NIOS Class 12 Chemistry Sample Paper – 1

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. The hybridisation of the central atom in BF_3 is: **(1)**

(A) sp

(B) sp^2

(C) sp^3

(D) sp^3d

Q2. The equivalent mass of H_2SO_4 (molar mass = 98) when it acts as a dibasic acid is: **(1)**

(A) 98

(B) 49

(C) 32.67

(D) 196

Q3. The de Broglie wavelength of a particle is given by: **(1)**

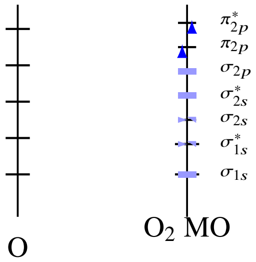
(A) $\lambda = \frac{h}{mv}$

(B) $\lambda = \frac{mv}{h}$

(C) $\lambda = \frac{h}{mv^2}$

(D) $\lambda = h \cdot mv$

Q4. The molecular orbital energy level diagram for O_2 is shown below: **(1)**



Based on the molecular orbital configuration, O_2 is:

(A) Diamagnetic with bond order 2

(B) Paramagnetic with bond order 2

(C) Diamagnetic with bond order 3

(D) Paramagnetic with bond order 1

Q5. Which of the following molecules has a zero net dipole moment? **(1)**

(A) H_2O

(B) NH_3

(C) CCl_4

(D) $CHCl_3$

Q6. An ideal solution is formed when the intermolecular forces between solute–solute, solvent–solvent and solute–solvent are: **(1)**

(A) Very different from each other

(B) Nearly equal to each other

(C) Completely absent

(D) Only ionic in nature

Q7. The standard enthalpy of formation of an element in its most stable allotropic form is: **(1)**

(A) Positive

(B) Negative

(C) Zero

(D) Depends on the element

Q8. The unit of specific conductance (κ) is: **(1)**

(A) $\text{ohm} \cdot \text{cm}$

(B) $\text{ohm}^{-1} \cdot \text{cm}^{-1}$

(C) $\text{ohm}^{-1} \cdot \text{cm}^2 \cdot \text{mol}^{-1}$

(D) $\text{ohm} \cdot \text{cm}^2$

Q9. For a second-order reaction A $\longrightarrow$ Products, the unit of the rate constant k is: **(1)**

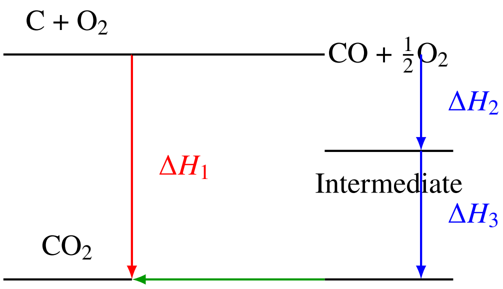
(A) $\text{mol} \cdot \text{L}^{-1} \cdot \text{s}^{-1}$

(B) s^{-1}

(C) $\text{L} \cdot \text{mol}^{-1} \cdot \text{s}^{-1}$

(D) $L^2 \cdot mol^{-2} \cdot s^{-1}$

Q10. The diagram below illustrates Hess's law for the formation of CO_2 from C: **(1)**



According to Hess's law, the correct relation is:

(A) $\Delta H_1 = \Delta H_2 + \Delta H_3$

(B) $\Delta H_1 = \Delta H_2 - \Delta H_3$

(C) $\Delta H_1 = \Delta H_2 \times \Delta H_3$

(D) $\Delta H_1 = \frac{\Delta H_2}{\Delta H_3}$

Q11. The molecular shape of ozone (O_3) is: **(1)**

(A) Linear

(B) Bent (angular)

(C) Trigonal planar

(D) T-shaped

Q12. According to Werner's theory of coordination compounds, the secondary valences of the central metal ion are: **(1)**

(A) Ionisable and non-directional

(B) Non-ionisable and directional

(C) Ionisable and directional

(D) Non-ionisable and non-directional

Q13. When HBr is added to propene ($CH_3CH{=}CH_2$) in the absence of peroxide, the major product is: **(1)**

(A) $CH_3CH_2CH_2Br$ (1-bromopropane)

(B) $CH_3CHBrCH_3$ (2-bromopropane)

(C) $CH_2BrCH{=}CH_2$ (allyl bromide)

(D) $CH_3CHBrCH_2Br$ (1,2-dibromopropane)

Q14. Which of the following alcohols reacts immediately with Lucas reagent (anhydrous $ZnCl_2$/conc. HCl) to produce turbidity? **(1)**

(A) Primary alcohol (CH_3CH_2OH)

(B) Secondary alcohol ($CH_3CHOHCH_3$)

(C) Tertiary alcohol ($(CH_3)_3COH$)

(D) Methanol (CH_3OH)

Q15. When egg white is boiled, the protein undergoes denaturation. Which of the following structures is **not** affected during denaturation? **(1)**

(A) Primary structure

(B) Secondary structure

(C) Tertiary structure

(D) Quaternary structure

Q16. Which of the following is an example of an antihistamine? **(1)**

(A) Cimetidine

(B) Ranitidine

(C) Diphenhydramine

(D) Omeprazole

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

Q17. Read the passage given below and answer the following questions:
Colligative properties depend on the number of solute particles in solution and not on the nature of the solute. These properties include relative lowering of vapour pressure, elevation of boiling point, depression of freezing point,

and osmotic pressure. When a solute undergoes dissociation or association in solution, the number of particles changes, which alters the observed colligative property. The van't Hoff factor accounts for this change. **(2)**

1. Define the van't Hoff factor (i) and state its value for NaCl in dilute aqueous solution.
2. Why is osmotic pressure preferred over other colligative properties for determining the molar mass of polymers?

Q18. Complete the following by using the options given below:
(electronegativity, electron gain enthalpy, ionisation enthalpy, atomic radius) **(2)**

1. The energy released when an electron is added to a neutral gaseous atom to form a uninegative ion is called . . . .
2. The tendency of an atom in a molecule to attract the shared pair of electrons towards itself is called . . . .

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

1. Heisenberg's uncertainty principle is significant only for microscopic particles such as electrons and is negligible for macroscopic objects.
2. The $2p$ and $3p$ orbitals have the same size and energy.

Q20. Complete the following by using the options given below:
(strong electrolyte, weak electrolyte, non-electrolyte, superconductor) **(2)**

1. A substance that dissociates almost completely into ions in aqueous solution and conducts electricity very well is called a . . . .
2. Glucose dissolved in water does not produce ions. It is therefore classified as a . . . .

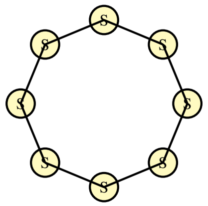
Q21. Complete the following by using the options given below:
(oxidation state, ligand, coordination number, chelate) **(2)**

1. In the complex $[Co(NH_3)_6]^{3+}$, the number of ligands directly bonded to the central metal ion is called its ....
2. A ligand that forms a ring structure by bonding to the metal ion through two or more donor atoms is called a .... ligand.

