valence electrons on Chlorine equal $7 - 3 = 4$ electrons, which constitute 2 lone pairs.

(d) The steric number is 3 bond pairs + 2 lone pairs = 5, corresponding to $sp^3d$ hybridization and a trigonal bipyramidal electron geometry.

(e) To minimize lone pair-lone pair repulsions, the 2 lone pairs occupy equatorial positions, distorting the molecular shape into a T-shaped geometry.

**Final Answer:** The molecular geometry is T-shaped with 2 lone pairs.

**Answer: (B)**

**Go Back to Question 6**

## Q7.

### Solution

**Concept:**
Molecular Orbital (MO) Theory determines bond order using the formula Bond Order = $0.5 \times (N_b - N_a)$, where $N_b$ is the number of bonding electrons and $N_a$ is the number of antibonding electrons. Diamagnetic species contain completely paired electrons.
**Solution:**

(a) Nitrogen molecule ($N_2$) has a total of 14 electrons.

(b) The electronic configuration according to MO theory is: $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \pi 2p_x^2 \pi 2p_y^2 \sigma 2p_z^2$.

(c) Number of bonding electrons ($N_b$) = 10, and antibonding electrons ($N_a$) = 4.

(d) Calculate Bond Order = $0.5 \times (10 - 4) = 3$.

(e) Since all molecular orbitals are completely filled and contain no unpaired electrons, $N_2$ is highly diamagnetic.

**Final Answer:** The species is $N_2$.

**Answer: (B)**

Go Back to Question 7

## Q8.

### Solution

**Concept:**
Balancing redox reactions in acidic medium involves tracking oxidation number changes or balancing using the ion-electron half-reaction method, ensuring both mass and charge are conserved on both sides.
**Solution:**

(a) Write the oxidation half-reaction: $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$.

(b) Write the reduction half-reaction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$.

(c) To balance electrons transferred, multiply the oxidation half-reaction by 5 and the reduction half-reaction by 2.

(d) Combining both balanced half-reactions gives: $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$.

(e) Matching coefficients with the given equation gives $x = 2$, $y = 5$, and $z = 16$.

**Final Answer:** The coefficients are 2, 5, and 16.

**Answer: (A)**

Go Back to Question 8

## Q9.

### Solution

**Concept:**
Calculating oxidation states based strictly on chemical structure prevents errors caused by chemical exceptions like peroxide linkages ($O - O$), where oxygen carries an oxidation state of $-1$ instead of $-2$.
**Solution:**

(a) Peroxodisulfuric acid ($H_2S_2O_8$), known as Marshall acid, contains a peroxide bond.

(b) The structural formula shows two oxygen atoms are involved in a peroxide linkage ($O - O$), and the remaining six are normal oxo-oxygen atoms.

(c) Assign oxidation values: Hydrogen is $+1$, peroxide oxygen is $-1$, and oxo-oxygen is $-2$.

(d) Let $x$ be the oxidation number of sulfur: $2(+1) + 2(x) + 6(-2) + 2(-1) = 0$.

(e) Simplify the equation: $2 + 2x - 12 - 2 = 0 \Rightarrow 2x - 12 = 0 \Rightarrow 2x = 12 \Rightarrow x = +6$.

**Final Answer:** The oxidation number of sulfur is +6.

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

Go Back to Question 9

## Q10.

### Solution

**Concept:**
For a first-order chemical reaction, the integrated rate equation is $k = (2.303/t)\log(a/(a - x))$, where $a$ is initial concentration, and $(a - x)$ is the remaining amount at time $t$. The half-life equation is $t_{1/2} = 0.693/k$.
**Solution:**

(a) For 99.9

(b) Substitute into the first-order rate expression: $t_{99.9\%} = (2.303/k)\log(a/10^{-3}a) = (2.303/k)\log(10^3)$.

(c) Simplify using log properties: $t_{99.9\%} = (2.303/k) \times 3 = 6.909/k$.

(d) Express using half-life: Since $t_{1/2} = 0.693/k$, substitute $k = 0.693/t_{1/2}$ into the calculation.

(e) $t_{99.9\%} = 6.909/(0.693/t_{1/2}) \approx 10 \times t_{1/2}$. Thus, it takes 10 times the half-life period.

**Final Answer:** The time required is 10 times the half-life.

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

Go Back to Question 10

## Q11.

### Solution

**Concept:**

The relationship between the equilibrium constants $K_p$ and $K_c$ for a reversible gaseous chemical reaction is given by the equation $K_p = K_c(RT)^{\Delta n_g}$. Here, $\Delta n_g$ represents the change in the number of moles of gaseous products minus the gaseous reactants.

**Solution:**

(a) For $K_p$ to equal $K_c$, the mathematical term $(RT)^{\Delta n_g}$ must be equal to 1, which directly implies that the exponent value $\Delta n_g$ must be exactly equal to zero.

(b) Evaluate each given option by calculating $\Delta n_g = \sum n_{\text{products}} - \sum n_{\text{reactants}}$ for components in the gas phase.

(c) In reaction (A), $\Delta n_g = (1+1) - 1 = 1$. In reaction (B), $\Delta n_g = 2 - (1+3) = -2$. In reaction (D), $\Delta n_g = 2 - (2+1) = -1$.

