NIOS Class 12 Chemistry Sample Paper – 2

Duration: 180 Minutes **Maximum Marks: 80**

Instructions

- This paper contains **43** Questions. The paper is divided into two sections: **Section A – 40** marks, **Section B – 40** marks.
- **Section A** consists of
  - **Q.No. 1 to 16** – Multiple Choice type questions (MCQs) carrying 1 mark each. Select and write the most appropriate option out of the four options given in each of these questions. An internal choice has been provided in some of these questions. You have to attempt only one of the given choices in such questions.
  - **Q. No. 17 to 28** – Objective type questions. Q. No. 17 to 28 carry 02 marks each (with 2 sub- parts of 1 mark each). Attempt these questions as per the instructions given for each of the questions 17 –28.
- **Section B** consists of
  - **Q.No. 29 to 37** – Very Short questions carrying 02 marks each to be answered in the range of 30 to 50 words.
  - **Q.No. 38 to 41** – Short Answer type questions carrying 03 marks each to be answered in the range of 50 to 80 words.
  - **Q.No. 42 and 43** – Long Answer type questions carrying 05 marks each to be answered in the range of 80 to 120 words.
- There is **No Negative marking**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section: A

Q1. Which of the following sets of quantum numbers is **not** possible for an electron in an atom? **(1)**

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

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

(C) $n = 4,\ l = 1,\ m_l = 0,\ s = +\frac{1}{2}$

(D) $n = 3,\ l = 0,\ m_l = 0,\ s = -\frac{1}{2}$

Q2. The mass percentage of carbon in ethanol (C_2H_5OH) is:

(Atomic masses: C = 12, H = 1, O = 16) **(1)**

(A) 52.17%

(B) 26.09%

(C) 34.78%

(D) 42.00%

Q3. The electronic configuration of Mn^{2+} (atomic number of Mn = 25) is: **(1)**

(A) $[Ar]\,3d^5$

(B) $[Ar]\,3d^4\,4s^1$

(C) $[Ar]\,3d^6$

(D) $[Ar]\,3d^3\,4s^2$

Q4. The number of sigma (σ) and pi (π) bonds in ethene (C_2H_4) are respectively: **(1)**

(A) 5 σ and 1 π

(B) 4 σ and 2 π

(C) 6 σ and 0 π

(D) 3 σ and 2 π

Q5. According to VSEPR theory, the molecular shape of SF_4 (sulphur tetrafluoride) is: **(1)**

(A) Tetrahedral

(B) See-saw

(C) Square planar

(D) Trigonal bipyramidal

Q6. According to Henry's law, the solubility of a gas in a liquid at a given temperature is: **(1)**

(A) Directly proportional to the temperature of the solution

(B) Directly proportional to the partial pressure of the gas above the liquid

(C) Inversely proportional to the partial pressure of the gas above the liquid

(D) Independent of the nature of the gas and the solvent

Q7. According to Hess's law of constant heat summation, the enthalpy change of a chemical reaction depends on: **(1)**

(A) The number of intermediate steps involved

(B) The initial and final states of the system only

(C) The rate at which the reaction proceeds

(D) The specific pathway followed from reactants to products

Q8. Given the standard reduction potentials $E^\circ(\mathrm{Zn^{2+}/Zn}) = -0.76$ V and $E^\circ(\mathrm{Cu^{2+}/Cu}) = +0.34$ V, the standard EMF of the cell $\mathrm{Zn}\,|\,\mathrm{Zn^{2+}}\,||\,\mathrm{Cu^{2+}}\,|\,\mathrm{Cu}$ is: **(1)**

(A) +1.10 V

(B) −1.10 V

(C) +0.42 V

(D) −0.42 V

Q9. For a reaction A → Products, if the rate law is given by Rate $= k[\mathrm{A}]^{1/2}$, the overall order of the reaction is: **(1)**

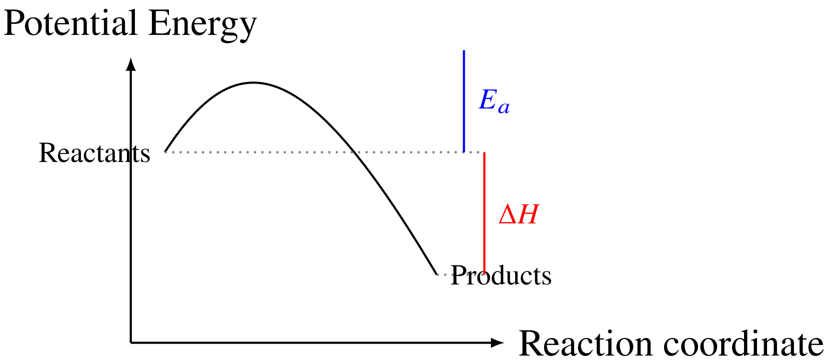
(A) 0

(B) $\frac{1}{2}$

(C) 1

(D) 2

Q10. The potential energy profile for a reaction is shown below: **(1)**



Based on the diagram, which of the following statements is correct?

(A) The products have higher energy than the reactants, and $\Delta H gt; 0$.

(B) The reaction is endothermic and the activation energy is positive.

(C) The reaction is exothermic; the products have lower energy than reactants and $\Delta H lt; 0$.

(D) The activation energy is equal in magnitude to the enthalpy change.

Q11. Boron shows anomalous behaviour compared to other group 13 elements mainly because of its: **(1)**

(A) Very small atomic size and high electronegativity

(B) Presence of vacant *d*-orbitals in the valence shell

(C) Lower ionisation enthalpy compared to aluminium

(D) Tendency to form only ionic bonds

Q12. The IUPAC name of the complex $[Co(NH_3)_5Cl]Cl_2$ is: **(1)**

(A) Pentaamminechloridocobalt(III) chloride

(B) Chloridopentaamminecobalt(III) chloride

(C) Pentaamminechloridocobalt(II) chloride

(D) Pentaamminecobalt(III) dichloride

Q13. The reaction of *tert*-butyl bromide ($(CH_3)_3CBr$) with aqueous NaOH proceeds predominantly by: **(1)**

(A) S_N2 mechanism

(B) S_N1 mechanism

(C) Electrophilic addition

(D) Free radical substitution

Q14. Which of the following compounds gives a positive test with Fehling's solution? **(1)**

(A) Acetone (CH_3COCH_3)

(B) Benzaldehyde (C_6H_5CHO)

(C) Acetaldehyde (CH_3CHO)

(D) Diethyl ketone ($CH_3CH_2COCH_2CH_3$)

Q15. The type of linkage that connects two adjacent nucleotides in a nucleic acid strand is: **(1)**

(A) Glycosidic linkage

(B) Peptide linkage

(C) Phosphodiester linkage

(D) Ester linkage

Q16. Which of the following is commonly used as an analgesic (pain-relieving drug)? **(1)**

(A) Phenacetin

(B) Paracetamol

(C) Chloramphenicol

(D) Bithionol

Note: Q. No. 17 to 28 are the objective type questions of 2 marks each.

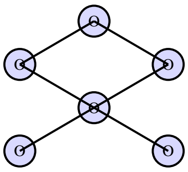
Q17. Complete the following by using the options given below:

(molality, molarity, mole fraction, osmotic pressure) **(2)**

1. The concentration term whose value does not change with temperature is
2. The pressure that must be applied to a solution to prevent the inward flow of solvent across a semipermeable membrane is called ....

Q18. Read the passage given below and answer the following questions:

Water (H_2O) has an unusually high boiling point compared to H_2S, H_2Se, and H_2Te. This is because oxygen is highly electronegative and small in size, which leads to strong intermolecular hydrogen bonding. In ice, the water molecules are arranged in a cage-like open structure due to extensive hydrogen bonding. **(2)**



Hexagonal arrangement in ice

1. Why does ice have a lower density than liquid water?
2. Name the type of intermolecular force responsible for the high boiling point of water.

Q19. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: **(2)**

1. According to Faraday's first law of electrolysis, the mass of a substance deposited at an electrode is directly proportional to the quantity of electric charge passed through the electrolyte.
2. The molar conductivity of a strong electrolyte decreases with decrease in concentration.

