

CBSE Class 12 Chemistry Question Paper 2014 with Solution PDF-Set 56/3 - Compartment



Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)

Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) All questions are compulsory.
- (ii) Questions number 1 to 8 are very short-answer questions and carry 1 mark each.
- (iii) Questions number 9 to 18 are short-answer questions and carry 2 marks each.
- (iv) Questions number 19 to 27 are also short-answer questions and carry 3 marks each.
- (v) Questions number 28 to 30 are long-answer questions and carry 5 marks each.
- (vi) Use Log Tables, if necessary. Use of calculators is not allowed.

1. Write a distinguishing feature of a metallic solid compared to an ionic solid.

[1 mark]

Solution:

Concept:

- Electrical conduction requires charged particles that can move through the solid.
- Metallic bonding provides mobile, delocalised electrons, whereas ions in an ionic crystal occupy fixed lattice positions.

Step 1: Consider charge carriers in a metal In a metallic solid, the valence electrons are delocalised throughout the lattice. They move under an applied potential difference, so a metal conducts electricity even in its solid state.

Step 2: Compare an ionic crystal In a solid ionic compound, both the cations and anions are held at their lattice sites. They cannot migrate to carry current. Ionic compounds conduct when molten or in aqueous solution because the ions then become mobile.

Step 3: Conclusion A metallic solid conducts electricity in the solid state, whereas an ionic solid does not.

Quick Tip to Solve: Specify the physical state when comparing conductivity: solid ionic compounds lack mobile ions.

2. What are enzymes?

[1 mark]

Solution:

Concept:

- A catalyst increases the rate of a reaction without being consumed in the overall reaction.
- Biological catalysts act in living systems and usually show specificity for a substrate and its reaction.

Step 1: Identify the biological role Living cells carry out many chemical reactions under mild conditions. Enzymes make these reactions sufficiently rapid by providing a pathway with lower activation energy; they are not used up in the overall process.

Step 2: State the chemical nature Enzymes are generally globular proteins. Their active sites bind particular substrates, which accounts for their high specificity. For example, invertase catalyses the hydrolysis of sucrose to glucose and fructose.

Step 3: Conclusion Enzymes are biological catalysts, generally globular proteins, that accelerate biochemical reactions in living organisms.

Quick Tip to Solve: Define enzymes by their catalytic function first, then mention their usual protein nature.

3. Name the chief ores of aluminium and zinc.

[1 mark]

Solution:

Concept:

- An ore is a naturally occurring mineral from which a metal can be extracted conveniently and economically.
- The chief ore is the principal commercial source of the metal; its name should be paired with its chemical composition.

Step 1: Identify the chief aluminium ore Aluminium is extracted chiefly from bauxite, a hydrated aluminium oxide. Its commonly used school-level formula is $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$. The ore is first purified to obtain alumina for electrolytic reduction.

Step 2: Identify the chief zinc ore Zinc is extracted chiefly from zinc blende, also called sphalerite. It is zinc sulphide, ZnS . Roasting converts the sulphide into zinc oxide, which can then be reduced to zinc.

Step 3: Conclusion The chief ores are **bauxite**, $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$, for aluminium and **zinc blende**, ZnS , for zinc.

Quick Tip to Solve: Pair aluminium with hydrated oxide bauxite and zinc with sulphide zinc blende; do not interchange the ores.

4. Draw the structure of PCl_5 (s) molecule.

[1 mark]

Solution:

Concept:

- The structure of phosphorus pentachloride depends on its physical state: the solid has an ionic constitution.
- In solid PCl_5 , the ions are tetrahedral $[\text{PCl}_4]^+$ and octahedral $[\text{PCl}_6]^-$.

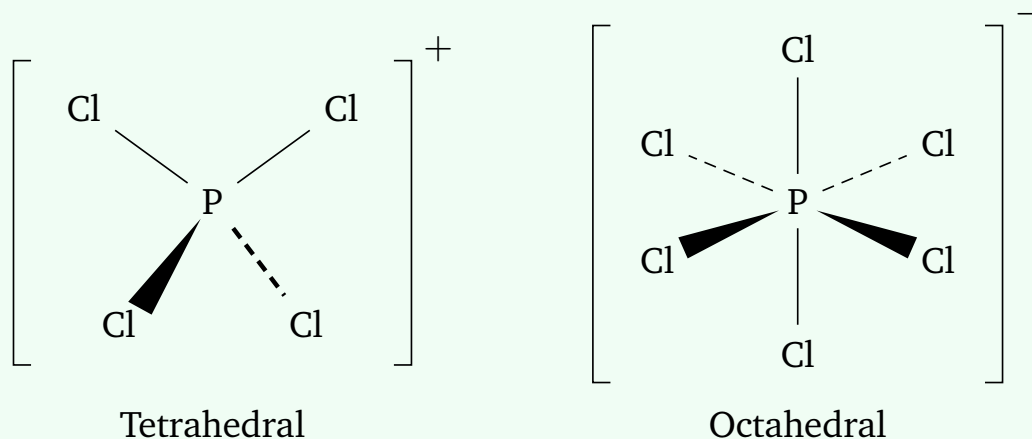
Step 1: Identify the solid-state species In the solid, two formula units redistribute chloride to give a cation and an anion:



Thus the solid must be represented by these two ions rather than by an isolated five-coordinate molecule.