(d) In reaction (C), which is $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, the number of product gaseous moles is 2 and reactant gaseous moles is $1 + 1 = 2$.

(e) Therefore, calculating for option (C) gives $\Delta n_g = 2 - 2 = 0$. This confirms that $K_p = K_c(RT)^0 = K_c$, which matches the required state.

**Final Answer:** The reaction is $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$.

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

**Go Back to Question 11**

# Q12.

## Solution

**Concept:**
Molar conductance ($\Lambda_m$) represents the conducting power of all the ions produced by dissolving one mole of an electrolyte in a solution. It is mathematically related to specific conductance ($\kappa$) and molarity ($M$) by the equation $\Lambda_m = (\kappa \times 1000)/M$.

**Solution:**

(a) Identify the given parameter values from the problem statement: Specific conductance ($\kappa$) is equal to 0.002 S $\text{cm}^{-1}$.

(b) The molar concentration ($M$) of the electrolytic solution is given as 0.01 M, which means 0.01 mol $\text{L}^{-1}$.

(c) Substitute these values directly into the standard molar conductivity formula: $\Lambda_m = (0.002 \times 1000)/0.01$.

(d) Calculate the numerator value: $0.002 \times 1000 = 2$.

(e) Complete the final division step: $\Lambda_m = 2/0.01 = 200$ S $\text{cm}^2$ $\text{mol}^{-1}$. This calculation determines the correct conductance value.

**Final Answer:** The molar conductance is 200 S $\text{cm}^2$ $\text{mol}^{-1}$.

**Answer: (B)**

**Go Back to Question 12**

# Q13.

## Solution

**Concept:**
The standard cell potential ($E^\circ_{\text{cell}}$) of a galvanic electrochemical cell is an intensive property calculated by subtracting the standard reduction potential of the anode from the standard reduction potential of the cathode: $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$.
**Solution:**

(a) Analyze the given galvanic cell setup diagram to identify the chemical electrodes. Zinc (Zn) acts as the anode where oxidation occurs, and Copper (Cu) acts as the cathode where reduction takes place.

(b) Retrieve the provided standard reduction electrode potentials: $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76$ V and $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34$ V.

(c) Substitute these explicit reduction potentials into the fundamental cell electromotive force equation: $E^\circ_{\text{cell}} = E^\circ(\text{Cu}^{2+}/\text{Cu}) - E^\circ(\text{Zn}^{2+}/\text{Zn})$.

(d) Perform the mathematical calculation: $E^\circ_{\text{cell}} = +0.34\text{ V} - (-0.76\text{ V})$.

(e) Simplifying the double negative sign converts the operation into addition: $0.34 + 0.76 = +1.10$ V. This positive potential indicates a thermodynamically spontaneous chemical process.

**Final Answer:** The standard cell potential is +1.10 V.

**Answer: (C)**

**Go Back to Question 13**

## Q14.

### Solution

**Concept:**

Elevation in boiling point ($\Delta T_b$) is a colligative property that depends entirely on the total concentration of solute particles in the solution. It is expressed by the formula $\Delta T_b = i \times K_b \times m$, where $i$ is the van 't Hoff factor representing particle dissociation.

**Solution:**

(a) Since all solutions have an identical molar concentration (0.1 M), the magnitude of the boiling point elevation depends entirely on the value of the van 't Hoff factor ($i$).

(b) Evaluate $i$ for each substance assuming complete ionic dissociation: Glucose is a non-electrolyte organic molecule, so it does not dissociate, giving $i = 1$.

(c) Sodium chloride (NaCl) dissociates completely into two individual ions ($Na^+$ and $Cl^-$), which results in a value of $i = 2$.

(d) Calcium chloride ($CaCl_2$) dissociates into three individual ions ($Ca^{2+}$ and $2Cl^-$), which results in a value of $i = 3$.

(e) Aluminium sulfate [$Al_2(SO_4)_3$] dissociates completely into five ions ($2Al^{3+}$ and $3SO_4^{2-}$), giving a maximum value of $i = 5$. A higher ion count creates the highest boiling point elevation.

**Final Answer:** The solution with the highest boiling point elevation is 0.1 M $Al_2(SO_4)_3$.

**Answer: (D)**

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# Q15.

## Solution

**Concept:**
The thermodynamic criterion for the absolute spontaneity of a chemical process is governed by the Gibbs Free Energy change equation: $\Delta G = \Delta H - T\Delta S$. For any process to occur spontaneously, $\Delta G$ must be strictly less than zero ($\Delta G < 0$).

**Solution:**

(a) Examine the algebraic mathematical terms in the expression $\Delta G = \Delta H - T\Delta S$, where $T$ represents the absolute temperature measured in Kelvin, which is always a positive value ($T > 0$).

(b) If the enthalpy change is negative ($\Delta H < 0$), the chemical process is exothermic, which thermodynamically favors spontaneity by lowering the energy of the system.

(c) If the entropy change is positive ($\Delta S > 0$), the system undergoes an increase in disorder, which also highly favors a spontaneous process.

(d) Substituting a negative $\Delta H$ and a positive $\Delta S$ into the equation yields: $\Delta G = (\text{Negative}) - T(\text{Positive}) = \text{Negative} - \text{Positive}$.