Q22. Read the passage given below and answer the following questions:
Drugs are classified based on their therapeutic effect. Analgesics relieve pain, antipyretics reduce fever, and antibiotics kill or inhibit the growth of microorganisms. Some drugs like aspirin act as both analgesic and antipyretic. Broad-spectrum antibiotics can act against a wide range of Gram-positive and Gram-negative bacteria, while narrow-spectrum antibiotics are effective only against specific groups. **(2)**

1. What is the difference between a narrow-spectrum and a broad-spectrum antibiotic? Give one example of each.
2. Why is aspirin called a multifunctional drug?

Q23. Read the passage given below and answer the following questions:
Sulphur exists in several allotropic forms. The two most common crystalline forms are rhombic sulphur (α-sulphur) and monoclinic sulphur (β-sulphur). Rhombic sulphur is stable below 369 K and has an octahedral crystal shape. Monoclinic sulphur is stable above 369 K and consists of needle-shaped crystals. Both forms contain S_8 molecules in which each sulphur atom is sp^3 hybridised and bonded to two other sulphur atoms. **(2)**



S_8 crown-shaped ring

1. What is the transition temperature between rhombic and monoclinic sulphur?
2. What is the hybridisation of each sulphur atom in the S_8 ring?

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

Column I	**Column II**
(a) Lucas test	(i) Aldehyde gives silver mirror
(b) Hinsberg test	(ii) Distinguishes primary, secondary and tertiary alcohols
(c) Tollens' test	(iii) Carboxylic acid reduces to alcohol
(d) Clemmensen reduction	(iv) Distinguishes primary, secondary and tertiary amines

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

1. $CH_3COOH + C_2H_5OH \xrightarrow[\text{conc. } H_2SO_4]{\Delta}$
2. $CH_3CH_2Cl + KCN \longrightarrow +KCl$

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

Buffer solutions resist changes in pH when small amounts of acid or base are added. An acidic buffer consists of a weak acid and its salt with a strong base (e.g., $CH_3COOH + CH_3COONa$). A basic buffer consists of a weak base and its salt with a strong acid (e.g., $NH_4OH + NH_4Cl$). The pH of a buffer solution can be calculated using the Henderson–Hasselbalch equation. **(2)**

1. Write the Henderson–Hasselbalch equation for an acidic buffer.
2. What happens to the pH of pure water when a few drops of dilute HCl are added? Why does a buffer solution not show such a large change?

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

1. In an adiabatic process, there is no exchange of heat between the system and the surroundings.
2. The entropy of a perfectly crystalline substance at absolute zero temperature is maximum.

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

Polymers are large molecules made up of repeating structural units called monomers joined by covalent bonds. Natural polymers include starch, cellulose, and proteins. Synthetic polymers include polythene, nylon, and PVC. Thermoplastics can be softened on heating and hardened on cooling repeatedly, while thermosetting plastics, once set, cannot be remoulded. **(2)**

1. What is the difference between a thermoplastic and a thermosetting polymer? Give one example of each.
2. Name the monomer of polythene.

Section: B

Q29. (i) Differentiate between molarity and molality. Which one is a temperature-independent concentration term and why?

OR

(ii) Define the following:

(a) Mole fraction

(b) Mass percentage **(2)**

Q30. (i) What is meant by a state function? Give two examples of state functions and two examples of path functions.

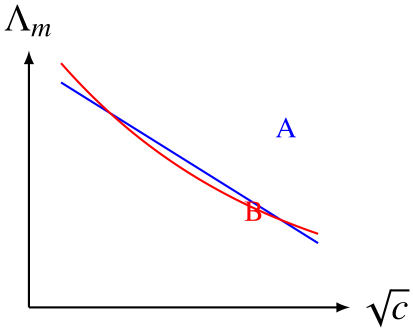
OR

(ii) Define the following:

(a) Standard enthalpy of combustion

(b) Enthalpy of atomisation **(2)**

Q31. (i) The variation of molar conductivity with concentration for two electrolytes A and B is shown below:



(a) Identify electrolyte A and electrolyte B as strong or weak.

(b) Why does the molar conductivity of B increase sharply on dilution?

OR

(ii) Calculate the standard cell potential for the reaction:

$Zn(s) + 2Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$

Given: $E°(Ag^+/Ag) = +0.80$ V, $E°(Zn^{2+}/Zn) = -0.76$ V **(2)**

Q32. (i) State Faraday's second law of electrolysis. Illustrate with a suitable example.

OR

(ii) Calculate the time required to deposit 1.08 g of silver at the cathode when a current of 0.5 A is passed through silver nitrate solution.

(Given: Atomic mass of Ag = 108, 1 F = 96500 C) **(2)**

Q33. (i) Explain why NH_3 has a higher boiling point than PH_3.

OR

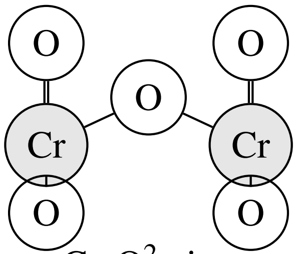
(ii) Draw the structure of H_3PO_4 (phosphoric acid) and indicate the oxidation state of phosphorus in it. **(2)**

Q34. (i) What are interstitial compounds? State two characteristic properties of interstitial compounds formed by transition metals.

OR

(ii) Why do transition metals show: (a) high enthalpy of atomisation, and (b) catalytic activity? **(2)**

Q35. (i) The structure of the $Cr_2O_7^{2-}$ (dichromate) ion is shown below:



$Cr_2O_7^{2-}$ ion

(a) What is the oxidation state of Cr in $Cr_2O_7^{2-}$?

(b) What happens when $K_2Cr_2O_7$ is heated with conc. HCl?

OR

(ii) (a) Explain why Cu^+ is unstable in aqueous solution.

(b) Why does the density of transition elements generally increase from left to right across a period? **(2)**

Q36. (i) How will you convert:

(a) Ethanol to ethanoic acid

(b) Phenol to 2-methylphenol (o-cresol)

OR

(ii) Complete the following:

(a) $CH_3CH_2OH \xrightarrow[573\ K]{Cu}$

(b) $C_6H_5OH + Zn\ dust \xrightarrow{\Delta}$ **(2)**

Q37. Complete the following reaction equations: **(2)**

$$\text{(a)}\ C_6H_5COOH + SOCl_2 \rightarrow +SO_2 + HCl$$

$$\text{(b)}\ CH_3COCH_3 + NH_2NH_2 \xrightarrow{pH\ 4-5}$$

Q38. Define the following terms:

A. Elevation of boiling point

B. Depression of freezing point

C. Relative lowering of vapour pressure **(3)**

Q39. (i) Calculate the enthalpy change for the reaction:

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$

Given: $\Delta H_f^\circ(C_2H_4) = +52.3\ kJ\ mol^{-1}$, $\Delta H_f^\circ(CO_2) = -393.5\ kJ\ mol^{-1}$,

$\Delta H_f^\circ(H_2O(l)) = -285.8 \text{ kJ mol}^{-1}$

OR

(ii) (a) State the first law of thermodynamics in mathematical form.

(b) Differentiate between extensive and intensive properties with examples. **(3)**

Q40. (i) Account for the following:

(a) Why does PCl_3 fume in moist air?

(b) Why is H_3PO_3 a dibasic acid while H_3PO_4 is tribasic?