Step 2: Draw the two coordination geometries The phosphorus atom in $[\text{PCl}_4]^+$ is bonded to four chlorine atoms in a tetrahedral arrangement. In $[\text{PCl}_6]^-$, phosphorus is bonded to six chlorine atoms arranged octahedrally, with four equatorial and two axial positions. Wedges and dashed bonds indicate bonds directed out of and behind the paper.

Quick Tip to Solve: Check the state symbol first: solid PCl_5 requires two ionic structures, not the gaseous trigonal-bipyramidal molecule.



Solid-state ions: tetrahedral cation and octahedral anion

Step 3: Conclusion Solid PCl_5 consists of tetrahedral $[\text{PCl}_4]^+$ cations and octahedral $[\text{PCl}_6]^-$ anions, as shown.

Quick Tip to Solve: Check the state symbol first: solid PCl_5 requires two ionic structures, not the gaseous trigonal-bipyramidal molecule.

5. Give a test to distinguish between propan-2-one and pentan-3-one.

[1 mark]

Solution:

Concept:

- The iodoform test detects methyl ketones, RCOCH_3 , where R is an alkyl or aryl group: iodine and aqueous sodium hydroxide produce yellow iodoform, CHI_3 .
- A ketone lacking a methyl group directly attached to its carbonyl carbon does not give this test.

Step 1: Apply the iodoform test Warm separate samples with iodine and aqueous sodium hydroxide. Propan-2-one, CH_3COCH_3 , contains the required methyl ketone group and gives a yellow precipitate of iodoform:



Step 2: Compare the second ketone Pentan-3-one has the structure $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$. Its carbonyl carbon is attached to ethyl groups on both sides, so it has no methyl group directly bonded to the carbonyl carbon and gives no yellow iodoform precipitate under the same conditions.

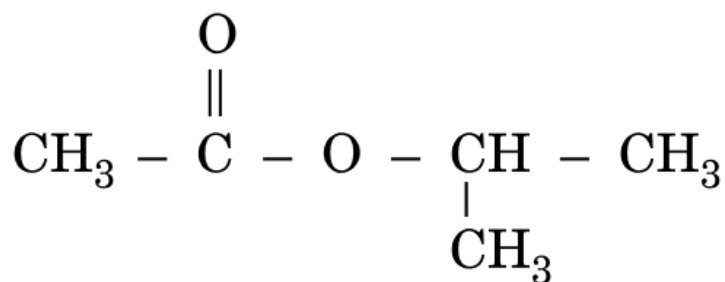
Step 3: Conclusion The iodoform test distinguishes the two: propan-2-one gives yellow CHI_3 , whereas pentan-3-one gives no precipitate.

Quick Tip to Solve: Inspect the groups directly next to the carbonyl carbon: a terminal methyl elsewhere in the chain does not ensure a positive iodoform test.

6. Name the alcohol that is used to make the following ester:



[1 mark]



Solution:

Concept:

- An ester has the general structure RCOOR' ; its OR' group comes from the alcohol $\text{R}'\text{OH}$.
- In esterification, a carboxylic acid reacts with an alcohol to form an ester and water.

Step 1: Identify the alcohol-derived group In the given ester, $\text{CH}_3\text{COOCH}(\text{CH}_3)\text{CH}_3$, the group attached to the ester oxygen is $-\text{CH}(\text{CH}_3)\text{CH}_3$. The $\text{CH}_3\text{CO}-$ portion comes from ethanoic acid.

Step 2: Recover the alcohol Replace the acyl group attached to this oxygen by hydrogen. The resulting alcohol is $\text{HOCH}(\text{CH}_3)\text{CH}_3$, or $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$. Its three-carbon chain has the hydroxyl group on carbon 2.

Step 3: Conclusion The alcohol is propan-2-ol (isopropyl alcohol).

Quick Tip to Solve: Split an ester at the acyl carbon–oxygen bond; the group on the oxygen side identifies the alcohol.

7. Define a 'Peptide linkage'.

[1 mark]

Solution:

Concept:

- Amino acids contain an amino group and a carboxyl group; these groups can undergo a condensation reaction.
- A peptide bond is an amide linkage, represented by $-\text{CO}-\text{NH}-$.

Step 1: Identify the reacting groups The carboxyl group $-\text{COOH}$ of one amino acid reacts with the amino group $-\text{NH}_2$ of another. The hydroxyl group from the carboxyl group and a hydrogen from the amino group are eliminated as one water molecule.

Step 2: Identify the linkage formed The carbonyl carbon of the first amino acid becomes bonded to the nitrogen of the second, producing the covalent $-\text{CO}-\text{NH}-$ linkage. Repetition of this condensation connects amino acid residues into peptide chains.