(e) Because both individual parts result in a negative contribution, $\Delta G$ will remain definitively negative at all possible numerical values of temperature, ensuring unconditional spontaneity.

**Final Answer:** The thermodynamic conditions are $\Delta H < 0$ and $\Delta S > 0$.

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

**Go Back to Question 15**

# Q16.

## Solution

**Concept:**

The pH value of an acidic buffer mixture consisting of a weak acid and its conjugate salt is calculated using the Henderson-Hasselbalch equation: $\mathrm{pH} = \mathrm{pK}_a + \log([\mathrm{Salt}]/[\mathrm{Acid}])$, where $\mathrm{pK}_a = -\log \mathrm{K}_a$.

**Solution:**

(a) Given that the acid dissociation constant ($\mathrm{K}_a$) for acetic acid is equal to $1.8 \times 10^{-5}$, first determine the value of $\mathrm{pK}_a$.

(b) Calculate $\mathrm{pK}_a = -\log(1.8 \times 10^{-5}) = 5 - \log(1.8) \approx 5 - 0.26 = 4.74$.

(c) Identify the molar concentrations provided in the problem: The concentration of weak acid $[\mathrm{Acid}] = 0.1$ M and conjugate salt $[\mathrm{Salt}] = 0.1$ M.

(d) Substitute these exact values into the buffer log ratio term: $\log([\mathrm{Salt}]/[\mathrm{Acid}]) = \log(0.1/0.1) = \log(1)$.

(e) Since the mathematical logarithm of 1 is exactly equal to zero ($\log 1 = 0$), the entire ratio term drops out of the calculation, leaving $\mathrm{pH} = \mathrm{pK}_a = 4.74$.

**Final Answer:** The pH of the buffer solution is 4.74.

**Answer: (B)**

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# Q17.

## Solution

**Concept:**

According to the official IUPAC systematic rules for naming organic chemical compounds, one must first identify the longest continuous carbon chain containing the principal functional group to establish the parent alkane name.

**Solution:**

(a) Analyze the provided structural layout: $CH_3 - CH(OH) - CH_2 - CH(CH_3) - CH_3$. The longest continuous carbon backbone contains a total of five carbon atoms, defining the parent chain as a pentane.

(b) Number the carbon chain to give the principal functional group—the hydroxyl group ($-OH$)—the lowest possible locant number.

(c) Numbering from left-to-right assigns position 2 to the hydroxyl group and position 4 to the methyl substituent group. Numbering right-to-left would give positions 4 and 2 respectively, which violates principal group priority.

(d) Therefore, the numbering follows the left-to-right direction, establishing the locations as 2-ol for the alcohol and 4-methyl for the branch.

(e) Combine these parts alphabetically into a single systematic name: 4-Methylpentan-2-ol.

**Final Answer:** The systematic name is 4-Methylpentan-2-ol.

**Answer: (B)**

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## Q18.

### Solution

**Concept:**
The relative stability of alkyl carbocations is determined by the electron-donating effects of adjacent groups, which help disperse the positive charge. This stabilizing mechanism occurs through inductive effects and hyperconjugation involving adjacent $\alpha$-hydrogen atoms.

**Solution:**

(a) Evaluate the structural features of each carbocation option to count the number of stabilizing $\alpha$-hydrogen atoms available for hyperconjugation.

(b) The methyl carbocation ($^+CH_3$) has zero adjacent carbons, resulting in 0 $\alpha$-hydrogens and making it highly unstable.

(c) The ethyl carbocation ($CH_3 -^+ CH_2$) is a primary carbocation containing a single adjacent methyl group, providing exactly 3 $\alpha$-hydrogens.

(d) The isopropyl carbocation $[(CH_3)_2^+CH]$ is a secondary carbocation with two attached methyl groups, providing a total of 6 stabilizing $\alpha$-hydrogens.

(e) The tert-butyl carbocation $[(CH_3)_3^+C]$ is a tertiary carbocation bound to three distinct methyl groups. This configuration provides 9 $\alpha$-hydrogens along with $+I$ inductive stabilization, making it the most stable.

**Final Answer:** The most stable carbocation is $(CH_3)_3^+C$.

**Answer: (D)**

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# Q19.

## Solution

**Concept:**

The catalytic hydration of alkynes using dilute sulfuric acid and a mercuric sulfate ($HgSO_4$) catalyst is known as Kucherov's reaction. This chemical transformation follows Markovnikov's rule for electrophilic addition, yielding an unstable enol intermediate that undergoes rapid tautomerism.

**Solution:**

(a) The starting material is propyne ($CH_3 - C \equiv CH$). The addition of a water molecule ($H - OH$) takes place across the carbon-carbon triple bond.

(b) According to Markovnikov's rule, the electrophilic hydrogen atom adds to the terminal alkyne carbon, which has more hydrogens, while the nucleophilic hydroxyl group ($-OH$) attaches to the internal carbonyl carbon.

(c) This regioselective addition produces an intermediate enol structure: $CH_3 - C(OH) = CH_2$, known as prop-1-en-2-ol.

(d) Enols are unstable structures that quickly undergo keto-enol tautomerism, involving a migration of the proton and shifting of the double bond.