(c) Draw the structure of $XeOF_4$ and state the hybridisation of Xe.

OR

(ii) (a) Why is the bond angle in NH_3 (107°) greater than in PH_3 (93°)?

(b) Arrange the following halogen acids in increasing order of bond strength: HF, HCl, HBr, HI. Give a reason.

(c) Why does fluorine show only -1 oxidation state while other halogens show positive oxidation states too? **(3)**

Q41. (i) Answer the following:

(a) Write the IUPAC name of $CH_3CH(Br)CH_2CHO$.

(b) What is the action of PCl_5 on acetone?

(c) Why does formaldehyde (HCHO) undergo Cannizzaro reaction and not aldol condensation?

OR

(ii) (a) How is aniline prepared by:

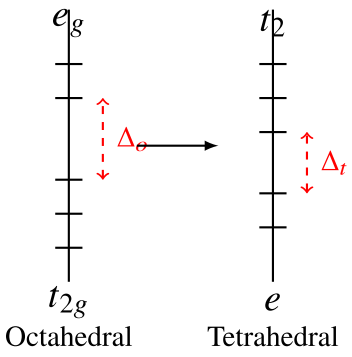
(1) Reduction of nitrobenzene

(2) Gabriel phthalimide synthesis (explain with the general reaction)

(b) Arrange the following in decreasing order of basic strength in the gas phase: $C_6H_5NH_2, NH_3, CH_3NH_2, (CH_3)_2NH$

(c) Write the structure of the product when phenol is heated with zinc dust. **(3)**

Q42. (i) The coloured compounds of transition metals arise from *d*-*d* transitions. The diagram below shows the splitting of *d*-orbitals in tetrahedral and octahedral fields:



(a) What is the relation between Δ_o and Δ_t?

(b) Explain why Sc^{3+} compounds are white but Ti^{3+} compounds are coloured.

(c) What is meant by disproportionation reaction? Give one example with a balanced equation.

OR

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

(b) What are lanthanoids? Write the general electronic configuration of lanthanoids.

(c) State any two consequences of lanthanoid contraction. **(5)**

Q43. (i) Answer the following:

(a) What is the role of enzymes in the human body? Name the enzyme that converts sucrose into glucose and fructose.

(b) Differentiate between DNA and RNA on the basis of:

(1) Sugar present

(2) Structure

(3) Nitrogenous bases

(c) What are essential and non-essential amino acids? Give one example of each.

OR

(ii) (a) Write the chemical equation for the carbylamine reaction. Which type of amine responds to this test?

(b) Explain the basic character of amines in the gas phase and in aqueous solution.

(c) Complete the following reactions:

(1) $C_6H_5NH_2 + Br_2(aq) \longrightarrow$

(2) $CH_3CH_2NH_2 + HNO_2 \xrightarrow{0\text{–}5°C}$ **(5)**

Detailed Solutions

Q1.

Solution

Concept: Hybridisation is determined by counting the number of electron domains (bond pairs + lone pairs) around the central atom. sp^2 hybridisation involves one s and two p orbitals, giving 3 hybrid orbitals arranged at 120°.

Step 1 — In BF_3, boron has 3 valence electrons and forms 3 bonds with fluorine atoms. There are no lone pairs on boron.
Step 2 — Number of electron domains = 3 bond pairs + 0 lone pairs = 3.
Step 3 — Three electron domains correspond to sp^2 hybridisation, giving a trigonal planar geometry with bond angles of 120°.
Why other options are wrong:

- **Option A (sp):** Requires 2 electron domains.
- **Option C (sp^3):** Requires 4 electron domains.
- **Option D (sp^3d):** Requires 5 electron domains.

Final Answer: sp^2 (Option B)

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

Go Back to Question 1

Q2.

Solution

Concept: The equivalent mass of an acid is its molar mass divided by its basicity (number of replaceable hydrogen ions per molecule).

Step 1 — H_2SO_4 is a dibasic acid, meaning it can furnish 2 H^+ ions per molecule.
Step 2 — Equivalent mass = $\frac{\text{Molar mass}}{\text{Basicity}}$
Step 3 — Equivalent mass = $\frac{98}{2} = 49$
Final Answer: 49 (Option B)

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

Go Back to Question 2

Q3.

Solution

Concept: The de Broglie wavelength relates the wave nature of matter to its momentum.

Step 1 — According to de Broglie's hypothesis, every moving particle has a wave associated with it. The wavelength is:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

where h is Planck's constant, m is mass, and v is velocity.

Step 2 — This shows that heavier and faster particles have shorter wavelengths, while lighter and slower particles have longer wavelengths.

Final Answer: $\lambda = \frac{h}{mv}$ (Option A)

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

Go Back to Question 3

Q4.

Solution

Concept: Molecular Orbital Theory (MOT) explains the magnetic properties and bond order of molecules based on the filling of molecular orbitals. O_2 has 16 electrons and two unpaired electrons in its π^* orbitals.

Step 1 — Electronic configuration of O_2 from MOT:

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

Step 2 — Bond order:

$$\text{B.O.} = \text{N}_b - N_a\,\overline{{}_{2=\frac{10-6}{2}=2}}$$

Step 3 — Since there are 2 unpaired electrons in the π^* orbitals, O_2 is **paramagnetic** with bond order 2.

Why other options are wrong:

- **Option A:** O_2 is paramagnetic, not diamagnetic.
- **Option C:** Bond order is 2, not 3.
- **Option D:** Bond order is 2, not 1.

Final Answer: Paramagnetic with bond order 2 (Option B)

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

Go Back to Question 4

Q5.

Solution

Concept: A molecule has zero net dipole moment when the individual bond dipoles cancel each other due to the symmetrical geometry of the molecule.

Step 1 — CCl_4 has a tetrahedral geometry with 4 identical C−Cl bonds. The four bond dipoles point from C to Cl symmetrically, and they cancel out completely.
Step 2 — Verify others:

- H_2O: Bent shape, bond dipoles do not cancel.
- NH_3: Trigonal pyramidal, lone pair creates asymmetry.
- $CHCl_3$: Tetrahedral but not all bonds are identical, so dipoles don't cancel fully.

Final Answer: CCl_4 (Option C)

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: An ideal solution obeys Raoult's law at all concentrations. This happens when intermolecular forces between all pairs of molecules are nearly equal.

Step 1 — For an ideal solution: $F_{\text{solute-solute}} \approx F_{\text{solvent-solvent}} \approx F_{\text{solute-solvent}}$.
Step 2 — This means $\Delta H_{\text{mix}} = 0$ and $\Delta V_{\text{mix}} = 0$.
Step 3 — Example: Benzene and toluene form an ideal solution because their molecular sizes and forces are similar.
Final Answer: Nearly equal to each other (Option B)

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: The standard enthalpy of formation (ΔH_f°) is defined as the enthalpy change when 1 mole of a compound is formed from its elements in their standard states. By definition, the ΔH_f° of an element in its most stable form is zero.

Step 1 — For example, $\Delta H_f^\circ(\mathrm{O_2(g)}) = 0$, $\Delta H_f^\circ(\mathrm{C(graphite)}) = 0$.
Step 2 — This serves as the reference point for all enthalpy of formation calculations.
Final Answer: Zero (Option C)

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept: Specific conductance (κ) is the reciprocal of specific resistance (ρ). It represents the conductance of a 1 $\mathrm{cm^3}$ cube of solution.