Step 3: Conclusion A peptide linkage is the $-\text{CO}-\text{NH}-$ bond formed between the carboxyl group of one amino acid and the amino group of another by elimination of water.

Quick Tip to Solve: Write both the linkage $-\text{CO}-\text{NH}-$ and its formation by loss of water when defining a peptide bond.

8. How does a homopolymer differ from a copolymer?

[1 mark]

Solution:

Concept:

- A monomer is a small molecule from which a polymer is formed through repeated linking.
- Homopolymers and copolymers are distinguished by the number of different monomer species used to prepare them.

Step 1: Describe a homopolymer A homopolymer is formed by polymerisation of only one kind of monomer. For example, polyethene is obtained from ethene alone; its chain contains repeating $-\text{CH}_2 - \text{CH}_2-$ units.

Step 2: Describe a copolymer A copolymer is formed from two or more different kinds of monomers. For example, Buna-S is prepared from 1,3-butadiene and styrene, so both monomer species contribute units to its polymer chain.

Step 3: Conclusion A homopolymer is made from one monomer species, whereas a copolymer is made from two or more different monomer species.

Quick Tip to Solve: Count the different starting monomer species, rather than the number of repeated units in a chain.

9. Set up Nernst equation for the standard dry cell. Using this equation show that the voltage of a dry cell has to decrease with use.

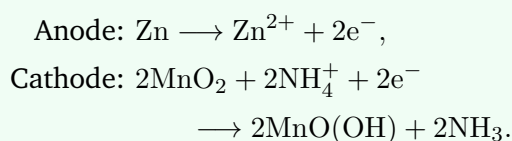
[2 marks]

Solution:

Concept:

- The Nernst equation is $E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{nF} \ln Q$, where Q is the reaction quotient and n is the number of electrons transferred.
- In a Leclanche dry cell, zinc is oxidised and manganese dioxide is reduced in an ammonium chloride paste. Activities of pure solids are unity.

Step 1: Write the cell reaction The electrode reactions can be represented as



Adding these gives $\text{Zn} + 2\text{MnO}_2 + 2\text{NH}_4^{+} \longrightarrow \text{Zn}^{2+} + 2\text{MnO}(\text{OH}) + 2\text{NH}_3$, with $n = 2$.

Step 2: Apply the Nernst equation and examine discharge With pure solids omitted, the reaction quotient is

$$Q = \frac{a_{\text{Zn}^{2+}} a_{\text{NH}_3}^2}{a_{\text{NH}_4^{+}}^2}.$$

Quick Tip to Solve: Balance the cell reaction first; two electrons give the Nernst coefficient $0.0591/2$ at 298 K.

Thus, at 298 K,

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591 \text{ V}}{2} \log_{10} \frac{a_{\text{Zn}^{2+}} a_{\text{NH}_3}^2}{a_{\text{NH}_4^+}^2}.$$

Here a denotes dimensionless activity; in a simple concentration approximation, activities are replaced by concentrations relative to their standard values. As the cell is used, products accumulate and ammonium ions are consumed, increasing Q . The logarithmic term subtracted from E_{cell}° therefore increases.

Step 3: Conclusion The dry-cell voltage decreases with use because discharge increases the reaction quotient Q , so the Nernst equation gives a progressively smaller E_{cell} .

Quick Tip to Solve: Balance the cell reaction first; two electrons give the Nernst coefficient $0.0591/2$ at 298 K.

10. A reaction is of second order with respect to its reactant. How will its reaction rate be affected if the concentration of the reactant is

(i) doubled

(ii) reduced to half?

[2 marks]

Solution:

Concept:

- For a reaction of second order with respect to reactant A , the rate law is $r = k[A]^2$, where k is the rate constant and $[A]$ is the reactant concentration.
- At constant temperature, k remains unchanged. If the concentration changes by a factor f , the rate changes by the factor f^2 , with other conditions fixed.

Step 1: Double the concentration Let the original concentration be c , so that the original rate is $r = kc^2$. When the concentration is doubled to $2c$, the new rate is

$$r_1 = k(2c)^2 = 4kc^2 = 4r.$$

Equivalently, $r_1/r = (2c/c)^2 = 4$. Thus doubling the concentration makes the reaction four times as fast under the same conditions.

Step 2: Reduce the concentration to half When the concentration is reduced from c to $c/2$, the new rate is

$$r_2 = k\left(\frac{c}{2}\right)^2 = \frac{kc^2}{4} = \frac{r}{4}.$$

Equivalently, $r_2/r = ((c/2)/c)^2 = 1/4$. The square applies to the entire concentration factor, so halving concentration reduces the rate to one-quarter of its initial value.

Step 3: Conclusion (i) The rate becomes $\boxed{4r}$, four times the original rate. (ii) The rate becomes $\boxed{r/4}$, one-quarter of the original rate.

Quick Tip to Solve: For an order-two rate law, square the concentration multiplier: $2^2 = 4$ and $(1/2)^2 = 1/4$.