(e) The hydrogen shifts from the oxygen to the terminal carbon, converting the enol into a stable carbonyl compound, propanone ($CH_3 - CO - CH_3$), commonly known as acetone.

**Final Answer:** The major organic product formed is Propanone.

**Answer: (B)**

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# Q20.

## Solution

**Concept:**
The chemical reaction of an alkyl halide with hot alcoholic potassium hydroxide (KOH) undergoes a dehydrohalogenation elimination process via an E2 pathway. The regiochemical distribution of alkene products is governed by Saytzeff's rule.

**Solution:**

(a) The substrate is 2-bromobutane: $CH_3 - CH_2 - CH(Br) - CH_3$. The elimination requires removing the bromine atom along with a hydrogen atom from an adjacent $\beta$-carbon.

(b) Identify the two distinct types of $\beta$-carbons available: The terminal carbon-1 ($CH_3$) and the internal carbon-3 ($CH_2$).

(c) Eliminating a hydrogen from carbon-1 yields the monosubstituted alkene product, but-1-ene, which has less thermodynamic stability.

(d) Eliminating a hydrogen from carbon-3 yields a disubstituted alkene, but-2-ene. According to Saytzeff's rule, the more highly substituted alkene is the major product due to greater hyperconjugation stability.

(e) But-2-ene exists as geometric isomers. The trans-but-2-ene isomer has lower steric hindrance and lower energy than cis-but-2-ene, making trans-but-2-ene the primary major product.

**Final Answer:** The major product is trans-But-2-ene.

**Answer: (C)**

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## Q21.

### Solution

**Concept:**
The IUPAC rules for naming coordination compounds require naming the ligands in alphabetical order before the central metal atom. Anionic ligands end in "o" or "ido", neutral ligands retain their names with exceptions like ammine for $NH_3$, and the oxidation state of the metal is denoted by a Roman numeral in parentheses.

**Solution:**

(a) Identify the coordination sphere and counter-ions in the given complex formula: $[Co(NH_3)_5Cl]Cl_2$. The complex cation is inside the square brackets, and two chloride anions balance the overall charge outside.

(b) Determine the ligands present within the coordination sphere: There are five neutral ammine ($NH_3$) molecules and one anionic chlorido ($Cl^-$) ligand.

(c) Arrange the ligands alphabetically to construct the prefix: Five ammines are labeled as "pentaammine" and one chloride as "chlorido", yielding "pentaamminechlorido".

(d) Determine the oxidation state of the central cobalt (Co) atom: Let $x$ be the oxidation state. The equation is $x + 5(0) + 1(-1) + 2(-1) = 0$, which simplifies to $x - 3 = 0$, giving $x = +3$.

(e) Combine the components into the final systematic name: Pentaamminechloridocobalt(III) chloride.

**Final Answer:** The systematic name is Pentaamminechloridocobalt(III) chloride.

**Answer: (C)**

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## Q22.

### Solution

**Concept:**
The magnetic behavior of coordination complexes depends on the electronic configuration of the central metal atom and the field strength of the surrounding ligands, as explained by Crystal Field Theory (CFT) and Valence Bond Theory (VBT). Strong-field ligands cause electron pairing, while weak-field ligands do not.

**Solution:**

(a) Identify the oxidation state and electronic configuration of Nickel (Ni) in both complex ions: In both $[Ni(CN)_4]^{2-}$ and $[NiCl_4]^{2-}$, Nickel exists in the +2 oxidation state with a $3d^8$ valence configuration.

(b) Analyze the ligand field strength for $[Ni(CN)_4]^{2-}$: Cyanide ($CN^-$) is a strong-field ligand that creates a large crystal field splitting energy, forcing the eight d-electrons to pair up completely in the lower energy orbitals.

(c) Since all electrons are paired up in $[Ni(CN)_4]^{2-}$, the complex exhibits a square planar geometry and is diamagnetic.

(d) Analyze the ligand field strength for $[NiCl_4]^{2-}$: Chloride ($Cl^-$) is a weak-field ligand that creates a small crystal field splitting energy, which is insufficient to force electron pairing.

(e) Consequently, the eight d-electrons are distributed according to Hund's rule, leaving two unpaired electrons. This results in a tetrahedral geometry and paramagnetic behavior.

**Final Answer:** The complexes are Diamagnetic and Paramagnetic respectively.

**Answer: (D)**

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## Q23.

### Solution

**Concept:**

Ionization isomerism occurs when coordination compounds with the same empirical formula release different ions into solution upon dissolution. This happens because a ligand inside the coordination sphere switches places with a counter-ion outside the sphere.

**Solution:**

(a) Examine the two given complex formulas: $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5Br]SO_4$. Both contain identical chemical constituent parts but differ in which ion is directly bound to the metal.

(b) Dissolve the first complex, $[Co(NH_3)_5(SO_4)]Br$, in water. It dissociates to produce a $[Co(NH_3)_5(SO_4)]^+$ complex cation and a free bromide ($Br^-$) counter-anion.

(c) Dissolve the second complex, $[Co(NH_3)_5Br]SO_4$, in water. It dissociates to produce a $[Co(NH_3)_5Br]^{2+}$ complex cation and a free sulfate ($SO_4^{2-}$) counter-anion.