Q20. Complete the following by using the options given below:

(limiting reagent, mass per cent, significant figures, molecular mass) **(2)**

1. The reactant that gets completely consumed first in a chemical reaction and determines the maximum amount of product formed is called the ....

2. The digits in a measured quantity that are known with certainty plus one uncertain digit are known as ....

Q21. Complete the following by using the options given below:

(amphoteric nature, variable oxidation states, paramagnetism, interstitial compounds) **(2)**

1. Zinc oxide reacts with both dilute acids and alkalis. This behaviour is an example of its ....
2. Transition metals exhibit different oxidation states mainly because of the involvement of both .... in bonding.

Q22. Read the passage given below and answer the following questions:

Food preservatives prevent the spoilage of food from microorganisms such as bacteria and fungi. Sodium benzoate and sodium metabisulphite are widely used preservatives in food industry. Antioxidants such as BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene) are added to foods containing fats and oils to prevent rancidity by slowing down oxidation. **(2)**

1. Why are antioxidants added to foods containing fats and oils?
2. Name one artificial sweetener that is used as a sugar substitute in caloric-control diets.

Q23. Read the passage given below and answer the following questions:

Transition metals and many of their compounds are often coloured, paramagnetic, and catalytically active. The colour of transition metal ions arises from *d*-*d* transitions of electrons within the partially filled *d*-subshell. For example, Cu^{2+} compounds appear blue, Fe^{2+} compounds appear green, and MnO_4^- is deep purple in colour. **(2)**

1. Why are compounds of Zn^{2+} typically colourless?

2. Give one reason why transition metals and their compounds often act as good catalysts.

Q24. Match the items given in Column I with the most appropriate items in Column II: **(2)**

Column I	amp; **Column II**
(a) Reimer–Tiemann reaction	amp; (i) Aldehydes without α-hydrogen
(b) Wurtz reaction	amp; (ii) Phenol to salicylaldehyde
(c) Friedel–Crafts acylation	amp; (iii) Alkyl halides to higher alkanes
(d) Cannizzaro reaction	amp; (iv) Aromatic compounds with acid chloride

Q25. Complete the following reaction equations: **(2)**

1. $CH_3CH_2Br + KOH_{(alc)} \xrightarrow{\Delta}$
2. $C_6H_5OH + CHCl_3 + NaOH \longrightarrow +NaCl + H_2O$

Q26. Read the passage given below and answer the following questions:

When a non-volatile solute is dissolved in a volatile solvent, the number of solvent molecules at the surface decreases. As a result, fewer solvent molecules escape into the vapour phase, causing the vapour pressure of the solution to be lower than that of the pure solvent. This lowering of vapour pressure leads to elevation of boiling point and depression of freezing point. **(2)**

1. Why does the addition of a non-volatile solute lower the vapour pressure of the solvent?
2. State Raoult's law for a solution containing a non-volatile solute.

Q27. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: **(2)**

1. Addition of a catalyst changes the value of the equilibrium constant of a reaction.
2. For a zero-order reaction, the half-life is directly proportional to the initial concentration of the reactant.

Q28. Read the passage given below and answer the questions given below:

Carbohydrates are broadly classified as reducing and non-reducing sugars. Reducing sugars possess a free aldehyde or a free ketone group and can reduce reagents such as Tollens' reagent or Fehling's solution. Sucrose is a non-reducing sugar because the aldehyde group of glucose and the ketone group of fructose are involved in the formation of the glycosidic bond. Disaccharides can be hydrolysed to give their constituent monosaccharides. **(2)**

1. Why is sucrose classified as a non-reducing sugar?
2. Name the two monosaccharides obtained on hydrolysis of lactose.

Section: B

Q29. (i) Define the following:

(a) Raoult's law (b) Ideal solution

OR

(ii) Define the following: (a) Henry's law (b) van't Hoff factor **(2)**

Q30. (i) Derive the relationship between C_p and C_v for an ideal gas.

OR

(ii) State and explain Hess's law of constant heat summation with a suitable example. **(2)**

Q31. (i) Calculate the EMF of the cell:

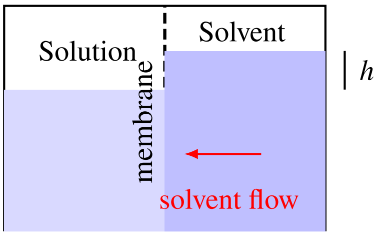
$\mathrm{Mg}\,|\,\mathrm{Mg}^{2+}(0.01\,\mathrm{M})\,||\,\mathrm{Cu}^{2+}(0.1\,\mathrm{M})\,|\,\mathrm{Cu}$

Given: $E^\circ(\mathrm{Mg}^{2+}/\mathrm{Mg}) = -2.37$ V, $E^\circ(\mathrm{Cu}^{2+}/\mathrm{Cu}) = +0.34$ V

OR

(ii) Calculate the degree of dissociation (α) of acetic acid ($K_a = 1.8 \times 10^{-5}$) in its 0.1 M aqueous solution. **(2)**

Q32. (i) The setup shown below illustrates the phenomenon of osmosis.



(a) Define osmotic pressure. (b) Why is the solvent level on the solution side higher at equilibrium?

OR

(ii) Calculate the osmotic pressure of a 0.1 M glucose solution at 27°C.

(Given: $R = 0.0821$ L atm K^{-1} mol^{-1}) **(2)**

Q33. (i) Explain why the +3 oxidation state becomes more stable than the +5 oxidation state as we move down group 15 of the periodic table.

OR

(ii) Draw the structure of PCl_5 in the gaseous state and explain why it is trigonal bipyramidal. Why does PCl_5 decompose on heating? **(2)**

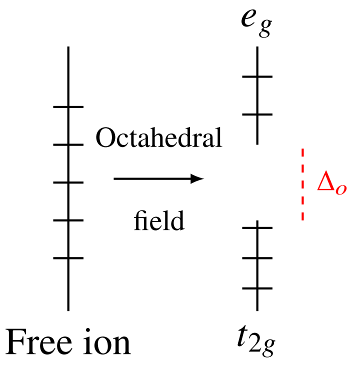
Q34. (i) Define the following terms:

(a) Specific conductance

(b) Molar conductance

How does the molar conductance of a strong electrolyte vary with dilution? **(2)**

Q35. (i) The diagram below shows the splitting of d-orbitals in an octahedral crystal field:



(a) Name the two sets of orbitals formed in the octahedral crystal field splitting.

(b) Write the d-electron configuration of Fe^{3+} ($Z = 26$) in an octahedral field for (i) a weak-field ligand and (ii) a strong-field ligand.

OR

(ii) (a) What is the difference between Δ_o and Δ_t?

(b) Explain why Cu^{2+} ($3d^9$) is coloured in aqueous solution while Cu^+ ($3d^{10}$) is colourless. **(2)**

Q36. How would you convert the following?

(a) Phenol to benzene

(b) Methanol to ethanoic acid **(2)**

Q37. (i) State Faraday's first law of electrolysis.

(ii) Calculate the mass of silver (atomic mass = 108) deposited at the cathode when a current of 2 A is passed through a silver nitrate solution for 30 minutes. (Given: $1\ F = 96500$ C) **(2)**

Q38. (i) Answer the following:

(a) Write the IUPAC name of $K_3[Fe(C_2O_4)_3]$.

(b) What type of isomerism is exhibited by the complex $[Co(NH_3)_5(NO_2)]^{2+}$?

(c) Why is $[NiCl_4]^{2-}$ paramagnetic but $[Ni(CN)_4]^{2-}$ diamagnetic?

OR

(ii) Explain the hybridisation, geometry and magnetic behaviour of the complex $[CoF_6]^{3-}$ on the basis of valence bond theory. (Atomic number of Co = 27) **(3)**

Q39. (i) Calculate the mass of NaCl (molar mass = 58.5 g mol^{-1}) that must be dissolved in 200 g of water so that it freezes at −4°C. Assume complete dissociation of NaCl.