11(a). Describe the underlying principle of each of the following processes:

(i) Recovery of silver from the solution obtained by leaching silver ore with a solution of NaCN

(ii) Electrolytic refining of a crude metal

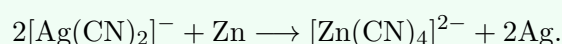
[2 marks]

Solution:

Concept:

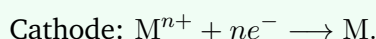
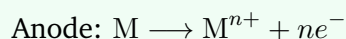
- Silver recovery uses displacement: a more reactive metal reduces silver(I) in its cyanide complex to metallic silver.
- Electrolytic refining uses selective anodic dissolution of an impure metal and deposition of pure metal at the cathode.

Step 1: (i) Recover silver from the cyanide leach The leach contains soluble dicyanoargentate(I), $[\text{Ag}(\text{CN})_2]^-$. Adding zinc displaces silver because zinc is more readily oxidised than silver. Zinc supplies electrons to reduce silver(I) to silver metal, while zinc enters solution as its cyanide complex:



Thus recovery is a redox displacement, rather than evaporation of the solution.

Step 2: (ii) Refine a crude metal electrolytically The impure metal is made the anode, a thin sheet of pure metal the cathode, and a solution of a suitable salt of the metal the electrolyte. On passing current, metal dissolves from the anode and deposits in pure form on the cathode:



Under suitable conditions, more reactive impurities remain in solution, whereas less reactive impurities settle below the anode as anode mud.

Step 3: Conclusion (i) Silver is recovered by reduction and displacement with zinc. (ii) Electrolytic refining transfers metal selectively from an impure anode to a pure cathode.

Quick Tip to Solve: For refining, remember impure anode loses metal and pure cathode gains metal; for cyanide leach, write the zinc displacement equation.

OR

11(b). Describe the principle involved in each of the following processes:

(i) Zone refining of a metal

(ii) Vapour phase refining of metals

[2 marks]

Solution:

Concept:

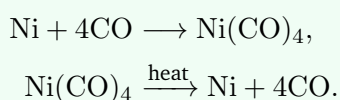
- Zone refining depends on impurities being more soluble in molten metal than in the solid metal.
- Vapour phase refining separates a metal through formation and subsequent decomposition of a

Quick Tip to Solve: State the solubility difference for zone refining, but the two chemical requirements for vapour phase refining.

volatile compound.

Step 1: (i) Principle of zone refining A narrow region of an impure metal rod is melted with a movable heater. As the heater moves along the rod, pure metal crystallises behind it, while impurities preferentially remain in the molten zone. Consequently, the moving liquid zone carries impurities towards one end of the rod. Repeated passage of the molten zone concentrates impurities at that end, which is then cut off. This method is used to obtain highly pure semiconductor materials such as silicon and germanium.

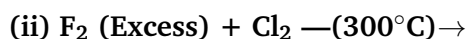
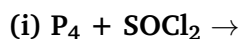
Step 2: (ii) Principle of vapour phase refining The impure metal is first converted into a volatile compound by reaction with a suitable reagent. This compound is separated from nonvolatile impurities and then decomposed under different conditions to regenerate pure metal. The essential requirements are that the metal should form a volatile compound with the reagent and that this compound should decompose readily to give back the metal. For example, in the Mond process nickel forms volatile nickel tetracarbonyl, which decomposes on heating:



Step 3: Conclusion Zone refining exploits unequal solubility of impurities in solid and molten metal; vapour phase refining exploits formation and decomposition of a volatile metal compound.

Quick Tip to Solve: State the solubility difference for zone refining, but the two chemical requirements for vapour phase refining.

12. Complete the following chemical equations:



[2 marks]

Solution:

Concept:

- White phosphorus reacts with thionyl chloride to form phosphorus trichloride, sulphur dioxide and disulphur dichloride.
- Fluorine forms interhalogen compounds with chlorine; excess fluorine at 300°C gives chlorine trifluoride.

Step 1: (i) Reaction of phosphorus with thionyl chloride The products are PCl_3 , SO_2 and S_2Cl_2 . Balance phosphorus first with four molecules of phosphorus trichloride, and then balance sulphur, oxygen and chlorine:

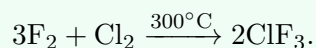


The two sides each contain four P atoms, eight S atoms, eight O atoms and sixteen Cl atoms.

Step 2: (ii) Reaction of excess fluorine with chlorine At the stated temperature, excess fluorine produces chlorine trifluoride, ClF_3 , rather than chlorine monofluoride. Since one chlorine molecule

Quick Tip to Solve: In part (ii), use both clues: excess fluorine and the stated temperature select chlorine trifluoride; then balance fluorine last.

supplies two chlorine atoms, the equation requires two molecules of ClF_3 and hence three molecules of fluorine:



This balances both the six fluorine atoms and the two chlorine atoms.

Step 3: Conclusion (i) $\text{P}_4 + 8\text{SOCl}_2 \rightarrow 4\text{PCl}_3 + 4\text{SO}_2 + 2\text{S}_2\text{Cl}_2$.