(d) Test the solutions with chemical reagents: The first solution yields a pale yellow precipitate with silver nitrate ($AgNO_3$), while the second yields a white precipitate with barium chloride ($BaCl_2$).

(e) Since these two coordination compounds provide entirely different ions in aqueous media despite sharing the same total formula, they are classified as ionization isomers.

**Final Answer:** The pair exhibits Ionization isomerism.

**Answer: (B)**

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# Q24.

## Solution

**Concept:**
The spectrochemical series is an empirically derived sequence that ranks chemical ligands based on their crystal field splitting energy ($\Delta$) values. Ligands that produce a small splitting energy are termed weak-field ligands, whereas those that produce a large splitting energy are strong-field ligands.

**Solution:**

(a) The splitting ability of ligands generally correlates with the donor atom type, following the donor order: Halogens < Oxygen donors < Nitrogen donors < Carbon donors.

(b) Halide ions are at the weak-field end of the series. Among the halogens, field strength increases as ionic radius decreases, establishing the order: $I^- < Cl^- < Br^- < F^-$.

(c) Oxygen-donor ligands like water ($H_2O$) exert a stronger field than halide ions but a weaker field than nitrogen-donor species.

(d) Nitrogen-donor ligands like ammonia ($NH_3$) produce significantly higher splitting energy values, making them strong-field ligands in most transition metal complexes.

(e) Carbon-donor ligands like cyanide ($CN^-$) and carbon monoxide (CO) produce the highest crystal field splitting due to strong metal-ligand back-bonding capabilities, placing them at the highest end of the spectrochemical series.

**Final Answer:** The correct order is $I^- < Cl^- < F^- < H_2O < NH_3 < CN^-$.

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

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# Q25.

## Solution

**Concept:**

Cation Exchange Capacity (CEC) is a fundamental chemical measure of a soil's ability to retain and exchange mineral cations. It is determined by the total quantity of negative electrical charges present on the surfaces of soil colloidal particles.

**Solution:**

(a) Soil colloidal fractions consist primarily of fine silicate clay mineral particles and highly decomposed organic fractions known as humus.

(b) Humus particles carry abundant active functional groups, such as carboxyl ($-COOH$) and phenolic ($-OH$) groups, which deprotonate under typical agricultural pH conditions to generate high negative surface charges.

(c) Silicate clay minerals, such as montmorillonite and vermiculite, possess a high negative surface charge resulting from isomorphic substitution within their crystalline lattices.

(d) Sand and silt fractions consist mostly of inert quartz grains, which have negligible surface area and almost zero surface charge contribution.

(e) Therefore, the combination of organic matter (humus) and silicate clay minerals provides the negative surface charge density required to yield high Cation Exchange Capacity values in productive agricultural soils.

**Final Answer:** The components are Organic matter (humus) and silicate clay minerals.

**Answer: (B)**

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## Q26.

### Solution

**Concept:**

Silicate clay minerals are classified structurally based on the arrangement of tetrahedral silica sheets and octahedral alumina sheets. A 2:1 clay mineral features one octahedral sheet sandwiched between two tetrahedral sheets. Expanding lattices allow water molecules and ions to enter the interlayer space.

**Solution:**

(a) Evaluate Kaolinite: It is a 1:1 type aluminosilicate clay mineral consisting of alternating single tetrahedral and octahedral sheets held tightly together by hydrogen bonds, preventing expansion.

(b) Evaluate Illite: It is a non-expanding 2:1 silicate clay mineral where the interlayer spaces are securely locked by potassium cations ($K^+$), which prevents swelling or expansion.

(c) Evaluate Montmorillonite: It belongs to the smectite group and features a 2:1 structural layer arrangement. The internal layers are held together weakly by van der Waals forces.

(d) This weak interlayer bonding allows water molecules and hydrated ions to easily penetrate the interlayer spaces, causing significant swelling and expansion when wet.

(e) Consequently, montmorillonite displays a prominent 2:1 expanding crystal lattice structure type, which is responsible for the shrink-swell behavior observed in black cotton soils.

**Final Answer:** The clay mineral is Montmorillonite.

**Answer: (B)**

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# Q27.

## Solution

**Concept:**

Alkaline or sodic soils contain high concentrations of exchangeable sodium cations ($Na^+$), which cause soil particle dispersion, poor structural stability, and restricted water permeability. Reclamation requires replacing exchangeable sodium ions with calcium ions ($Ca^{2+}$).

**Solution:**

(a) Adding calcium carbonate (lime) is ineffective for alkaline soil reclamation because lime is insoluble at high soil pH levels; it is used instead to raise the pH of acidic soils.

(b) Gypsum, chemically known as calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$), is a moderately soluble mineral salt that serves as an excellent source of calcium ions.

(c) When gypsum is mixed into sodic soils, it dissolves to release soluble calcium cations into the soil solution: $CaSO_4 \rightleftharpoons Ca^{2+} + SO_4^{2-}$.

(d) The divalent calcium cations ($Ca^{2+}$) displace the monovalent sodium cations ($Na^+$) from the soil exchange complex via cation exchange processes.

(e) The displaced sodium ions react with the remaining sulfate ions to form soluble sodium sulfate ($Na_2SO_4$), which can then be leached out of the root zone by irrigation.