(Given: K_f for water = 1.86 K kg mol^{-1})

OR

(ii) (a) What are secondary (rechargeable) cells? Give one example.

(b) Why is the fuel cell considered more efficient than a thermal power plant? **(3)**

Q40. (i) Write the chemical equations and conditions for the following named reactions:

(a) Wolff–Kishner reduction

(b) Aldol condensation

(c) Kolbe's reaction **(3)**

Q41. (i) Explain the following:

(a) Why do amino acids show amphoteric behaviour?

(b) What is the difference between the α-helix and β-pleated sheet structures of proteins?

(c) Name the nitrogenous bases present in DNA but not in RNA.

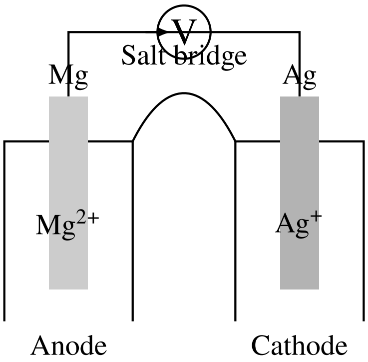
OR

(ii) (a) Write the structure of the product when aniline is treated with bromine water at room temperature.

(b) Arrange the following in order of increasing basicity in aqueous solution: CH_3NH_2, $(CH_3)_2NH$, $(CH_3)_3N$

(c) Why is aniline less basic than cyclohexylamine? **(3)**

Q42. (i) The electrochemical cell shown below operates spontaneously:



(a) Write the half-reactions at the anode and cathode.

(b) Explain any two properties of transition metals: (1) formation of coloured ions, (2) catalytic activity.

(c) What is meant by lanthanoid contraction? State one of its consequences.

OR

(ii) (a) Write the general electronic configuration of *d*-block elements.

(b) Explain why Sc^{3+} is colourless but Ti^{3+} is coloured in aqueous solution. (Sc = 21, Ti = 22)

(c) What are interstitial compounds? State any two of their characteristic properties. **(5)**

Q43. (i) Answer the following:

(a) Write the product of the following reaction (Schiemann reaction):

$C_6H_5N_2^+BF_4^- \xrightarrow{\Delta}$

(b) Explain:

(1) Why does chlorobenzene not undergo nucleophilic substitution reactions readily?

(2) What is the action of HNO_2 on primary aliphatic amines?

(c) Write the IUPAC name of CH_3-$CH(OH)$-CH_2-CHO.

OR

(ii) (a) What are enzymes? Name one enzyme that converts glucose into ethanol and carbon dioxide.

(b) Differentiate between S_N1 and S_N2 reactions on the basis of:

(1) Molecularity

(2) Stereochemical outcome

(c) Write the products of:

(1) $CH_3CH_2OH + PCl_3 \rightarrow$

(2) $C_6H_5O^-Na^+ + CO_2 \xrightarrow[\text{heat}]{\text{pressure}} \xrightarrow{H^+}$ **(5)**

Detailed Solutions

Q1.

Solution

Concept: The four quantum numbers describe the state of an electron: n (principal), l (azimuthal), m_l (magnetic), and s (spin). The rules are: l ranges from 0 to $n-1$, m_l ranges from $-l$ to $+l$, and $s = \pm\frac{1}{2}$.

Step 1 — Check each set against the quantum number rules.
Step 2 — For option (B): $n = 2, l = 2$. But the maximum value of l is $n - 1 = 1$. Since $l = 2$ is not allowed when $n = 2$, this set is **not possible**.
Step 3 — Verify the others:

- (A) $n = 3, l = 2, m_l = -2, s = +\frac{1}{2}$: Valid ($l \leq 2$, $m_l \in \{-2, \ldots, +2\}$).
- (C) $n = 4, l = 1, m_l = 0, s = +\frac{1}{2}$: Valid.
- (D) $n = 3, l = 0, m_l = 0, s = -\frac{1}{2}$: Valid.

Final Answer: $n = 2,\ l = 2$ is not possible (Option B)

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: Mass percentage of an element in a compound is calculated as:

$$\text{Mass \%} = \text{Total mass of the element in one mole}\,\overline{\text{Molar mass of the compound}\times 100}$$

Step 1 — Ethanol has the molecular formula $C_2H_5OH = C_2H_6O$.

Step 2 — Molar mass of ethanol:

$$M = 2(12) + 6(1) + 16 = 24 + 6 + 16 = 46 \ \text{g mol}^{-1}$$

Step 3 — Mass of carbon in one mole:

$$\text{Mass of C} = 2 \times 12 = 24 \text{ g}$$

Step 4 — Mass percentage of carbon:

$$24\,\overline{46\times 100 = 52.17\%}$$

Why other options are wrong:

- **Option B (26.09%):** This is half the correct value, likely from dividing by 92.
- **Option C (34.78%):** This corresponds to an incorrect formula.
- **Option D (42.00%):** Does not match the correct calculation.

Final Answer: 52.17% (Option A)

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

Go Back to Question 2

Q3.

Solution

Concept: When electrons are removed to form a cation, they are removed from the outermost shell first (highest n), then from inner shells.

Step 1 — Electronic configuration of Mn ($Z = 25$):

[Ar] $3d^5\ 4s^2$

Step 2 — To form Mn^{2+}, remove 2 electrons from the outermost shell ($4s$):

Mn^{2+} : [Ar] $3d^5$

Step 3 — The $3d^5$ configuration is half-filled and extra stable.

Why other options are wrong:

- **Option B:** Electrons are not removed from $4s$ and promoted to $3d$.
- **Option C:** This would be Fe^{2+}, not Mn^{2+}.
- **Option D:** This would be V^{2+}, not Mn^{2+}.

Final Answer: [Ar] $3d^5$ (Option A)

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: A single bond consists of one σ bond, a double bond consists of one σ and one π bond, and a triple bond consists of one σ and two π bonds.

Step 1 — Structure of ethene: $H_2C{=}CH_2$
Step 2 — Count the bonds:

- C=C: $1\ \sigma + 1\ \pi$
- Four C−H bonds: $4\ \sigma$

Step 3 — Total: σ bonds = $1 + 4 = 5$; π bonds = 1.
Final Answer: $5\ \sigma$ and $1\ \pi$ (Option A)

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: VSEPR theory predicts molecular geometry based on the number of bond pairs and lone pairs around the central atom.

Step 1 — In SF_4, sulphur has 6 valence electrons. Four are used in bonding with fluorine atoms, leaving one lone pair. So there are 4 bond pairs and 1 lone pair.
Step 2 — Total electron pairs = 5 $\Rightarrow$ electron geometry is trigonal bipyramidal. With one lone pair occupying an equatorial position, the molecular shape becomes **see-saw**.
Step 3 — The lone pair occupies an equatorial position to minimise lone-pair–bond-pair repulsions.
Why other options are wrong:

- **Option A:** Tetrahedral requires 4 bond pairs and 0 lone pairs.
- **Option C:** Square planar requires 4 bond pairs and 2 lone pairs.
- **Option D:** Trigonal bipyramidal is the electron geometry, not the molecular shape.

Final Answer: See-saw (Option B)

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: Henry's law states that at a constant temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid.

Step 1 — Mathematically: $p = K_H \cdot x$, where p is partial pressure, K_H is Henry's constant, and x is the mole fraction of the dissolved gas.
Step 2 — As the partial pressure increases, more gas dissolves in the liquid, so solubility increases proportionally.
Step 3 — This law applies well to dilute solutions and low pressures.
Final Answer: Directly proportional to the partial pressure of the gas (Option B)

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: Hess's law states that the total enthalpy change for a reaction is the same whether the reaction occurs in one step or multiple steps. It is a consequence of enthalpy being a state function.

Step 1 — Since enthalpy is a state function, ΔH depends only on the initial state (reactants) and the final state (products).
Step 2 — The number of steps, the rate, or the specific pathway taken does not affect ΔH.
Step 3 — Therefore, according to Hess's law, the enthalpy change depends only on the initial and final states.
Final Answer: The initial and final states of the system only (Option B)

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The standard EMF of a galvanic cell is calculated as:

$$\mathrm{E}^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

where the cathode is the electrode where reduction occurs (higher reduction potential) and the anode is where oxidation occurs.