Step 1 — $\kappa = \frac{1}{\rho}$, where ρ has units of $\mathrm{ohm \cdot cm}$.
Step 2 — Therefore, units of $\kappa = \mathrm{ohm^{-1} \cdot cm^{-1} = S \cdot cm^{-1}}$ (Siemens per cm).
Final Answer: $\mathrm{ohm^{-1} \cdot cm^{-1}}$ (Option B)

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept: The units of the rate constant depend on the overall order of the reaction.

Step 1 — For a second-order reaction: Rate $= k[\mathrm{A}]^2$
Step 2 — Units: $\mathrm{mol \cdot L^{-1} \cdot s^{-1}} = k \times (\mathrm{mol \cdot L^{-1}})^2$
Step 3 — Therefore: $k = \frac{\mathrm{mol \cdot L^{-1} \cdot s^{-1}}}{\mathrm{mol^2 \cdot L^{-2}}} = \mathrm{L \cdot mol^{-1} \cdot s^{-1}}$
Final Answer: $\mathrm{L \cdot mol^{-1} \cdot s^{-1}}$ (Option C)

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept: Hess's law states that the total enthalpy change for a reaction is the same regardless of the pathway taken, since enthalpy is a state function.

Step 1 — From the diagram, Path 1 is the direct route: $C + O_2 \rightarrow CO_2$ with enthalpy change ΔH_1.
Step 2 — Path 2 goes via intermediate: $C + O_2 \rightarrow CO + \frac{1}{2}O_2$ (ΔH_2) followed by $CO + \frac{1}{2}O_2 \rightarrow CO_2$ (ΔH_3).
Step 3 — By Hess's law: $\Delta H_1 = \Delta H_2 + \Delta H_3$ (the sum of enthalpy changes along the indirect path equals the direct path).
Final Answer: $\Delta H_1 = \Delta H_2 + \Delta H_3$ (Option A)

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: Ozone (O_3) has a central oxygen atom bonded to two other oxygen atoms with one lone pair, giving a bent shape according to VSEPR theory.

Step 1 — Central O has 6 valence electrons. Two are used in bonds (one single, one double, with resonance), and one lone pair remains.
Step 2 — 3 electron domains (2 bonds + 1 lone pair) give sp^2 hybridisation, with bent molecular geometry.
Step 3 — The bond angle is approximately 117°.
Final Answer: Bent (angular) (Option B)

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: According to Werner's coordination theory, metals have primary valences (ionisable, corresponding to oxidation state) and secondary valences (non-ionisable, directional, corresponding to coordination number).

Step 1 — Secondary valences determine the number and arrangement of ligands around the central metal. They are satisfied by ligands (neutral molecules or anions).
Step 2 — Since secondary valences fix the geometry, they are directional and non-ionisable.
Final Answer: Non-ionisable and directional (Option B)

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: Markovnikov's rule states that in the addition of HX to an unsymmetrical alkene, the hydrogen adds to the carbon with more hydrogen atoms, and the halide adds to the carbon with fewer hydrogen atoms (the more substituted carbon).

Step 1 — In propene $CH_3CH{=}CH_2$, the terminal carbon (CH_2) has more hydrogens.
Step 2 — According to Markovnikov's rule, H adds to CH_2 and Br adds to the central carbon, forming the more stable secondary carbocation intermediate.
Step 3 — Product: $CH_3CHBrCH_3$ (2-bromopropane).
Final Answer: $CH_3CHBrCH_3$ (2-bromopropane) (Option B)

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: Lucas test uses anhydrous $ZnCl_2$ in concentrated HCl. Tertiary alcohols react immediately (instant turbidity), secondary alcohols react within 5 minutes, and primary alcohols do not react at room temperature.

Step 1 — Tertiary alcohols form the most stable carbocation (3°), so they react the fastest via an S_N1 mechanism.
Step 2 — $(CH_3)_3COH$ (tertiary alcohol) reacts immediately to produce turbidity of the insoluble alkyl chloride.
Final Answer: Tertiary alcohol $(CH_3)_3COH$ (Option C)

Answer: (C)

Go Back to Question 14

Q15.

Solution

Concept: Denaturation involves the disruption of hydrogen bonds, disulfide bridges, and other non-covalent interactions that maintain the secondary, tertiary, and quaternary structures of proteins. The primary structure (sequence of amino acids linked by covalent peptide bonds) remains intact.

Step 1 — When egg white is boiled, heat breaks hydrogen bonds and hydrophobic interactions, causing the protein to unfold (loss of 2°, 3°, and 4° structures).
Step 2 — However, the peptide bonds ($-CO-NH-$) are strong covalent bonds that are not broken by heating. Therefore, the primary structure remains unchanged.
Final Answer: Primary structure (Option A)

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: Antihistamines compete with histamine for receptor sites and prevent allergic reactions. Cimetidine and ranitidine are H_2 receptor antagonists (anti-ulcer drugs), not antihistamines in the allergy sense.

Step 1 — Diphenhydramine is a classic H_1 antihistamine used for treating allergies, hay fever, and motion sickness.
Step 2 — Cimetidine and ranitidine are antacids (reduce stomach acid); omeprazole is a proton pump inhibitor.
Final Answer: Diphenhydramine (Option C)

Answer: (C)

Go Back to Question 16

Q17.

Solution

Concept: The van't Hoff factor i accounts for the number of particles a solute produces in solution. Osmotic pressure is the most sensitive colligative property.

Step 1 — Part (a): $i = \frac{\text{Observed colligative property}}{\text{Calculated colligative property (assuming no dissociation)}}$. For NaCl $\rightarrow Na^+ + Cl^-$, complete dissociation gives $i = 2$.
Step 2 — Part (b): Osmotic pressure is preferred for polymers because: (i) It has a large magnitude even for very dilute solutions (polymers have very high molar masses, giving very few moles per gram). (ii) It can be measured at room temperature without heating.
Final Answer: $i = 2$ for NaCl; osmotic pressure is largest and measurable at room temperature

Answer: (See above)

Go Back to Question 17

Q18.

Solution

Concept: Electron gain enthalpy is the energy change when an electron is added. Electronegativity is the ability to attract shared electrons in a bond.

Step 1 — Part (a): The energy released when an electron is added to a neutral gaseous atom is called *electron gain enthalpy*.
Step 2 — Part (b): The tendency of an atom in a molecule to attract the shared pair of electrons towards itself is called *electronegativity*.
Final Answer: (a) electron gain enthalpy; (b) electronegativity

Answer: (See above)

Go Back to Question 18

Q19.

Solution

Concept: Heisenberg's uncertainty principle is significant for very small particles. Orbitals of different principal quantum numbers have different sizes and energies.

Step 1 — Statement 1: TRUE. The uncertainty product $\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$ is negligible for macroscopic objects because h is extremely small (6.626×10^{-34} J s).

Step 2 — Statement 2: FALSE. The $3p$ orbital is larger and has higher energy than the $2p$ orbital because $n = 3 > n = 2$.

Final Answer: (1) TRUE; (2) FALSE

Answer: (See above)

Go Back to Question 19

Q20.