(ii) $3\text{F}_2 + \text{Cl}_2 \xrightarrow{300^\circ\text{C}} 2\text{ClF}_3$.

Quick Tip to Solve: In part (ii), use both clues: excess fluorine and the stated temperature select chlorine trifluoride; then balance fluorine last.

13. Assign reasons for the following:

(i) Transition metals and many of their compounds act as good catalysts.

(ii) Transition metals generally form coloured compounds.

[2 marks]

Solution:

Concept:

- A catalyst provides an alternative reaction pathway of lower activation energy and is regenerated during the reaction.
- In a ligand field, the five d orbitals split into groups of different energies; visible-light absorption can promote a d electron between them.

Step 1: (i) Explain catalytic activity Transition metals show variable oxidation states and can form intermediate compounds with reactants. By undergoing successive oxidation and reduction steps, a metal ion can provide an alternative reaction pathway with lower activation energy and then return to its original state. Finely divided transition metals also adsorb reactant molecules on their surfaces. Adsorption brings reactants together and can weaken their bonds, facilitating reaction. For example, iron catalyses ammonia synthesis and vanadium(V) oxide catalyses oxidation of sulphur dioxide.

Step 2: (ii) Explain the colour of compounds In many transition-metal compounds, the metal ion has partially filled d orbitals. The surrounding ligands split the d orbitals into sets of unequal energy. An electron absorbs a photon of suitable energy and moves from a lower to a higher d level:

$$\Delta E = h\nu,$$

where ΔE is the energy separation, h is Planck's constant and ν is the frequency absorbed. When this absorption is in the visible region, the transmitted or reflected light has the complementary colour. This explains the general trend; ions with d^0 or d^{10} configurations cannot undergo these d-d transitions, though other mechanisms may produce colour.

Step 3: Conclusion (i) Variable oxidation states, intermediate formation and surface adsorption account for catalytic activity. (ii) Visible-light absorption during d-d transitions commonly causes colour.

Quick Tip to Solve: Connect catalysis to variable oxidation states and adsorption; connect colour to partially filled, ligand-split d orbitals.

14. Write the structures of the following organic halogen compounds:

(i) p-Bromochlorobenzene

(ii) 1-Chloro-4-ethylcyclohexane

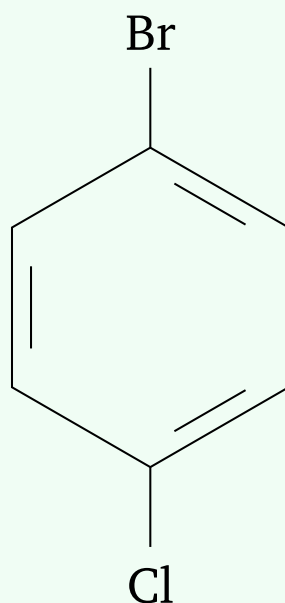
[2 marks]

Solution:

Concept:

- The prefix para, written *p*, places two substituents at positions 1 and 4 of a benzene ring, opposite one another.
- In cyclohexane all six ring bonds are single bonds. Number the ring from the carbon carrying chlorine so that the ethyl group is on carbon 4.

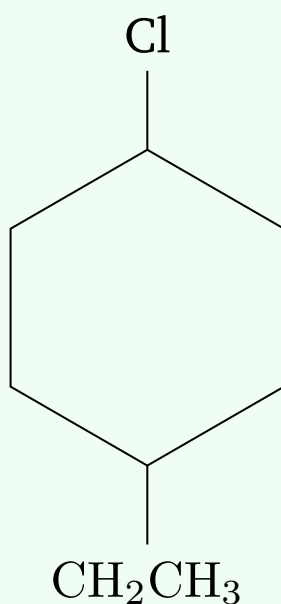
Step 1: (i) Construct p-bromochlorobenzene Draw a six-membered benzene ring with three alternating double bonds. Attach Br to one carbon and Cl to the opposite carbon; these are the 1,4 positions. The four remaining ring carbons each carry one hydrogen, giving the condensed representation $p\text{-BrC}_6\text{H}_4\text{Cl}$.



(i) *p*-Bromochlorobenzene

Step 2: (ii) Construct 1-chloro-4-ethylcyclohexane Draw a saturated six-membered carbon ring. Attach Cl at carbon 1 and CH_2CH_3 at the opposite carbon, carbon 4. Each substituted ring carbon is CH, while each of the other four ring carbons is CH_2 . The name does not specify cis or trans stereochemistry, so an ordinary planar structural drawing is sufficient.

Quick Tip to Solve: First identify whether the parent ring is aromatic or saturated; then place the two substituents on opposite ring carbons for positions 1 and 4.



(ii) 1-Chloro-4-ethylcyclohexane

Step 3: Conclusion The required structures are the 1,4-substituted benzene and cyclohexane rings shown above, respectively.

Quick Tip to Solve: First identify whether the parent ring is aromatic or saturated; then place the two substituents on opposite ring carbons for positions 1 and 4.