Step 1 — In the given cell, Zn is oxidised (anode) and $\mathrm{Cu^{2+}}$ is reduced (cathode):

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

$$\mathrm{E}^\circ_{\text{anode}} = E^\circ(\mathrm{Zn^{2+}/Zn}) = -0.76\ \mathrm{V}$$

Step 2 — Calculate:

$$\mathrm{E}^\circ_{\text{cell}} = 0.34 - (-0.76) = 0.34 + 0.76 = +1.10\ \mathrm{V}$$

Step 3 — The positive EMF confirms that the cell reaction is spontaneous.
Final Answer: +1.10 V (Option A)

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: The overall order of a reaction is the sum of the exponents of the concentration terms in the rate law expression.

Step 1 — The given rate law is:

Rate = $k[A]^{1/2}$

Step 2 — The exponent of $[A]$ is $\frac{1}{2}$. Since there is only one reactant, the overall order is simply $\frac{1}{2}$.
Step 3 — Fractional-order reactions are not uncommon; they often indicate a complex multi-step mechanism.
Final Answer: $\frac{1}{2}$ (Option B)

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: In a potential energy profile, the vertical difference between reactants and products gives the enthalpy change (ΔH). If products are lower in energy, the reaction is exothermic ($\Delta H < 0$); if higher, it is endothermic ($\Delta H > 0$).

Step 1 — From the diagram, reactants are at a higher energy level and products are at a lower energy level.
Step 2 — Therefore, $\Delta H = E_{\text{products}} - E_{\text{reactants}} < 0$, meaning the reaction is exothermic.
Step 3 — The activation energy E_a is the energy difference between the reactants and the peak (transition state), which is positive.
Step 4 — Evaluate the options: Option (C) correctly states that the reaction is exothermic with products at lower energy and $\Delta H < 0$.
Why other options are wrong:

- **Option A:** Products are at lower energy, not higher.
- **Option B:** The reaction is exothermic, not endothermic.
- **Option D:** $E_a \neq \Delta H$; they measure different energy differences.

Final Answer: The reaction is exothermic; $\Delta H < 0$ (Option C)

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept: The first element of a group often shows anomalous behaviour due to its exceptionally small size, high ionisation enthalpy, high electronegativity, and absence of d-orbitals.

Step 1 — Boron, the first element of group 13, has very small atomic size and high electronegativity compared to aluminium and heavier members.
Step 2 — These factors cause boron to form predominantly covalent compounds, have a higher ionisation enthalpy, and behave as a metalloid rather than a typical metal.
Step 3 — The absence of d-orbitals limits its maximum covalency to 4, unlike aluminium which can expand further.
Final Answer: Very small atomic size and high electronegativity (Option A)

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: IUPAC naming of coordination compounds: list ligands alphabetically, then the metal with its oxidation state in Roman numerals, then the counter ion.

Step 1 — The complex ion is $[Co(NH_3)_5Cl]^{2+}$. The ligands are: NH_3 (ammine, 5) and Cl^- (chlorido, 1). Alphabetically: ammine before chlorido.
Step 2 — Oxidation state of Co: $x + 5(0) + (-1) = +2 \Rightarrow x = +3$. So cobalt is in the +3 state.
Step 3 — Name: Pentaamminechloridocobalt(III), followed by the counter ion *chloride* (2 chloride ions outside the sphere).
Final Answer: Pentaamminechloridocobalt(III) chloride (Option A)

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: Tertiary alkyl halides preferentially undergo S_N1 reactions because they form relatively stable tertiary carbocations. Steric hindrance prevents back-side attack required for S_N2.

Step 1 — *tert*-Butyl bromide $(CH_3)_3CBr$ is a tertiary alkyl halide. The carbon bonded to bromine is surrounded by three methyl groups.
Step 2 — The bulky methyl groups create steric hindrance that blocks the back-side attack of the nucleophile (OH^-), ruling out S_N2.
Step 3 — Instead, the C−Br bond breaks first to form the stable tertiary carbocation $(CH_3)_3C^+$, which is then attacked by OH^-. This is the S_N1 pathway.
Final Answer: S_N1 mechanism (Option B)

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: Fehling's solution (alkaline Cu^{2+} with tartrate) is reduced by *aliphatic* aldehydes to give a red precipitate of Cu_2O. Aromatic aldehydes and ketones do not give this test.

Step 1 — Acetaldehyde (CH_3CHO) is an aliphatic aldehyde with a free aldehyde group that can be easily oxidised. It gives a positive Fehling's test.
Step 2 — Benzaldehyde (C_6H_5CHO) is an aromatic aldehyde. Due to resonance stabilisation, it does **not** reduce Fehling's solution under normal conditions.
Step 3 — Acetone and diethyl ketone are ketones; they are not oxidised by Fehling's solution.
Final Answer: Acetaldehyde (CH_3CHO) (Option C)

Answer: (C)

Go Back to Question 14

Q15.

Solution

Concept: In nucleic acids (DNA and RNA), adjacent nucleotides are linked by phosphodiester bonds formed between the $3'$-OH of one sugar and the $5'$-phosphate of the next.

Step 1 — A nucleotide consists of a nitrogenous base, a pentose sugar, and a phosphate group.
Step 2 — The phosphate group forms two ester bonds — one with the $3'$ carbon of one sugar and another with the $5'$ carbon of the adjacent sugar — creating a phosphodiester linkage.
Step 3 — This creates the sugar-phosphate backbone of the nucleic acid strand.
Why other options are wrong:

- **Option A:** Glycosidic linkage connects the base to the sugar, not two nucleotides.
- **Option B:** Peptide linkage is found in proteins.
- **Option D:** A simple ester linkage does not describe the internucleotide bond.

Final Answer: Phosphodiester linkage (Option C)

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept: Analgesics are drugs that relieve pain without causing loss of consciousness. They are classified as non-narcotic (e.g., aspirin, paracetamol) and narcotic (e.g., morphine).

Step 1 — Paracetamol (acetaminophen) is a widely used non-narcotic analgesic and antipyretic.
Step 2 — Chloramphenicol is an antibiotic; bithionol is an antiseptic; phenacetin was formerly used but is largely withdrawn due to side effects.
Step 3 — Therefore, paracetamol is the correct answer.
Final Answer: Paracetamol (Option B)

Answer: (B)

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Q17.

Solution

Concept: Concentration terms such as molarity depend on volume (which changes with temperature), while molality, mole fraction, and osmotic pressure-based definitions involve different dependencies.

Step 1 — Part (a): Molality is defined as moles of solute per kilogram of solvent. Since mass does not change with temperature, molality is temperature-independent.
Step 2 — Part (b): Osmotic pressure is the pressure that must be applied to a solution to prevent the net flow of solvent through a semipermeable membrane.
Step 3 — Therefore: (a) molality; (b) osmotic pressure.
Final Answer: (a) molality; (b) osmotic pressure

Answer: (See above)

Go Back to Question 17

Q18.

Solution

Concept: In ice, water molecules form an open hexagonal lattice held together by hydrogen bonds. This structure has large empty spaces, making ice less dense than liquid water.

Step 1 — Part (a): In ice, each water molecule is hydrogen-bonded to four neighbours in a tetrahedral arrangement, creating an open hexagonal structure with significant empty space. When ice melts, the structure collapses partially and molecules pack more closely, so liquid water is denser than ice.
Step 2 — Part (b): The strong intermolecular force responsible for the high boiling point of water is **hydrogen bonding**. Oxygen's high electronegativity and small size allow it to form strong hydrogen bonds with hydrogen atoms of neighbouring molecules.
Final Answer: (a) Open hexagonal structure with empty spaces; (b) Hydrogen bonding

Answer: (See above)

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Q19.

Solution

Concept: Faraday's first law relates mass deposited to charge passed. Molar conductivity of strong electrolytes increases with dilution because interionic attractions decrease.