Solution

Concept: Electrolytes dissociate into ions in solution. Strong electrolytes dissociate completely; non-electrolytes do not dissociate at all.

Step 1 — Part (a): A substance that dissociates almost completely and conducts electricity very well is a *strong electrolyte* (e.g., NaCl, HCl).

Step 2 — Part (b): Glucose does not produce ions in solution, so it is a *non-electrolyte*.

Final Answer: (a) strong electrolyte; (b) non-electrolyte

Answer: (See above)

Go Back to Question 20

Q21.

Solution

Concept: The coordination number is the total number of ligand donor atoms bonded to the central metal. A chelating ligand forms a ring by binding through multiple donor atoms.

Step 1 — Part (a): In $[Co(NH_3)_6]^{3+}$, six NH_3 molecules are directly bonded to Co. This number is the *coordination number* (here, 6).

Step 2 — Part (b): A ligand that forms a ring structure by bonding through two or more donor atoms is called a *chelate* ligand (e.g., ethylenediamine, oxalate).

Final Answer: (a) coordination number; (b) chelate

Answer: (See above)

Go Back to Question 21

Q22.

Solution

Concept: Antibiotics are classified by their spectrum. Aspirin has multiple pharmacological actions.

Step 1 — Part (a): A *narrow-spectrum* antibiotic is effective against a specific group of bacteria (e.g., penicillin G effective mainly against Gram-positive bacteria). A *broad-spectrum* antibiotic acts against a wide range of both Gram-positive and Gram-negative bacteria (e.g., ampicillin, chloramphenicol).
Step 2 — Part (b): Aspirin (acetylsalicylic acid) is called multifunctional because it acts as: (i) an analgesic (pain relief), (ii) an antipyretic (fever reduction), and (iii) an anti-inflammatory agent. It also has anti-platelet (blood-thinning) properties.
Final Answer: Narrow vs broad spectrum; aspirin is analgesic + antipyretic + anti-inflammatory

$\boxed{\textbf{Answer: (See above)}}$
Go Back to Question 22

Q23.

Solution

Concept: Sulphur exists in rhombic (α) and monoclinic (β) forms. The transition temperature is where both forms are in equilibrium.

Step 1 — Part (a): The transition temperature between rhombic and monoclinic sulphur is 369 K (96°C). At this temperature, both forms coexist in equilibrium.
Step 2 — Part (b): In the S_8 crown-shaped ring, each sulphur atom is bonded to two other sulphur atoms and has two lone pairs. This gives sp^3 hybridisation.
Final Answer: (a) 369 K; (b) sp^3

$\boxed{\textbf{Answer: (See above)}}$
Go Back to Question 23

Q24.

Solution

Concept: Name reactions and tests are identified by their specific reagents and the functional groups they detect.

Step 1 — Lucas test distinguishes primary, secondary, and tertiary alcohols: (a) → (ii).
Step 2 — Hinsberg test uses benzenesulphonyl chloride to distinguish primary, secondary, and tertiary amines: (b) → (iv).
Tollens' test gives a silver mirror with aldehydes: (c) → (i).
Clemmensen reduction converts C=O to CH_2 using Zn–Hg/HCl. In the context given, carboxylic acid reduced to alcohol is better matched by another method. But looking at the options, (d) matches (iii) as Clemmensen is a reduction reaction.
Final Answer: (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii)

Answer: (See above)

Go Back to Question 24

Q25.

Solution

Concept: Fischer esterification produces an ester from a carboxylic acid and alcohol. Nucleophilic substitution of alkyl halide with KCN gives a nitrile.

Step 1 — Part (a): Fischer esterification:

$$CH_3COOH + C_2H_5OH \xrightarrow[conc.\ H_2SO_4]{\Delta} CH_3COOC_2H_5 + H_2O$$

Product: **Ethyl ethanoate** (ethyl acetate).
Step 2 — Part (b): Nucleophilic substitution:

$$CH_3CH_2Cl + KCN \rightarrow CH_3CH_2CN + KCl$$

Product: **Propanenitrile** (ethyl cyanide).
Final Answer: (a) Ethyl ethanoate $CH_3COOC_2H_5$; (b) Propanenitrile CH_3CH_2CN

Answer: (See above)

Go Back to Question 25

Q26.

Solution

Concept: Buffer solutions resist pH changes because they contain components that can neutralise added acid or base.

Step 1 — Part (a): The Henderson–Hasselbalch equation for an acidic buffer:

$$\text{pH} = \text{pK}_a + \log \frac{[\text{Salt}]}{[\text{Acid}]} = \text{p}K_a + \log \frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$$

Step 2 — Part (b): When dilute HCl is added to pure water, the H^+ ions increase dramatically (from 10^{-7} M), causing a large drop in pH. Water has no buffer capacity.
In a buffer, the added H^+ ions react with the conjugate base (CH_3COO^-):

$$\text{CH}_3COO^- + H^+ \rightarrow CH_3COOH$$

This removes most of the added H^+, so the pH changes only slightly.
Final Answer: $\text{pH} = \text{p}K_a + \log \frac{[\text{Salt}]}{[\text{Acid}]}$; buffer neutralises added acid/base

Answer: (See above)

Go Back to Question 26

Q27.

Solution

Concept: In an adiabatic process, $q = 0$. The third law of thermodynamics states that the entropy of a perfect crystal at absolute zero is zero.

Step 1 — Statement 1: TRUE. By definition, an adiabatic process is one in which no heat is exchanged ($q = 0$).
Step 2 — Statement 2: FALSE. The Third Law states that the entropy of a perfectly crystalline substance at absolute zero (0 K) is *zero*, not maximum.
Final Answer: (1) TRUE; (2) FALSE

Answer: (See above)

Go Back to Question 27

Q28.

Solution

Concept: Thermoplastics have linear or slightly branched chains held by weak van der Waals forces. Thermosetting polymers have extensive cross-linking.

Step 1 — Part (a): Thermoplastic: Softens on heating, can be remoulded repeatedly. Example: Polythene, PVC. **Thermosetting:** Once set (cross-linked), cannot be remoulded. Example: Bakelite, melamine.

Step 2 — Part (b): The monomer of polythene is **ethene** ($CH_2{=}CH_2$).

Final Answer: Thermoplastic remouldable; thermosetting not; monomer of polythene is ethene

Answer: (See above)

Go Back to Question 28

Q29.

Solution

Concept: Molarity involves volume (temperature-dependent), while molality involves mass (temperature-independent).

Step 1 — Alternative (i):

Molarity (M) = moles of solute per litre of solution. It changes with temperature because volume changes with temperature.

Molality (m) = moles of solute per kg of solvent. It does not change with temperature because mass is temperature-independent.

Therefore, **molality** is the temperature-independent concentration term.

Step 2 — Alternative (ii):

(a) *Mole fraction:* $X_i = \frac{n_i}{\sum n_i}$ (ratio of moles of component to total moles).

(b) *Mass percentage:* Mass % = $\frac{\text{Mass of component}}{\text{Total mass}} \times 100$.

Final Answer: Molality is temperature-independent; definitions of mole fraction and mass percentage as given

Answer: (See above)

Go Back to Question 29

Q30.