**Final Answer:** The amendment added is Calcium sulfate dihydrate (Gypsum).

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

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## Q28.

### Solution

**Concept:**
Essential plant nutrients play specific biochemical and structural roles in plant metabolism. A nutrient is considered a structural constituent if it is incorporated directly into the molecular framework of an essential organic compound or cell component.

**Solution:**

(a) Examine the chemical structure of a chlorophyll molecule: It features a complex porphyrin ring structure connected to a long phytol tail.

(b) At the center of this porphyrin ring system sits a single metal atom coordinated to four surrounding nitrogen atoms, which stabilizes the electronic configuration required for light absorption.

(c) This central coordinating metal atom is Magnesium ($Mg^{2+}$). Without sufficient magnesium, plants cannot synthesize chlorophyll, leading to interveinal chlorosis.

(d) Iron (Fe) is essential for chlorophyll biosynthesis as a catalyst in the enzymatic pathway, but it is not built into the final molecular structure of chlorophyll.

(e) Manganese (Mn) is involved in the photolysis of water during photosynthesis, while phosphorus (P) is a structural component of nucleic acids and ATP.

**Final Answer:** The essential plant nutrient is Magnesium (Mg).

**Answer: (B)**

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## Q29.

### Solution

**Concept:**
Chemical fertilizers are classified based on the chemical nature of the compounds that deliver essential macronutrients. An organic fertilizer contains carbon atoms covalently bonded within its molecular structure, matching the conventions of organic chemistry.

**Solution:**

(a) Evaluate Ammonium sulfate [$(NH_4)_2SO_4$] and Calcium ammonium nitrate: Both are purely inorganic mineral salts composed of ammonium and sulfate or nitrate ions, lacking carbon-hydrogen chains or organic carbon covalent bonds.

(b) Evaluate Potassium nitrate ($KNO_3$): It is an inorganic salt that supplies both potassium and nitrogen.

(c) Evaluate Urea: The chemical formula for urea is $CO(NH_2)_2$. It features an organic carbonyl group covalently bonded to two amino groups.

(d) Although urea is synthesized industrially from inorganic carbon dioxide and ammonia, it is structurally identical to the organic waste compound excreted by mammals and classified as an organic nitrogenous fertilizer.

(e) Once applied to soil, urea undergoes enzymatic hydrolysis via the urease enzyme to release plant-available ammonium ions.

**Final Answer:** The organic nitrogenous fertilizer is Urea.

**Answer: (B)**

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## Q30.

### Solution

**Concept:**

Soil pH governs the solubility, chemical form, and availability of primary plant nutrients (N, P, K) in the soil solution. Extreme pH values induce nutrient fixation reactions or toxicities that restrict plant growth.

**Solution:**

(a) In strongly acidic soils ($pH < 5.5$), phosphorus combines with aluminum and iron to form insoluble compounds, while essential base cations ($Ca^{2+}$, $Mg^{2+}$) leach out of the root zone.

(b) In alkaline soils ($pH > 8.0$), phosphorus precipitates with calcium ions to form insoluble calcium phosphates, and micronutrients like iron, manganese, and zinc become largely unavailable.

(c) A neutral to slightly acidic pH range of 6.5 to 7.5 balances these competing chemical reactions.

(d) Within this intermediate range, microbial activity for nitrogen mineralization peaks, and phosphorus remains in its most soluble ionic forms ($H_2PO_4^-$ and $HPO_4^{2-}$).

(e) Consequently, a pH range of 6.5 to 7.5 ensures optimal availability of primary and secondary nutrients for the majority of agricultural crops.

**Final Answer:** The ideal pH range is 6.5 - 7.5.

**Answer: (B)**

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# Q31.

## Solution

**Concept:**
The position of an element in the modern periodic table is determined directly by its ground-state electronic configuration. The principal quantum number ($n$) of the outermost valence shell specifies its period, while the distribution of electrons within the outermost s, p, or d subshells defines its specific group.

**Solution:**

(a) Given the full electronic configuration: [Ar] $3d^{10}\,4s^{1}$. The highest principal quantum number containing electrons is $n = 4$, which places the element in Period 4.

(b) Look closely at the subshell filling sequence: The 3d subshell is completely filled with 10 electrons, and the outermost 4s orbital has a single electron. This represents Copper (Cu).

(c) For d-block elements, the specific group number is calculated using the formula: Group Number $=$ Number of electrons in $(n-1)$d subshell $+$ Number of electrons in $n$s subshell.

(d) Substitute the electronic values into the equation: Group Number $= 10 + 1 = 11$.

(e) This means the element is located in Group 11 and Period 4 of the periodic table, representing a transition metal belonging to the coinage metal family.

**Final Answer:** The element belongs to Group 11, Period 4.

**Answer: (B)**

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## Q32.

### Solution

**Concept:**

A single covalent bond consists of exactly one sigma ($\sigma$) bond. A double covalent bond contains one sigma ($\sigma$) bond and one pi ($\pi$) bond. The total molecular structure must be evaluated to count every individual atomic overlap accurately.

**Solution:**

(a) Examine the molecular framework of benzene ($C_6H_6$), which forms a planar, cyclic hexagonal ring containing six carbon atoms.