Step 1 — Statement 1: This is a correct statement of Faraday's first law: $m \propto Q$, i.e., mass deposited is directly proportional to charge. So this is **TRUE**.
Step 2 — Statement 2: For a strong electrolyte, molar conductivity *increases* with dilution (decrease in concentration) because the ions move farther apart and interionic attractions weaken. So the statement is **FALSE**.
Final Answer: (1) TRUE; (2) FALSE

Answer: (See above)

Go Back to Question 19

Q20.

Solution

Concept: In stoichiometry, the limiting reagent determines the maximum product. Significant figures indicate the precision of a measurement.

Step 1 — Part (a): The reactant that is completely consumed first, limiting the amount of product, is the *limiting reagent*.
Step 2 — Part (b): The certain digits plus one uncertain digit in a measurement are called *significant figures*.
Final Answer: (a) limiting reagent; (b) significant figures

Answer: (See above)

Go Back to Question 20

Q21.

Solution

Concept: Amphoteric oxides react with both acids and bases. Transition metals show variable oxidation states because both ns and $(n-1)d$ electrons participate in bonding.

Step 1 — Part (a): ZnO reacts with HCl to give $ZnCl_2$ and with NaOH to give Na_2ZnO_2. This dual behaviour is called *amphoteric nature*.
Step 2 — Part (b): Transition metals show variable oxidation states because the energy difference between ns and $(n-1)d$ orbitals is small, allowing both to participate in bonding.
Final Answer: (a) amphoteric nature; (b) involvement of ns and $(n-1)d$ electrons

Answer: (See above)

Go Back to Question 21

Q22.

Solution

Concept: Antioxidants prevent oxidation of fats and oils. Artificial sweeteners provide sweetness without significant caloric intake.

Step 1 — Part (a): Antioxidants are added to fatty foods because they prevent or slow down the oxidation of fats and oils, which would otherwise lead to rancidity (unpleasant smell and taste).
Step 2 — Part (b): Aspartame, saccharin, or sucralose are examples of artificial sweeteners used in caloric-control diets.
Final Answer: (a) To prevent rancidity; (b) Aspartame/Saccharin/Sucralose

Answer: (See above)

Go Back to Question 22

Q23.

Solution

Concept: The colour of transition metal ions depends on partially filled d-orbitals. Catalysts work by providing alternative reaction pathways.

Step 1 — Part (a): Zn^{2+} has the configuration $[\mathrm{Ar}]\,3d^{10}$. Since all d-orbitals are completely filled, no d-d transitions are possible. Hence, Zn^{2+} compounds are colourless.
Step 2 — Part (b): Transition metals act as good catalysts because: (i) they have variable oxidation states that allow them to form intermediates, and (ii) they provide a suitable surface for adsorption of reactants.
Final Answer: (a) d^{10} – no d-d transitions; (b) Variable oxidation states / surface activity

Answer: (See above)

Go Back to Question 23

Q24.

Solution

Concept: Name reactions in organic chemistry are identified by their specific reagents and products.

Step 1 — Reimer–Tiemann reaction converts phenol to salicylaldehyde using $CHCl_3$ and NaOH. So (a) matches (ii).
Step 2 — Wurtz reaction couples two alkyl halides with sodium metal to form a higher alkane. So (b) matches (iii). Friedel–Crafts acylation introduces an acyl group onto an aromatic ring using an acid chloride and $AlCl_3$. So (c) matches (iv). Cannizzaro reaction occurs in aldehydes lacking α-hydrogens, giving disproportionation products. So (d) matches (i).
Final Answer: (a)-(ii), (b)-(iii), (c)-(iv), (d)-(i)

Answer: (See above)

Go Back to Question 24

Q25.

Solution

Concept: Alcoholic KOH causes dehydrohalogenation (elimination), while the Reimer–Tiemann reaction formylates phenol at the ortho position.

Step 1 — Part (a): CH_3CH_2Br with alcoholic KOH undergoes β-elimination (dehydrohalogenation):

$$\mathrm{CH_3}CH_2Br + KOH_{(alc)} \xrightarrow{\Delta} CH_2{=}CH_2 + KBr + H_2O$$

The product is ethene.

Step 2 — Part (b): Phenol with $CHCl_3$ and NaOH undergoes the Reimer–Tiemann reaction. The dichlorocarbene intermediate attacks the ortho position:

$$\mathrm{C_6}H_5OH + CHCl_3 + NaOH \rightarrow 2\text{-}HOC_6H_4CHO + NaCl + H_2O$$

The product is salicylaldehyde (2-hydroxybenzaldehyde).

Final Answer: (a) Ethene ($CH_2{=}CH_2$); (b) Salicylaldehyde

Answer: (See above)

Go Back to Question 25

Q26.

Solution

Concept: When a non-volatile solute is added, it occupies some surface sites, reducing the number of solvent molecules that can escape into the vapour phase.

Step 1 — Part (a): The non-volatile solute particles at the surface reduce the effective surface area available for solvent evaporation. Fewer solvent molecules escape per unit time, so the vapour pressure decreases.
Step 2 — Part (b): Raoult's law for a solution with a non-volatile solute states: The relative lowering of vapour pressure is equal to the mole fraction of the solute.

$$\mathrm{p}^{\circ} - p\,\frac{}{p^{\circ}=x_{\text{solute}}}$$

where p° is the vapour pressure of the pure solvent and p is the vapour pressure of the solution.
Final Answer: (a) Solute reduces solvent molecules at surface; (b) $\frac{p^{\circ}-p}{p^{\circ}} = x_{\text{solute}}$

Answer: (See above)

Go Back to Question 26

Q27.

Solution

Concept: A catalyst speeds up both forward and reverse reactions equally, so it does not change the equilibrium constant. For a zero-order reaction, $t_{1/2} = [A]_0/(2k)$.

Step 1 — Statement 1: A catalyst lowers the activation energy of both the forward and reverse reactions by the same amount. Since K_{eq} depends on the energy difference between products and reactants (which the catalyst does not change), K_{eq} remains unchanged. So this is **FALSE**.
Step 2 — Statement 2: For a zero-order reaction, $t_{1/2} = \frac{[A]_0}{2k}$, which is directly proportional to $[A]_0$. So this is **TRUE**.
Final Answer: (1) FALSE; (2) TRUE

Answer: (See above)

Go Back to Question 27

Q28.

Solution

Concept: A reducing sugar must have a free aldehyde or ketone group. In non-reducing sugars, these groups are involved in the glycosidic bond.

Step 1 — Part (a): In sucrose, the glycosidic bond is formed between the anomeric carbon (C-1) of α-glucose and the anomeric carbon (C-2) of β-fructose. Both the reducing groups are involved in the bond, so neither free aldehyde nor free ketone group is available. Hence, sucrose is non-reducing.

Step 2 — Part (b): Lactose is a disaccharide composed of β-D-galactose and β-D-glucose linked by a $\beta(1 \rightarrow 4)$ glycosidic bond. Hydrolysis yields **D-galactose** and **D-glucose**.

Final Answer: (a) Both reducing groups involved in glycosidic bond; (b) D-Galactose and D-Glucose

$\boxed{\textbf{Answer: (See above)}}$

Go Back to Question 28

Q29.

Solution

Concept: Raoult's law relates vapour pressure of a solution to mole fraction of components. Henry's law relates gas solubility to partial pressure.

Step 1 — Alternative (i):

(a) **Raoult's law:** For a solution of volatile liquids, the partial vapour pressure of each component is directly proportional to its mole fraction in the solution: $p_i = p_i^\circ \cdot x_i$.

(b) **Ideal solution:** A solution that obeys Raoult's law over the entire range of concentrations. In an ideal solution, intermolecular forces between solute–solute, solvent–solvent, and solute–solvent are nearly equal, so $\Delta H_{\text{mix}} = 0$ and $\Delta V_{\text{mix}} = 0$.

Step 2 — Alternative (ii):

(a) **Henry's law:** At constant temperature, the partial pressure of a gas in vapour phase is directly proportional to its mole fraction in the solution: $p = K_H \cdot x$.