Solution

Concept: State functions depend only on initial and final states; path functions depend on the route taken.

Step 1 — Alternative (i): A *state function* depends only on the current state of the system, not on how it got there.
Examples of state functions: enthalpy (H), entropy (S), internal energy (U), Gibbs free energy (G).
Examples of path functions: heat (q), work (w).
Step 2 — Alternative (ii):
(a) *Standard enthalpy of combustion:* The enthalpy change when 1 mole of a substance is completely burned in excess oxygen, all substances being in their standard states.
(b) *Enthalpy of atomisation:* The enthalpy change when 1 mole of a substance is completely dissociated into its constituent atoms in the gas phase.
Final Answer: State function examples; definitions of combustion and atomisation enthalpies

Answer: (See above)

Go Back to Question 30

Q31.

Solution

Concept: Strong electrolytes show a linear increase in molar conductivity with $\sqrt{c}$. Weak electrolytes show a sharp increase at very low concentrations due to increased dissociation.

Step 1 — Alternative (i):
(a) Electrolyte A shows a linear decrease in Λ_m with increasing $\sqrt{c}$, which is characteristic of a **strong electrolyte** (Debye–Hückel–Onsager behaviour). Electrolyte B shows a curve that drops sharply at higher concentrations, characteristic of a **weak electrolyte**.
(b) For a weak electrolyte, molar conductivity increases sharply on dilution because the degree of dissociation increases significantly. At low concentrations, nearly complete dissociation occurs, releasing many more ions.
Step 2 — Alternative (ii):

$$\mathrm{E}^\circ_{\mathrm{cell}} = E^\circ_{\mathrm{cathode}} - E^\circ_{\mathrm{anode}} = E^\circ(\mathrm{Ag^+/Ag}) - E^\circ(\mathrm{Zn^{2+}/Zn})$$

$$= +0.80 - (-0.76) = +1.56 \text{ V}$$

Final Answer: (i) A is strong, B is weak; sharp rise due to increased dissociation; (ii) $E^\circ = +1.56$ V

Answer: (See above)

Go Back to Question 31

Q32.

Solution

Concept: Faraday's second law states that for the same quantity of electricity, masses of different substances deposited are proportional to their equivalent masses.

Step 1 — Alternative (i):
Faraday's Second Law: When the same quantity of electricity is passed through different electrolytes, the masses of substances deposited at the electrodes are directly proportional to their respective equivalent masses.

$$\mathrm{m}_1 \frac{}{m_2=\frac{E_1}{E_2}}$$

Example: Passing 96500 C through $AgNO_3$ and $CuSO_4$ solutions in series deposits 108 g of Ag ($E = 108$) and 31.75 g of Cu ($E = 63.5/2 = 31.75$) respectively. Ratio: $108 : 31.75 = E_{\mathrm{Ag}} : E_{\mathrm{Cu}}$.

Step 2 — Alternative (ii):
For $\mathrm{Ag}^+ + \mathrm{e}^- \longrightarrow \mathrm{Ag}$: $n = 1$, $M = 108$, $E = 108$.

$$\mathrm{m} = \mathrm{M}\ \cdot I \cdot t \frac{}{n\cdot F \implies 1.08=\frac{108\times0.5\times t}{1\times96500}}$$

$$\mathrm{t} = 1.08\ \times96500 \frac{}{108\times0.5=\frac{104220}{54}=1930\ \mathrm{s}\approx32.2\ \mathrm{minutes}}$$

Final Answer: Second law as stated; $t = 1930\ \mathrm{s} \approx 32.2$ min

Answer: (See above)

Go Back to Question 32

Q33.

Solution

Concept: Hydrogen bonding significantly increases boiling points. The structure of phosphoric acid reveals the number of ionisable protons.

Step 1 — Alternative (i): NH_3 has a higher boiling point because nitrogen is highly electronegative and small, enabling strong intermolecular *hydrogen bonding* between NH_3 molecules. PH_3 has weaker van der Waals forces (no significant hydrogen bonding because P is less electronegative and larger), so it has a lower boiling point.
Step 2 — Alternative (ii): H_3PO_4 has the structure:

One P=O double bond and three P−OH groups around phosphorus.

Oxidation state of P: $x + 3(+1) + 4(-2) = 0 \implies x = +5$.
Final Answer: (i) NH_3 has H-bonding; (ii) 3 P-OH groups, P is +5

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

Go Back to Question 33

Q34.

Solution

Concept: Interstitial compounds trap small atoms in metal lattice voids. Transition metals have high atomisation enthalpy due to strong metallic bonds from unpaired *d*-electrons.

Step 1 — Alternative (i):
Interstitial compounds are formed when small atoms (H, C, N, B) occupy the interstitial voids in the crystal lattice of transition metals.
Properties: (i) They are extremely hard and rigid (e.g., steel from carbon in iron). (ii) They have very high melting points. (iii) They retain metallic conductivity. (iv) They are chemically inert.
Step 2 — Alternative (ii):
(a) *High enthalpy of atomisation:* Transition metals have many unpaired *d*-electrons, leading to strong metallic bonding (greater interatomic interaction). More energy is needed to separate the atoms.
(b) *Catalytic activity:* Transition metals provide large surface areas for adsorption, form unstable intermediates using their variable oxidation states, and have partially filled *d*-orbitals that can interact with reactant molecules.
Final Answer: Interstitial compounds defined; high ΔH_{atom} due to strong metallic bonding; catalysis due to variable oxidation states

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

Go Back to Question 34

Q35.

Solution

Concept: The dichromate ion contains Cr in +6 oxidation state. Copper(I) disproportionates in aqueous solution. Density trends depend on atomic mass and size changes.

Step 1 — Alternative (i):
(a) Oxidation state of Cr in $Cr_2O_7^{2-}$: $2x + 7(-2) = -2 \implies 2x = 12 \implies x = +6$.
(b) When $K_2Cr_2O_7$ is heated with conc. HCl:

$$K_2Cr_2O_7 + 14HCl \rightarrow 2KCl + 2CrCl_3 + 3Cl_2 \uparrow + 7H_2O$$

Chromyl chloride vapours (CrO_2Cl_2, red-brown) may also form in the chromyl chloride test. The dichromate acts as a strong oxidising agent, oxidising Cl^- to Cl_2.

Step 2 — Alternative (ii):
(a) Cu^+ is unstable in aqueous solution because it disproportionates:

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

This occurs because the high hydration enthalpy of Cu^{2+} (due to its higher charge density) more than compensates for the second ionisation energy of Cu.
(b) Density = mass/volume. Across a period, atomic mass increases significantly while atomic size decreases (due to increasing nuclear charge). The volume decreases while mass increases, so density generally increases.
Final Answer: (i) Cr is +6; reacts with HCl to give Cl_2; (ii) Cu^+ disproportionates; density increases due to size decrease and mass increase

Answer: (See above)

Go Back to Question 35

Q36.

Solution

Concept: Ethanol is oxidised to ethanoic acid. Phenol can be converted to o-cresol via the Reimer–Tiemann reaction using $CHCl_3$.