(b) Count the localized single bonds: There are six individual carbon-hydrogen ($C-H$) single covalent bonds around the ring perimeter. Each of these counts as 1 sigma bond, contributing a total of $6\,\sigma$ bonds.

(c) Analyze the internal cyclic ring bonds: The six carbon atoms are joined by alternating single and double bonds ($C-C$ and $C=C$).

(d) This includes three single $C-C$ links ($3\,\sigma$ bonds) and three double $C=C$ links (where each contains $1\,\sigma$ and $1\,\pi$ bond, giving $3\,\sigma$ and $3\,\pi$ bonds).

(e) Sum the values together: Total $\sigma$ bonds $= 6$ (from $C-H$) $+ 3$ (from $C-C$) $+ 3$ (from $C=C$) $= 12\,\sigma$. Total $\pi$ bonds $= 3\,\pi$.

**Final Answer:** There are $12\,\sigma$ and $3\,\pi$ bonds present.

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

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# Q33.

## Solution

**Concept:**

The rate law of a multi-step chemical reaction is determined entirely by its slowest elementary step, known as the rate-determining step. Molecularity represents the number of reacting molecules colliding in an individual elementary step and cannot be defined as a single value for an overall complex reaction.

**Solution:**

(a) Examine the given mechanism: Step 1 is $A + B \rightarrow C$ (Slow), and Step 2 is $C + B \rightarrow D$ (Fast).

(b) Because Step 1 is the slow, rate-determining step, the overall rate law matches this step exactly, giving the expression: $\text{Rate} = k[A][B]$.

(c) Count the reactant molecules colliding in this specific rate-determining step: One molecule of A reacts with one molecule of B, making Step 1 bimolecular.

(d) However, molecularity is a theoretical concept that applies strictly to individual elementary steps. For a multi-step reaction mechanism, an "overall molecularity" cannot be defined because multiple distinct collisions occur in sequence.

(e) Therefore, the overall molecularity cannot be defined, and the correct rate law expression is $\text{Rate} = k[A][B]$.

**Final Answer:** Molecularity cannot be defined overall, Rate = k[A][B].

**Answer: (C)**

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## Q34.

### Solution

**Concept:**
Gibbs Phase Rule describes the degrees of freedom ($F$) available in a chemical system at thermodynamic equilibrium using the equation: $F = C - P + 2$. Here, $C$ represents the number of independent chemical components, and $P$ represents the number of coexisting phases.

**Solution:**

(a) Identify the number of independent chemical components ($C$) for the water system layout. Since the system consists exclusively of $H_2O$ across all states, the component value is $C = 1$.

(b) Identify the number of coexisting phases ($P$) present at the specific triple point of water. At this unique condition, solid ice, liquid water, and gaseous water vapor coexist simultaneously in dynamic equilibrium.

(c) This simultaneous coexistence means the number of phases present is exactly $P = 3$.

(d) Substitute these defined parameters into the phase rule equation: $F = 1 - 3 + 2$.

(e) Perform the arithmetic calculation: $F = -2 + 2 = 0$. A value of zero indicates that the system is invariant, meaning the triple point can only exist at one specific temperature and pressure.

**Final Answer:** The number of degrees of freedom is 0.

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

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## Q35.

### Solution

**Concept:**
Biogas is generated through the anaerobic digestion of organic matter, such as agricultural cattle waste, by methanogenic bacterial populations. This biochemical breakdown converts complex organic carbon polymers into simple gaseous molecules.

**Solution:**

(a) Anaerobic digestion occurs in a completely oxygen-free environment and proceeds through four successive metabolic stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

(b) During the final methanogenesis phase, specialized anaerobic archaea break down acetic acid, hydrogen, and carbon dioxide into simpler gases.

(c) This process yields a mixed gas composition containing methane ($CH_4$), carbon dioxide ($CO_2$), and trace amounts of hydrogen sulfide ($H_2S$), moisture, and siloxanes.

(d) Methane gas typically makes up 50% to 75% of the total volume of biogas produced, making it the primary fuel source.

(e) Carbon dioxide constitutes the remaining 25% to 50%, while toxic components like hydrogen sulfide are restricted to very low concentrations.

**Final Answer:** The major component of biogas is Methane.

**Answer: (B)**

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# Q36.

## Solution

**Concept:**

Infrared (IR) spectroscopy measures the vibrational transitions of covalent bonds when exposed to infrared radiation. The specific wavenumber ($cm^{-1}$) where an absorption band appears depends on the bond strength and the reduced mass of the vibrating atoms.

**Solution:**

(a) Evaluate hydroxyl groups ($-OH$): They produce a very broad, strong absorption band spanning 3200–3600 $cm^{-1}$ due to intermolecular hydrogen bonding.

(b) Evaluate amino groups ($-NH_2$): They exhibit moderate absorption stretching peaks located between 3300 and 3500 $cm^{-1}$.

(c) Evaluate alkyne triple bonds ($-C \equiv C-$): They show a weak, sharp stretching vibration found in the range of 2100–2250 $cm^{-1}$.

(d) Evaluate carbonyl groups ($C = O$): The carbon-oxygen double bond possesses a high dipole moment and strong bond stiffness.