15. (i) Arrange the following compounds in an increasing order of basic strength:

$\text{C}_6\text{H}_5\text{NH}_2$, $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$, $(\text{C}_2\text{H}_5)_2\text{NH}$ and CH_3NH_2

(ii) Arrange the following compounds in a decreasing order of $\text{p}K_b$ values:

$\text{C}_2\text{H}_5\text{NH}_2$, $\text{C}_6\text{H}_5\text{NHCH}_3$, $(\text{C}_2\text{H}_5)_2\text{NH}$ and $\text{C}_6\text{H}_5\text{NH}_2$

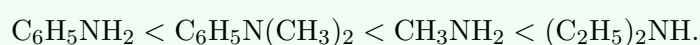
[2 marks]

Solution:

Concept:

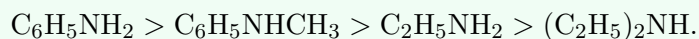
- Basicity measures the readiness of the nitrogen lone pair to accept a proton. Delocalisation of this pair into a benzene ring lowers the basicity of aromatic amines.
- Alkyl groups exert an electron-releasing inductive effect. Also, $\text{p}K_b = -\log_{10} K_b$, so a stronger base has a smaller $\text{p}K_b$.

Step 1: (i) Compare the basic strengths Aniline and N,N-dimethylaniline both have the nitrogen lone pair conjugated with the benzene ring and are weaker bases than the aliphatic amines listed. The methyl groups increase electron density at nitrogen in N,N-dimethylaniline, making it stronger than aniline. Among the two aliphatic amines, diethylamine is stronger than methylamine in aqueous solution, with its alkyl groups increasing the availability of the lone pair. Hence the increasing order is



Quick Tip to Solve: Rank basic strength first, then reverse the inequality for $\text{p}K_b$; an aromatic nitrogen lone pair is less available because of resonance.

Step 2: (ii) Relate basic strength to the requested pK_b order The aromatic amines again have lower basic strengths than the aliphatic amines. N-Methylaniline is stronger than aniline because of the electron-releasing methyl group, while diethylamine is stronger than ethylamine in aqueous solution. Thus their basic strength increases in the order aniline, N-methylaniline, ethylamine, diethylamine. Reversing basic strength gives decreasing pK_b:



Step 3: Conclusion (i) Basic strength: $\text{C}_6\text{H}_5\text{NH}_2 < \text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2 < \text{CH}_3\text{NH}_2 < (\text{C}_2\text{H}_5)_2\text{NH}$.
(ii) pK_b: $\text{C}_6\text{H}_5\text{NH}_2 > \text{C}_6\text{H}_5\text{NHCH}_3 > \text{C}_2\text{H}_5\text{NH}_2 > (\text{C}_2\text{H}_5)_2\text{NH}$.

Quick Tip to Solve: Rank basic strength first, then reverse the inequality for pK_b; an aromatic nitrogen lone pair is less available because of resonance.

16. What are ambident nucleophiles? Explain with an example.

[2 marks]

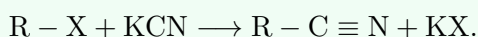
Solution:

Concept:

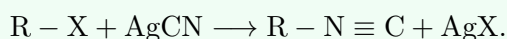
- A nucleophile donates an electron pair to an electron-deficient centre to form a covalent bond.
- An ambident nucleophile has two alternative donor atoms through which it can attack an electrophile. In a particular substitution it forms the new bond through one of these atoms.

Step 1: Define an ambident nucleophile Ambident nucleophiles possess two different nucleophilic centres. Consequently, the same nucleophilic species can give different connectivity in its substitution products depending on which donor atom makes the bond. The cyanide ion, CN^- , is an example: it can attack through either its carbon atom or its nitrogen atom.

Step 2: Illustrate the two possible modes of attack When a haloalkane $\text{R} - \text{X}$ reacts with predominantly ionic KCN, the carbon end of cyanide attacks the carbon carrying the halogen, forming an alkyl cyanide (nitrile):



With predominantly covalent AgCN, the carbon end is bound to silver and the nitrogen end attacks, so the main product is an alkyl isocyanide:



Here R is an alkyl group and X a halogen. The two products demonstrate bonding through different atoms of the cyanide group.

Step 3: Conclusion Ambident nucleophiles attack through either of two different donor atoms; CN^- is an example, giving $\text{R} - \text{C} \equiv \text{N}$ through carbon and $\text{R} - \text{N} \equiv \text{C}$ through nitrogen.

Quick Tip to Solve: For cyanide, inspect the atom bonded directly to R: R-CN is a nitrile, whereas R-NC is an isocyanide.

17. Write the names and structures of monomers used for getting the following polymers:

(i) Buna-S

(ii) Nylon-6, 6

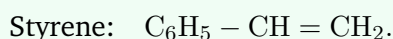
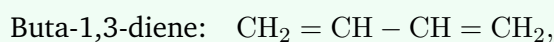
[2 marks]

Solution:

Concept:

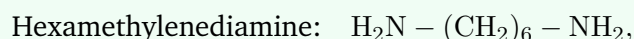
- Monomers are the small molecules that combine to form a polymer. Buna-S is an addition copolymer made from a conjugated diene and a vinyl aromatic compound.
- Nylon-6,6 is a condensation polyamide made from a diamine and a dicarboxylic acid, each containing six carbon atoms. Amino and carboxyl groups form amide links with elimination of water.