(b) **van't Hoff factor (i):** The ratio of the observed colligative property to the calculated colligative property (assuming no dissociation or association). It equals the total number of moles of particles after dissociation/association per mole of solute dissolved.

Final Answer: Definitions of Raoult's law, ideal solution / Henry's law, van't Hoff factor as given

$\boxed{\textbf{Answer: (See above)}}$

Go Back to Question 29

Q30.

Solution

Concept: C_p and C_v are related through the gas constant for ideal gases. Hess's law is a consequence of enthalpy being a state function.

Step 1 — Alternative (i): For one mole of an ideal gas: $H = U + pV = U + RT$. Differentiating:

$$\text{dH}\frac{}{dT=\frac{dU}{dT}+R \implies C_p=C_v+R}$$

Therefore, $C_p - C_v = R$.

Step 2 — Alternative (ii): Hess's Law: The total enthalpy change for a reaction is independent of the pathway; it depends only on the initial and final states.

Example: Formation of CO_2 from C can occur directly:

$$\text{C} + \text{O}_2 \rightarrow CO_2, \quad \Delta H = -393.5 \text{ kJ}$$

Or in two steps:

$$\text{C} + \tfrac{1}{2}O_2 \rightarrow CO, \quad \Delta H_1 = -110.5 \text{ kJ}$$

$$\text{CO} + \tfrac{1}{2}O_2 \rightarrow CO_2, \quad \Delta H_2 = -283.0 \text{ kJ}$$

Total: $\Delta H_1 + \Delta H_2 = -110.5 + (-283.0) = -393.5$ kJ, which equals ΔH of the direct route.

Final Answer: $C_p - C_v = R$; Hess's law: ΔH is path-independent

$\boxed{\textbf{Answer: (See above)}}$

Go Back to Question 30

Q31.

Solution

Concept: The Nernst equation relates cell EMF to standard EMF and ion concentrations. The degree of dissociation for a weak acid can be calculated using Ostwald's dilution law.

Step 1 — Alternative (i): The Nernst equation for the cell $\text{Mg}|\text{Mg}^{2+}(0.01\,\text{M})||\text{Cu}^{2+}(0.1\,\text{M})|\text{Cu}$:

$$\text{E}_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.059}{n}\log\frac{[\text{Mg}^{2+}]}{[\text{Cu}^{2+}]}$$

Here, $n = 2$ and $E^\circ_{\text{cell}} = 0.34 - (-2.37) = 2.71$ V.

$$\text{E}_{\text{cell}} = 2.71 - \frac{0.059}{2}\log\frac{0.01}{0.1} = 2.71 - 0.0295 \times \log(10^{-1})$$

$$= 2.71 - 0.0295 \times (-1) = 2.71 + 0.0295 = 2.7395 \approx 2.74 \text{ V}$$

Step 2 — Alternative (ii): For a weak acid using Ostwald's dilution law:

$$\alpha = \sqrt{\frac{K_a}{C}} = \sqrt{\frac{1.8\times10^{-5}}{0.1}} = \sqrt{1.8\times10^{-4}}$$

$$\alpha = \sqrt{1.8}\times10^{-2} = 1.34\times10^{-2} = 0.0134 \text{ (or } 1.34\%)$$

Final Answer: (i) $E \approx 2.74$ V; (ii) $\alpha \approx 0.0134$ (1.34%)

Answer: (See above)

Go Back to Question 31

Q32.

Solution

Concept: Osmotic pressure is the pressure needed to stop osmosis. It is a colligative property proportional to molar concentration and temperature.

Step 1 — Alternative (i):
(a) **Osmotic pressure** (π) is the minimum pressure that must be applied to a solution to prevent the flow of pure solvent into the solution through a semipermeable membrane.
(b) In the diagram, solvent flows from the pure solvent side to the solution side through the semipermeable membrane (osmosis). This increases the solution level until the hydrostatic pressure equals the osmotic pressure, establishing equilibrium at a higher level on the solution side.
Step 2 — Alternative (ii):
Given: $C = 0.1$ M, $T = 27 + 273 = 300$ K, $R = 0.0821$ L atm K^{-1} mol^{-1}.

$$\pi = CRT = 0.1 \times 0.0821 \times 300 = 2.463 \text{ atm} \approx 2.46 \text{ atm}$$

Final Answer: (i) π prevents osmosis; solvent level rises due to osmosis; (ii) $\pi \approx 2.46$ atm

$\boxed{\textbf{Answer: (See above)}}$

Go Back to Question 32

Q33.

Solution

Concept: The inert pair effect makes the lower oxidation state more stable for heavier p-block elements. PCl_5 has a trigonal bipyramidal structure with unequal bond lengths.

Step 1 — Alternative (i): As we move down group 15, the ns^2 electrons (inert pair) become increasingly reluctant to participate in bonding due to poor shielding by intervening d and f electrons. Therefore, the +3 state (using only np^3 electrons) becomes more stable relative to +5 (using $ns^2 + np^3$). This is the inert pair effect.

Step 2 — Alternative (ii): In PCl_5, phosphorus is sp^3d hybridised with 5 bond pairs and 0 lone pairs, giving a trigonal bipyramidal shape. The three equatorial P−Cl bonds (120° apart) are equivalent and shorter, while the two axial bonds (90° to equatorial) are longer and weaker. On heating, the weaker axial bonds break first:

$$\mathrm{PCl_5} \xrightarrow{\Delta} PCl_3 + Cl_2$$

Final Answer: (i) Inert pair effect stabilises +3; (ii) sp^3d hybridisation, axial bonds weaker

$\boxed{\textbf{Answer: (See above)}}$

Go Back to Question 33

Q34.

Solution

Concept: Specific conductance (κ) is the conductance of a 1 cm^3 cube of solution. Molar conductance (Λ_m) is the conductance of a solution containing 1 mole of electrolyte.

Step 1 — (a) **Specific conductance** (κ) is defined as the conductance of a solution column of length 1 cm and cross-sectional area 1 cm^2. It is the reciprocal of specific resistance:

$$\kappa = \frac{1}{\rho}$$

Units: S cm^{-1} or S m^{-1}.

Step 2 — (b) **Molar conductance** (Λ_m) is the conducting power of all ions produced by one mole of electrolyte in a given volume of solution:

$$\Lambda_m = \frac{\kappa \times 1000}{C} \quad (\text{in S cm}^2\text{mol}^{-1})$$

Step 3 — For a **strong electrolyte**, molar conductance increases gradually with dilution. This is because as the concentration decreases, interionic attractions weaken and ions move more freely. The increase is small and follows the Debye–Hückel–Onsager equation.

Final Answer: Definitions as given; Λ_m increases with dilution for strong electrolytes

Answer: (See above)

Go Back to Question 34

Q35.

Solution

Concept: In an octahedral crystal field, the five d-orbitals split into a lower t_{2g} set (3 orbitals) and a higher e_g set (2 orbitals). The electron distribution depends on whether Δ_o is greater or less than the pairing energy.

Step 1 — Alternative (i):
(a) The two sets formed are: t_{2g} (d_{xy}, d_{yz}, d_{xz}) at lower energy and e_g $(d_{x^2-y^2}, d_{z^2})$ at higher energy.
(b) Fe^{3+} $(Z = 26)$: Fe = [Ar] $3d^6\,4s^2$, so Fe^{3+} = [Ar] $3d^5$ (5 d-electrons).
(i) **Weak-field ligand** $(\Delta_o < P)$: Electrons occupy all five orbitals singly first (high spin):

$\mathrm{t}_{2g}^{3}\,e_{g}^{2}$

(ii) **Strong-field ligand** $(\Delta_o > P)$: All 5 electrons pair up in t_{2g} first (low spin):

$\mathrm{t}_{2g}^{5}\,e_{g}^{0}$

Step 2 — Alternative (ii):
(a) Δ_o is the crystal field splitting in an octahedral field; Δ_t is the splitting in a tetrahedral field. $\Delta_t \approx \frac{4}{9}\Delta_o$, so tetrahedral splitting is much smaller.
(b) Cu^{2+} has a $3d^9$ configuration with one unpaired electron, allowing d-d transitions that absorb visible light and impart colour. Cu^{+} has $3d^{10}$ with no partially filled d-orbitals, so no d-d transitions are possible, making it colourless.
Final Answer: t_{2g} and e_g; weak-field: $t_{2g}^3 e_g^2$; strong-field: $t_{2g}^5 e_g^0$

Answer: (See above)

Go Back to Question 35

Q36.