(e) This combination produces a highly characteristic, intense, and sharp absorption band centered between 1700 and 1750 $cm^{-1}$, which is used to identify aldehydes, ketones, and carboxylic acids.

**Final Answer:** The functional group is the Carbonyl group (C=O).

**Answer: (B)**

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# Q37.

## Solution

**Concept:**

Geometric isomerism occurs in alkenes due to the restricted rotation around the carbon-carbon double bond ($C = C$). If identical substituent groups are positioned on the same side of the double bond, the molecule is designated as the cis-isomer.

**Solution:**

(a) Identify the longest continuous carbon chain containing the double bond to determine the parent alkane name: The chain contains four carbon atoms, so the parent name is butene.

(b) Number the carbon chain from the end closest to the double bond: $C_1 - C_2 = C_3 - C_4$. The double bond starts at position 2, defining the IUPAC base name as but-2-ene.

(c) Examine the spatial arrangement of the substituent groups attached to the double-bonded carbons.

(d) Both hydrogen atoms ($-H$) point upward on the same side of the double bond, and both methyl groups ($-CH_3$) point downward on the opposite side.

(e) Because the identical methyl groups are oriented on the same side of the rigid double-bond plane, the compound is identified as the cis-isomer, making its full name cis-but-2-ene.

**Final Answer:** This compound is named cis-But-2-ene.

**Answer: (A)**

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# Q38.

## Solution

**Concept:**
The concentration of a component in a solution expressed as a mass percentage defines the mass of that specific solute present per 100 parts of total solution mass. It is calculated using the formula: Mass % = (Mass of Solute/Total Mass of Solution) × 100.

**Solution:**

(a) Identify the independent components given in the problem statement: The mass of the solute, benzene ($C_6H_6$), is equal to 22 g.

(b) The mass of the solvent, carbon tetrachloride ($CCl_4$), is given as 122 g.

(c) Calculate the total mass of the resulting binary solution by adding the mass of the solute and the solvent together: Total Mass = 22 g + 122 g = 144 g.

(d) Substitute these values into the mass percentage formula: Mass % of Benzene = $(22/144) \times 100$.

(e) Perform the final calculation: $22/144 = 0.15277$. Multiplying by 100 gives 15.28%.

**Final Answer:** The mass percentage of benzene is 15.28

**Answer: (A)**

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## Q39.

### Solution

**Concept:**

Radioactive decay follows first-order kinetics. The remaining fraction of an isotope after a given time can be calculated by determining the number of elapsed half-lives ($n$) using the expression: Remaining Fraction = $(1/2)^n$, where $n$ = Total Time/Half-life.

**Solution:**

(a) Identify the parameters provided in the problem statement: The half-life ($t_{1/2}$) of the radioactive isotope is 10 days, and the total decay period is 40 days.

(b) Calculate the total number of half-life cycles ($n$) that occur during this timeframe: $n = 40/10 = 4$ cycles.

(c) Track the step-by-step decay: After 10 days (1 half-life), 1/2 of the sample remains. After 20 days (2 half-lives), 1/4 remains. After 30 days (3 half-lives), 1/8 remains.

(d) After 40 days (4 half-lives), the remaining fraction is calculated as: $(1/2)^4 = 1/16$.

(e) Therefore, exactly 1/16 of the original radioactive material remains undecayed.

**Final Answer:** The fraction remaining undecayed is 1/16.

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

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# Q40.

## Solution

**Concept:**

Nitrification is a two-step aerobic biochemical pathway driven by specialized soil chemoautotrophic bacteria. This process converts reduced environmental nitrogen in the form of ammonia into oxidized nitrate ions.

**Solution:**

(a) The first step of the nitrification pathway involves the biological oxidation of ammonia ($NH_3$) or ammonium ions ($NH_4^+$) into nitrite ions ($NO_2^-$).

(b) This rate-limiting step is carried out by ammonia-oxidizing bacteria, primarily belonging to the genus Nitrosomonas.

(c) The second step involves the further oxidation of the toxic nitrite ions ($NO_2^-$) into plant-available nitrate ions ($NO_3^-$), which is carried out by nitrite-oxidizing bacteria like Nitrobacter.

(d) Evaluate the remaining options: Azotobacter is a genus of free-living, heterotrophic bacteria that fix atmospheric nitrogen gas into ammonium.

(e) Rhizobium is a group of symbiotic bacteria that form nodules on legume roots to fix nitrogen, making Nitrosomonas the correct organism for the ammonia-to-nitrite oxidation step.

**Final Answer:** The soil micro-organism is Nitrosomonas.

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

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## Answer Key

| Q | Ans | Q | Ans | Q | Ans | Q | Ans | Q | Ans |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 2 | A | 3 | D | 4 | B | 5 | A |
| 6 | B | 7 | B | 8 | A | 9 | B | 10 | C |
| 11 | C | 12 | B | 13 | C | 14 | D | 15 | A |
| 16 | B | 17 | B | 18 | D | 19 | B | 20 | C |
| 21 | C | 22 | D | 23 | B | 24 | A | 25 | B |
| 26 | B | 27 | B | 28 | B | 29 | B | 30 | B |
| 31 | B | 32 | B | 33 | C | 34 | A | 35 | B |
| 36 | B | 37 | A | 38 | A | 39 | C | 40 | B |