Step 1: (i) Monomers of Buna-S The two monomers are buta-1,3-diene (1,3-butadiene) and styrene (phenylethene). Their condensed structural formulae are



Both contain carbon-carbon double bonds that participate in addition copolymerisation. The phenyl group of styrene remains a side group in the resulting polymer.

Step 2: (ii) Monomers of nylon-6,6 The two monomers are hexamethylenediamine (hexane-1,6-diamine) and adipic acid (hexanedioic acid). Their condensed structural formulae are



Each monomer has a reactive group at both ends, allowing chain growth by successive amide-link formation. In adipic acid, the two carboxyl carbon atoms and four methylene carbon atoms give six carbons in total.

Step 3: Conclusion Buna-S: buta-1,3-diene and styrene. Nylon-6,6: hexamethylenediamine and adipic acid, with the structures given above.

Quick Tip to Solve: In nylon-6,6, count both carboxyl carbons of adipic acid; its central chain has four methylene groups, whereas the diamine has six.

18. Give a chemical test to distinguish between each of the following pairs of compounds:

(i) Ethylamine and Aniline

(ii) Aniline and Benzylamine

[2 marks]

Solution:

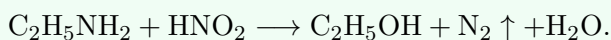
Concept:

- Primary aliphatic amines react with nitrous acid to liberate nitrogen gas, whereas aniline forms a diazonium salt stable in ice-cold solution.

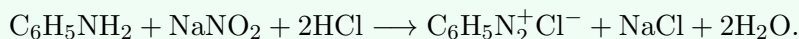
Quick Tip to Solve: Keep the test ice-cold; distinguish aniline by direct attachment of $-\text{NH}_2$ to the ring, not merely by the presence of a benzene ring.

- Prepare nitrous acid in situ using aqueous NaNO_2 and dilute HCl , keeping the temperature at 273–278 K.

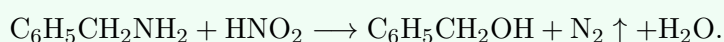
Step 1: (i) Ethylamine and aniline Add ice-cold sodium nitrite and dilute hydrochloric acid to separate samples. Ethylamine produces brisk effervescence of colourless nitrogen gas, forming ethanol:



Aniline instead forms benzenediazonium chloride without nitrogen evolution at this low temperature:



Step 2: (ii) Aniline and benzylamine Repeat the same cold nitrous-acid test. Benzylamine is a primary aliphatic amine because its amino group is attached to the side-chain carbon. It evolves nitrogen gas and gives benzyl alcohol:



Aniline forms the cold diazonium-salt solution without gas evolution, as in part (i). Keep both samples cold: warming aniline's diazonium salt would also liberate nitrogen and obscure this distinction.

Step 3: Conclusion The cold nitrous-acid test distinguishes both pairs: ethylamine and benzylamine evolve N_2 , while aniline forms benzenediazonium chloride without gas evolution at 273–278 K.

Quick Tip to Solve: Keep the test ice-cold; distinguish aniline by direct attachment of $-\text{NH}_2$ to the ring, not merely by the presence of a benzene ring.

19. Iron has a body centred cubic unit cell with a cell dimension of 286.65 pm. The density of iron is 7.874 g cm^{-3} . Use this information to calculate Avogadro's number (Gram atomic mass of Fe = 55.84 g mol^{-1}). [3 marks]

Solution:

Concept:

- A body-centred cubic (bcc) unit cell contains $z = 8(1/8) + 1 = 2$ atoms: eight shared corner atoms and one complete body-centre atom.
- For molar mass M , unit-cell edge a , density ρ , and Avogadro constant N_A , the cell mass is zM/N_A and cell volume is a^3 . Hence $\rho = zM/(N_A a^3)$.

Step 1: Convert the edge length and calculate the cell volume The density is in g cm^{-3} , so express the cell edge in centimetres. Since $1 \text{ pm} = 10^{-10} \text{ cm}$,

$$a = 286.65 \times 10^{-10} \text{ cm} = 2.8665 \times 10^{-8} \text{ cm}.$$

The cubic cell volume is therefore

$$V = a^3 = (2.8665 \times 10^{-8})^3 = 2.35535 \times 10^{-23} \text{ cm}^3.$$

Quick Tip to Solve: For a bcc cell put $z = 2$, and convert pm to cm before cubing because the given density uses cubic centimetres.

The exponent must also be cubed; it is 10^{-24} before incorporating the cube of 2.8665.