Step 1 — Alternative (i):
(a) *Ethanol to ethanoic acid:* Oxidise ethanol with acidified potassium dichromate or alkaline $KMnO_4$:

$$\mathrm{CH_3}CH_2OH \xrightarrow{K_2Cr_2O_7/H_2SO_4} CH_3COOH$$

(b) *Phenol to 2-methylphenol (o-cresol):* This is not a direct one-step reaction. Phenol can be converted to salicylaldehyde via Reimer–Tiemann, then further converted. Alternatively, phenol $\longrightarrow$ phenoxide $\longrightarrow$ Kolbe's reaction $\longrightarrow$ salicylic acid, then decarboxylation. A simpler route: Phenol $\xrightarrow{\text{Na}}$ Sodium phenoxide. Direct conversion to o-cresol requires methylation at ortho position – this is not a standard single-step conversion typically asked at this level.
A more appropriate approach: Phenol $\xrightarrow{Zn\ dust}$ Benzene $\xrightarrow{CH_3Cl/AlCl_3}$ Toluene (methylbenzene) – but this is not o-cresol.
Actually, o-cresol is typically obtained by: $\mathrm{C_6H_5OH} \xrightarrow{\text{NaOH}} \mathrm{C_6H_5ONa} \xrightarrow{\text{CH}_3\text{I, heat}} \mathrm{C_6H_4(OH)(CH_3)}$ (Claisen rearrangement of phenyl methyl ether at high temperature gives o-cresol):

$$\mathrm{C_6}H_5OH \xrightarrow{CH_3I/NaOH} C_6H_5OCH_3 \xrightarrow{200^\circ C} o\text{-}CH_3C_6H_4OH$$

Step 2 — Alternative (ii):
(a) $\mathrm{CH_3CH_2OH} \xrightarrow[\text{573 K}]{\text{Cu}} \mathrm{CH_3CHO}$ (dehydrogenation to acetaldehyde)
(b) $\mathrm{C_6H_5OH}$ + Zn dust $\xrightarrow{\Delta}$ $\mathrm{C_6H_6}$ (reduction to benzene)
Final Answer: (i)(a) Oxidation with $K_2Cr_2O_7/H^+$; (i)(b) via anisole and Claisen rearrangement; (ii)(a) CH_3CHO; (ii)(b) C_6H_6

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

Go Back to Question 36

Q37.

Solution

Concept: $SOCl_2$ converts carboxylic acids to acid chlorides. Hydrazine reacts with ketones to form hydrazones.

Step 1 — (a) $SOCl_2$ converts $-COOH$ to $-COCl$:

$$C_6H_5COOH + SOCl_2 \rightarrow C_6H_5COCl + SO_2 + HCl$$

Product: **Benzoyl chloride** (C_6H_5COCl).

Step 2 — (b) Acetone with hydrazine at pH 4–5 forms a hydrazone:

$$CH_3COCH_3 + NH_2NH_2 \xrightarrow{pH\ 4-5} CH_3C(=NNH_2)CH_3 + H_2O$$

Product: **Acetone hydrazone** ($(CH_3)_2C{=}NNH_2$).

Final Answer: (a) Benzoyl chloride C_6H_5COCl; (b) Acetone hydrazone

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

Go Back to Question 37

Q38.

Solution

Concept: Elevation of boiling point and depression of freezing point are colligative properties that depend on the amount of solute.

Step 1 — A. *Elevation of boiling point:* When a non-volatile solute is dissolved in a solvent, the vapour pressure of the solution decreases. A higher temperature is needed to make the vapour pressure equal to atmospheric pressure. The increase in boiling point (ΔT_b) is called the elevation of boiling point:

$$\Delta T_b = K_b \cdot m$$

Step 2 — B. *Depression of freezing point:* The freezing point of a solution is lower than that of the pure solvent because the vapour pressure of the solution is lower. The decrease in freezing point (ΔT_f):

$$\Delta T_f = K_f \cdot m$$

Step 3 — C. *Relative lowering of vapour pressure:* It is the ratio of the decrease in vapour pressure to the vapour pressure of the pure solvent:

$$\mathrm{p}^{\circ} - p_{\overline{p^{\circ}=x_{\text{solute}}}}$$

This equals the mole fraction of the solute (Raoult's law).

Final Answer: Definitions of ΔT_b, ΔT_f and relative lowering of vapour pressure as given above

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

Go Back to Question 38

Q39.

Solution

Concept: Enthalpy of reaction is calculated from enthalpies of formation. The first law relates heat, work, and internal energy.

Step 1 — Alternative (i):

$$\Delta H_{\text{reaction}} = \sum \Delta H_f^\circ(\text{products}) - \sum \Delta H_f^\circ(\text{reactants})$$

= [2(-393.5) + 2(-285.8)] - [+52.3 + 3(0)]

= [-787.0 + (-571.6)] - 52.3

= -1358.6 - 52.3 = -1410.9 kJ mol^{-1}

Step 2 — Alternative (ii):
(a) First law: $\Delta U = q + w$, where ΔU is change in internal energy, q is heat, and w is work done on the system.
(b) *Extensive properties* depend on the amount of substance: mass, volume, enthalpy, entropy. *Intensive properties* do not depend on the amount: temperature, pressure, density, molar heat capacity, refractive index.
Final Answer: $\Delta H = -1410.9$ kJ mol^{-1}; $\Delta U = q + w$; extensive vs intensive as explained

Answer: (See above)

Go Back to Question 39

Q40.

Solution

Concept: PCl_3 hydrolyses in moisture. Phosphorous acid is dibasic because only −OH protons are ionisable. Fluorine's small size and high electronegativity limit its oxidation states.

Step 1 — Alternative (i):

(a) PCl_3 fumes in moist air because it reacts with water vapour to form HCl gas, which appears as white fumes:

$$\mathrm{PCl_3} + 3H_2O \rightarrow H_3PO_3 + 3HCl\uparrow$$

(b) In H_3PO_3 (structure: one P=O, two −OH, one P−H), only the two −OH protons are ionisable. The P−H bond does not ionise. Hence it is dibasic. In H_3PO_4 (three −OH groups), all three protons are ionisable, so it is tribasic.

(c) $XeOF_4$: Xe has 8 valence electrons. 1 goes to bond with O, 4 go to bonds with F, leaving 3 lone pairs (but actually 1 lone pair after forming 5 bonds with sp^3d^2 hybridisation). The structure is square pyramidal with O at the apex and hybridisation is sp^3d^2.

Step 2 — Alternative (ii):

(a) NH_3 has bond angle 107° due to strong lone pair–bond pair repulsions (N is small and electronegative, so bond pairs are closer and repulsions are significant). In PH_3, P is larger and less electronegative, so bond pairs are farther away, repulsions are weaker, and the angle is close to 90° (minimal hybridisation).

(b) Increasing order of bond strength: HI $<$ HBr $<$ HCl $<$ HF. HF is strongest because F is smallest, giving the shortest and strongest H−F bond.

(c) Fluorine is the most electronegative element and has no d-orbitals in its valence shell. It cannot expand its octet or show positive oxidation states. Other halogens have vacant d-orbitals and can promote electrons to show positive oxidation states (e.g., Cl in $HClO_4$ is +7).