Solution

Concept: Phenol can be converted to benzene by reduction with zinc dust. Methanol can be converted to ethanoic acid via a nitrile intermediate.

Step 1 — (a) **Phenol to benzene:** Phenol vapours are passed over heated zinc dust, which reduces the −OH group:

$$\mathrm{C}_6H_5OH + Zn \xrightarrow{\Delta} C_6H_6 + ZnO$$

Step 2 — (b) **Methanol to ethanoic acid:** This conversion requires increasing the carbon chain length by one carbon. The route is:

$$\mathrm{CH}_3OH \xrightarrow{PCl_3} CH_3Cl \xrightarrow{KCN} CH_3CN \xrightarrow{H_3O^+} CH_3COOH$$

Final Answer: (a) Zn dust, Δ; (b) $\mathrm{CH_3OH} \xrightarrow{\mathrm{PCl_3}} \mathrm{CH_3Cl} \xrightarrow{\mathrm{KCN}} \mathrm{CH_3CN} \xrightarrow{\mathrm{H_3O^+}} \mathrm{CH_3COOH}$

$\boxed{\textbf{Answer: (See above)}}$

Go Back to Question 36

Q37.

Solution

Concept: Faraday's first law of electrolysis states that the mass of substance deposited at an electrode is directly proportional to the quantity of electricity (charge) passed through the electrolyte.

Step 1 — (i) **Faraday's First Law:**

$$\mathrm{m} \propto Q \quad \text{or} \quad m = Z \cdot Q = Z \cdot I \cdot t$$

where m is mass deposited, Q is charge, Z is the electrochemical equivalent, I is current, and t is time.

Step 2 — (ii) Given: $I = 2$ A, $t = 30$ min $= 1800$ s, $M_{\mathrm{Ag}} = 108$ g mol^{-1}, $n = 1$ (since $\mathrm{Ag^+ + e^- \longrightarrow Ag}$).

Charge passed:

$$\mathrm{Q = I} \times t = 2 \times 1800 = 3600\ \mathrm{C}$$

Step 3 — Using $m = \frac{M \cdot Q}{n \cdot F}$:

$$\mathrm{m} = 108 \times 3600\frac{}{1\times 96500=\frac{388800}{96500}=4.03\ \mathrm{g}}$$

Final Answer: $m = 4.03$ g of silver

Answer: (See above)

Go Back to Question 37

Q38.

Solution

Concept: IUPAC naming of coordination compounds follows specific rules. Isomerism depends on the nature of ligands. Magnetic behaviour depends on electron pairing influenced by ligand field strength.

Step 1 — Alternative (i):
(a) $K_3[Fe(C_2O_4)_3]$: The complex anion is $[Fe(C_2O_4)_3]^{3-}$. The ligand $C_2O_4^{2-}$ is oxalato. With 3 oxalato ligands: trioxalato. Iron is in the +3 state:

IUPAC name: **Potassium trioxalatoferrate(III)**

(b) $[Co(NH_3)_5(NO_2)]^{2+}$: The NO_2^- ligand can bind through N (nitro/κN) or O (nitrito/κO). This gives **linkage isomerism**.
(c) In $[NiCl_4]^{2-}$: Ni^{2+} is $3d^8$. Cl^- is a weak-field ligand, so no pairing occurs. The complex is sp^3 (tetrahedral) with 2 unpaired electrons $\Rightarrow$ **paramagnetic**.
In $[Ni(CN)_4]^{2-}$: CN^- is a strong-field ligand, causing pairing. The complex is dsp^2 (square planar) with 0 unpaired electrons $\Rightarrow$ **diamagnetic**.
Step 2 — Alternative (ii):
$[CoF_6]^{3-}$: Co^{3+} is $3d^6$. F^- is a weak-field ligand, so pairing does not occur. The $3d$ orbitals remain as $3d^6$ with 4 unpaired electrons.
The hybridisation uses outer orbitals: one $4s$, three $4p$, and two $4d$ orbitals $\Rightarrow sp^3d^2$ hybridisation.
Geometry: **Octahedral**. Magnetic behaviour: **Paramagnetic** (4 unpaired electrons).
Final Answer: (i) Potassium trioxalatoferrate(III); linkage isomerism; weak/strong field; (ii) sp^3d^2, octahedral, paramagnetic

Answer: (See above)
Go Back to Question 38

Q39.

Solution

Concept: Freezing point depression is a colligative property: $\Delta T_f = i \cdot K_f \cdot m$. Secondary cells can be recharged. Fuel cells convert chemical energy directly to electrical energy.

Step 1 — Alternative (i): Given: $\Delta T_f = 4$ K (from 0°C to −4°C), $K_f = 1.86$ K kg mol^{-1}, mass of water = 200 g = 0.2 kg. NaCl dissociates completely: $NaCl \rightarrow Na^+ + Cl^-$, so $i = 2$.
Using $\Delta T_f = i \cdot K_f \cdot m$:

$$4 = 2 \times 1.86 \times m \implies m = \frac{4}{3.72} = 1.075 \text{ mol kg}^{-1}$$

Mass of NaCl needed:

$$\text{Mass} = \text{m} \times M \times W = 1.075 \times 58.5 \times 0.2 = 12.58 \text{ g}$$

Step 2 — Alternative (ii):
(a) **Secondary cells** (rechargeable cells) can be recharged by passing current in the reverse direction, restoring the original reactants. Example: **Lead storage battery** ($Pb|PbSO_4|H_2SO_4|PbSO_4|PbO_2$).
(b) A **fuel cell** converts the chemical energy of fuel (e.g., H_2) directly into electrical energy without combustion. This direct conversion avoids the thermodynamic losses of heat-to-work conversion in thermal power plants, making fuel cells more efficient (up to 70–75% efficiency vs. 30–40% for thermal plants).
Final Answer: (i) 12.58 g of NaCl; (ii) Secondary cells are rechargeable; fuel cells have higher efficiency

$\boxed{\textbf{Answer: (See above)}}$

Go Back to Question 39

Q40.

Solution

Concept: Named reactions in organic chemistry involve specific reagents and conditions. Each name reaction has a characteristic transformation.

Step 1 — (a) **Wolff–Kishner reduction:** An aldehyde or ketone is reduced to the corresponding alkane by heating with hydrazine (NH_2NH_2) in the presence of a strong base (KOH) in a high-boiling solvent (ethylene glycol):

$$R_2C{=}O + NH_2NH_2 \xrightarrow[ethylene\ glycol]{KOH,\ \Delta} R_2CH_2 + N_2 \uparrow$$

Step 2 — (b) **Aldol condensation:** Aldehydes or ketones with at least one α-hydrogen react in the presence of dilute NaOH to form a β-hydroxy aldehyde (aldol), which on heating loses water to give an α, β-unsaturated aldehyde:

$$2\,CH_3CHO \xrightarrow{dil.\ NaOH} CH_3CH(OH)CH_2CHO \xrightarrow{\Delta} CH_3CH{=}CHCHO + H_2O$$

Step 3 — (c) **Kolbe's reaction:** Phenol is converted to salicylic acid by treatment with NaOH, followed by heating with CO_2 under pressure, and then acidification:

$$C_6H_5ONa + CO_2 \xrightarrow[\text{heat}]{\text{pressure, }125^\circ\text{C}} C_6H_4(OH)COONa \xrightarrow{H^+} C_6H_4(OH)COOH$$

The product is salicylic acid (2-hydroxybenzoic acid).