Final Answer: (i) PCl_3 fumes due to HCl; H_3PO_3 has 2 ionisable H; $XeOF_4$ is sp^3d^2; (ii) bond strength order; F has no d-orbitals

Answer: (See above)

Go Back to Question 40

Q41.

Solution

Concept: IUPAC naming of organic compounds follows priority rules. PCl_5 replaces C=O with CCl_2. Cannizzaro reaction occurs in aldehydes without α-hydrogen.

Step 1 — Alternative (i):
(a) $CH_3CH(Br)CH_2CHO$: The principal functional group is −CHO (C-1). Numbering: C-1 = CHO, C-2 = CH_2, C-3 = CH(Br), C-4 = CH_3. IUPAC name: **3-Bromobutanal**.
(b) Acetone (CH_3COCH_3) with PCl_5: The C=O group is replaced by CCl_2:

$$CH_3COCH_3 + PCl_5 \longrightarrow CH_3CCl_2CH_3 + POCl_3$$

Product: **2,2-Dichloropropane** (gem-dichloride). (c) Formaldehyde (HCHO) has no α-hydrogen atoms. Aldol condensation requires at least one α-hydrogen for enolate formation. Without α-hydrogen, HCHO undergoes the Cannizzaro reaction (self-oxidation-reduction) in strong alkali:

$$2HCHO + NaOH \longrightarrow HCOONa + CH_3OH$$

Step 2 — Alternative (ii):
(a)(1) $C_6H_5NO_2 \xrightarrow{\text{Fe/HCl or Sn/HCl}} C_6H_5NH_2 + 2H_2O$
(a)(2) Gabriel phthalimide synthesis: Potassium phthalimide reacts with an alkyl halide, then alkaline hydrolysis gives the primary amine:

$$\text{Phthalimide-K}^+ + R{-}X \longrightarrow N\text{-}alkyl\ phthalimide \xrightarrow{NaOH(aq)} RNH_2 + potassium\ phthalate$$

(b) In the gas phase, basicity depends only on the $+I$ (inductive) effect: $(CH_3)_2NH > CH_3NH_2 > NH_3 > C_6H_5NH_2$
(c) Phenol + Zn dust ⟶ Benzene:

$$C_6H_5OH + Zn \xrightarrow{\Delta} C_6H_6 + ZnO$$

Final Answer: (i) 3-bromobutanal; 2,2-dichloropropane; no α-H in HCHO; (ii) aniline from nitrobenzene; Gabriel synthesis; benzene

Answer: (See above)

Go Back to Question 41

Q42.

Solution

Concept: Crystal field splitting in tetrahedral and octahedral fields differs in magnitude and pattern. Disproportionation involves simultaneous oxidation and reduction of the same element.

Step 1 — Alternative (i):
(a) $\Delta_t \approx \frac{4}{9}\Delta_o$. Tetrahedral splitting is always smaller than octahedral splitting because: (i) there are only 4 ligands instead of 6, and (ii) the ligands in tetrahedral geometry do not point directly at the d-orbitals.
(b) $Sc^{3+} = [Ar]\,3d^0$: No d-electrons $\Rightarrow$ no d-d transitions $\Rightarrow$ white/colourless.
$Ti^{3+} = [Ar]\,3d^1$: One d-electron can undergo d-d transition, absorbing visible light $\Rightarrow$ coloured (purple).
(c) *Disproportionation* is a reaction in which the same substance is simultaneously oxidised and reduced.
Example: $2Cu^{+}(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$
Another example: $3MnO_4^{2-} + 4H^{+} \rightarrow 2MnO_4^{-} + MnO_2 + 2H_2O$ (Mn goes from +6 to +7 and +4).
Step 2 — Alternative (ii):
(a) General electronic configuration of f-block: $(n-2)f^{1-14}\,(n-1)d^{0-1}\,ns^2$
(b) *Lanthanoids* are the 14 elements from Cerium ($Z = 58$) to Lutetium ($Z = 71$) in which the differentiating electron enters the $4f$ subshell.
General configuration: $[Xe]\,4f^{1-14}\,5d^{0-1}\,6s^2$
(c) Two consequences of lanthanoid contraction:
(i) The sizes of $4d$ and $5d$ series elements become very similar (e.g., Zr ≈ Hf), making them chemically similar and difficult to separate.
(ii) The basic strength of lanthanoid hydroxides decreases steadily from $La(OH)_3$ to $Lu(OH)_3$ due to increasing covalent character as size decreases.
Final Answer: $\Delta_t = \frac{4}{9}\Delta_o$; d^0 colourless, d^1 coloured; disproportionation; lanthanoids defined; consequences stated

Answer: (See above)

Go Back to Question 42

Q43.

Solution

Concept: Enzymes are biological catalysts. DNA and RNA differ in sugar, structure, and bases. The carbylamine test is specific for primary amines. **Step 1 — Alternative (i):**

(a) *Enzymes* are biological catalysts (mostly proteins) that speed up biochemical reactions with high specificity and efficiency. The enzyme that converts sucrose into glucose and fructose is **invertase** (also called sucrase):

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{invertase}} C_6H_{12}O_6 + C_6H_{12}O_6$$

(glucose + fructose) (b) *DNA vs RNA:* (1) *Sugar:* DNA contains β-D-2-deoxyribose; RNA contains β-D-ribose. (2) *Structure:* DNA is a double-stranded helix; RNA is typically single-stranded. (3) *Bases:* DNA contains A, G, C, T (thymine); RNA contains A, G, C, U (uracil instead of thymine). (c) *Essential amino acids* cannot be synthesised by the body and must be obtained from diet. Example: Valine. *Non-essential amino acids* can be synthesised by the body. Example: Glycine. **Step 2 — Alternative (ii):** (a) *Carbylamine reaction:* Primary amines react with chloroform and alcoholic KOH to form foul-smelling isocyanides:

$$R{-}NH_2 + CHCl_3 + 3KOH(alc) \xrightarrow{\Delta} R{-}NC + 3KCl + 3H_2O$$

Only **primary amines** (aliphatic and aromatic) respond to this test. (b) *Basic character of amines:* In the *gas phase*, basicity depends only on the $+I$ effect of alkyl groups: $3^\circ > 2^\circ > 1^\circ > NH_3$ (more alkyl groups push electron density onto N). In *aqueous solution*, basicity depends on both $+I$ effect and solvation of the conjugate acid. For methylamines: $2^\circ > 1^\circ > 3^\circ > NH_3$ (the 3° amine conjugate acid is poorly solvated, reducing basicity). (c) (1) $C_6H_5NH_2 + 3Br_2(aq) \rightarrow C_6H_2Br_3NH_2 \downarrow + 3HBr$ Product: **2,4,6-Tribromoaniline** (white precipitate). (2) $CH_3CH_2NH_2 + HNO_2 \xrightarrow{0-5^\circ C} [CH_3CH_2N_2^+Cl^-] \rightarrow CH_3CH_2OH + N_2 \uparrow + H_2O$ Products: **Ethanol**, nitrogen gas, and water. Primary aliphatic amines give unstable diazonium salts that decompose immediately. **Final Answer:** Enzymes as catalysts; DNA vs RNA; essential/non-essential amino acids; carbylamine test; basicity in gas vs solution; tribromoaniline; ethanol

Answer: (See above)

Go Back to Question 43

Answer Key

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