Final Answer: Equations for Wolff–Kishner, Aldol condensation, and Kolbe's reaction as given above

Answer: (See above)

Go Back to Question 40

Q41.

Solution

Concept: Amino acids contain both acidic ($-COOH$) and basic ($-NH_2$) groups, making them amphoteric. Protein structure involves different levels of folding. Amine basicity depends on solvation and inductive effects in aqueous solution.

Step 1 — Alternative (i):

(a) Amino acids have both a carboxyl group ($-COOH$) and an amino group ($-NH_2$). In aqueous solution, the $-COOH$ group can donate a proton (acting as acid) and the $-NH_2$ group can accept a proton (acting as base). The amino acid exists as a zwitterion $^{+}H_3N-CHR-COO^{-}$ and can react with both acids and bases, showing amphoteric behaviour.

(b) The α-helix is a right-handed coiled structure stabilised by intramolecular hydrogen bonds between C=O of residue n and N−H of residue $n + 4$. The β-pleated sheet consists of extended polypeptide chains lying side by side, held together by intermolecular hydrogen bonds between adjacent chains.

(c) The nitrogenous base present in DNA but not in RNA is **thymine** (T). RNA contains uracil (U) instead.

Step 2 — Alternative (ii):

(a) Aniline + bromine water → **2,4,6-tribromoaniline** (white precipitate):

$$C_6H_5NH_2 + 3Br_2(aq) \rightarrow C_6H_2Br_3NH_2 \downarrow + 3HBr$$

(b) In aqueous solution, basicity order is:

$$(CH_3)_2NH > (CH_3)_3N > CH_3NH_2 > NH_3$$

So increasing basicity: $CH_3NH_2 < (CH_3)_3N < (CH_3)_2NH$.

The secondary amine is most basic due to the balance of $+I$ effect and solvation. The tertiary amine is less basic than secondary because of poor solvation of its conjugate acid.

(c) Aniline is less basic than cyclohexylamine because in aniline, the lone pair on nitrogen is delocalised into the benzene ring by resonance, reducing its availability for protonation. In cyclohexylamine, no such delocalisation occurs.

Final Answer: (i) Zwitterion behaviour; helix vs sheet; thymine; (ii) Tribromoaniline; basicity order; resonance effect

$\boxed{\textbf{Answer: (See above)}}$

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Q42.

Solution

Concept: Galvanic cells convert chemical energy to electrical energy through spontaneous redox reactions. Transition metals show characteristic properties due to partially filled d-orbitals.

Step 1 — Alternative (i):
(a) **Half-reactions:**
Anode (oxidation): $\mathrm{Mg} \rightarrow \mathrm{Mg}^{2+} + 2\mathrm{e}^-$
Cathode (reduction): $\mathrm{Ag}^+ + \mathrm{e}^- \rightarrow \mathrm{Ag}$ (multiplied by 2 for balance)
Overall: $\mathrm{Mg} + 2\mathrm{Ag}^+ \rightarrow \mathrm{Mg}^{2+} + 2\mathrm{Ag}$
(b) **Properties of transition metals:**
(1) **Coloured ions:** Transition metal ions have partially filled d-orbitals. When visible light falls on them, electrons undergo d-d transitions, absorbing certain wavelengths. The complementary colour is transmitted, giving the ion its colour.
(2) **Catalytic activity:** Transition metals provide a large surface area for adsorption of reactants and can form unstable intermediates by utilising their variable oxidation states. This lowers the activation energy and increases the reaction rate.
(c) **Lanthanoid contraction:** The steady decrease in atomic/ionic size across the lanthanoid series (La to Lu) due to poor shielding of nuclear charge by $4f$ electrons. One consequence: the sizes of $4d$ and $5d$ series elements become very similar (e.g., Zr and Hf have nearly identical radii), making them chemically very similar and difficult to separate.
Step 2 — Alternative (ii):
(a) General electronic configuration of d-block elements: $(n-1)d^{1-10}\,ns^{0-2}$
(b) Sc^{3+} ($Z = 21$): $\mathrm{Sc} = [\mathrm{Ar}]\,3d^1\,4s^2$, so $\mathrm{Sc}^{3+} = [\mathrm{Ar}]\,3d^0$. With no d-electrons, no d-d transitions are possible, making it colourless.
Ti^{3+} ($Z = 22$): $\mathrm{Ti} = [\mathrm{Ar}]\,3d^2\,4s^2$, so $\mathrm{Ti}^{3+} = [\mathrm{Ar}]\,3d^1$. With one d-electron, d-d transitions can occur, absorbing visible light and producing colour.
(c) **Interstitial compounds** are formed when small atoms (H, C, N, B) occupy the interstitial voids in the metal lattice of transition metals. Properties: (i) They are extremely hard (e.g., steel), (ii) they have high melting points, (iii) they retain metallic conductivity, (iv) they are chemically inert.
Final Answer: Half-reactions; properties explained; lanthanoid contraction; d^0 colourless, d^1 coloured; interstitial compounds

$\boxed{\textbf{Answer: (See above)}}$

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Q43.

Solution

Concept: The Schiemann reaction converts diazonium fluoroborate to fluoroarene. Chlorobenzene's low reactivity towards nucleophilic substitution is due to resonance and sp^2 hybridisation of the carbon. **Step 1 — Alternative (i):** (a) **Schiemann reaction:**

$$C_6H_5N_2^+BF_4^- \xrightarrow{\Delta} C_6H_5F + BF_3 + N_2\uparrow$$

Product: **Fluorobenzene** (C_6H_5F). (b) (1) **Chlorobenzene** resists nucleophilic substitution because: (i) The lone pairs on Cl are delocalised into the benzene ring by resonance, giving the C−Cl bond partial double-bond character, making it stronger and harder to break. (ii) The carbon attached to Cl is sp^2 hybridised (more electronegative), holding the electron pair more tightly. (2) Primary aliphatic amines react with HNO_2 (generated in situ from $NaNO_2$ + HCl) to form unstable diazonium salts, which immediately decompose to give a mixture of products (alcohols, alkenes, alkyl chlorides) with evolution of N_2 gas:

$$RNH_2 + HNO_2 \xrightarrow{0\text{–}5^\circ C} [R - N_2^+Cl^-] \rightarrow ROH + N_2\uparrow + H_2O + \text{other products}$$

(c) $CH_3{-}CH(OH){-}CH_2{-}CHO$: The longest chain with the principal functional group (−CHO) has 4 carbons. Numbering from the aldehyde carbon: C-1 = CHO, C-2 = CH_2, C-3 = CH(OH), C-4 = CH_3. IUPAC name: **3-Hydroxybutanal Step 2 — Alternative (ii):** (a) **Enzymes** are biological catalysts (mostly proteins) that accelerate biochemical reactions with high specificity and efficiency. The enzyme that converts glucose to ethanol and CO_2 is **zymase** (present in yeast).

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2C_2H_5OH + 2CO_2$$

(b) S_N1 **vs** S_N2**:** (1) **Molecularity:** S_N1 is unimolecular (rate-determining step involves only the substrate). S_N2 is bimolecular (rate depends on both substrate and nucleophile). (2) **Stereochemistry:** S_N1 gives racemisation (mixture of retention and inversion). S_N2 gives complete inversion of configuration (Walden inversion). (c) (1) $CH_3CH_2OH + PCl_3 \rightarrow 3CH_3CH_2Cl + H_3PO_3$ Product: **Chloroethane** (CH_3CH_2Cl) (2) $C_6H_5O^-Na^+ + CO_2 \xrightarrow[\text{heat}]{\text{pressure}} C_6H_4(ONa)COOH \xrightarrow{H^+} C_6H_4(OH)COOH$ Final product: **Salicylic acid** (2-hydroxybenzoic acid) **Final Answer:** (i) Fluorobenzene; resonance reason; 3-hydroxybutanal; (ii) Zymase; SN1 vs SN2; chloroethane; salicylic acid

$\boxed{\textbf{Answer: (See above)}}$

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	A	3	A	4	A	5	B
6	B	7	B	8	A	9	B	10	C
11	A	12	A	13	B	14	C	15	C
16	B								