Step 2: Relate the mass of a cell to its two iron atoms Using $z = 2$, $M = 55.84 \text{ g mol}^{-1}$, and $\rho = 7.874 \text{ g cm}^{-3}$, rearrange the density equation:

$$N_A = \frac{zM}{\rho a^3} = \frac{2 \times 55.84}{7.874 \times 2.35535 \times 10^{-23}} = 6.0218 \times 10^{23} \text{ mol}^{-1}.$$

Equivalently, the cell mass is $\rho a^3 = 1.85460 \times 10^{-22} \text{ g}$, which corresponds to two atoms of iron. In the density expression, grams cancel and the remaining unit is mol^{-1} .

Step 3: Conclusion Avogadro's number calculated from the given data is $N_A \approx 6.022 \times 10^{23} \text{ mol}^{-1}$.

Quick Tip to Solve: For a bcc cell put $z = 2$, and convert pm to cm before cubing because the given density uses cubic centimetres.

20. For a decomposition reaction, the values of k at two different temperatures are given below:

$k_1 = 2.15 \times 10^{-8} \text{ L/(mol.s)}$ at 650 K

$k_2 = 2.39 \times 10^{-7} \text{ L/(mol.s)}$ at 700 K

Calculate the value of E_a for the reaction.

(Log 11.11 = 1.046) ($R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$)

[3 marks]

Solution:

Concept:

- The Arrhenius equation is $k = Ae^{-E_a/(RT)}$, where E_a is activation energy, A is the frequency factor, R is the gas constant and T is absolute temperature.
- For the same reaction at two temperatures, $\log_{10}(k_2/k_1) = \frac{E_a}{2.303R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$, assuming A is unchanged over this interval.

Step 1: Calculate the rate-constant ratio Identify the paired values correctly:

$$\begin{aligned} T_1 &= 650 \text{ K}, & k_1 &= 2.15 \times 10^{-8} \text{ L mol}^{-1} \text{ s}^{-1}, \\ T_2 &= 700 \text{ K}, & k_2 &= 2.39 \times 10^{-7} \text{ L mol}^{-1} \text{ s}^{-1}. \end{aligned}$$

Since both rate constants have the same units, their ratio is dimensionless:

$$\frac{k_2}{k_1} = \frac{2.39 \times 10^{-7}}{2.15 \times 10^{-8}} \approx 11.11, \quad \log_{10}(k_2/k_1) = 1.046.$$

Use the logarithm supplied in the question.

Step 2: Substitute in the two-temperature Arrhenius equation The reciprocal-temperature difference is positive:

$$\frac{1}{650} - \frac{1}{700} = \frac{50}{650 \times 700} \text{ K}^{-1}.$$

Quick Tip to Solve: Pair the larger rate constant with the higher temperature and use $1/T_1 - 1/T_2$ with $\log(k_2/k_1)$ to keep the sign positive.

Rearranging for the activation energy and substituting $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$,

$$\begin{aligned} E_a &= \frac{2.303R \log_{10}(k_2/k_1)}{1/T_1 - 1/T_2} \\ &= \frac{2.303 \times 8.314 \times 1.046 \times 650 \times 700}{50} \\ &= 1.82254 \times 10^5 \text{ J mol}^{-1}. \end{aligned}$$

The positive sign agrees with the observed increase of the rate constant on heating. Dividing by 1000 converts joules to kilojoules.

Step 3: Conclusion The activation energy is $E_a \approx 182.3 \text{ kJ mol}^{-1}$.

Quick Tip to Solve: Pair the larger rate constant with the higher temperature and use $1/T_1 - 1/T_2$ with $\log(k_2/k_1)$ to keep the sign positive.

21. The resistance of 0.01 M NaCl solution at 25°C is 200 Ω . The cell constant of the conductivity cell used is unity. Calculate the molar conductivity of the solution. [3 marks]

Solution:

Concept:

- Conductance is the reciprocal of resistance: $G = 1/R$, where R is measured in ohms and G in siemens.
- Conductivity is $\kappa = G(l/A)$, where l/A is the cell constant. For concentration c in mol L^{-1} , molar conductivity is $\Lambda_m = 1000\kappa/c$ when κ is in S cm^{-1} .

Step 1: Calculate conductance from the measured resistance The given resistance is $R = 200 \Omega$. Hence the conductance of the solution in this cell is

$$G = \frac{1}{R} = \frac{1}{200} = 5.0 \times 10^{-3} \text{ S}.$$

The reciprocal is necessary because a larger resistance corresponds to a smaller conductance.

Step 2: Use the cell constant to obtain conductivity Taking the stated unity cell constant in the conventional centimetre-based units, $l/A = 1 \text{ cm}^{-1}$, we obtain

$$\kappa = G \frac{l}{A} = (5.0 \times 10^{-3})(1) = 5.0 \times 10^{-3} \text{ S cm}^{-1}.$$

Conductivity includes the correction for the geometry of the conductivity cell.

Step 3: Convert conductivity to molar conductivity Here $c = 0.01 \text{ mol L}^{-1}$. The factor 1000 converts the litre in the concentration unit into cubic centimetres:

$$\Lambda_m = \frac{1000\kappa}{c} = \frac{1000 \times 5.0 \times 10^{-3}}{0.01} = 500 \text{ S cm}^2 \text{ mol}^{-1}.$$

Step 4: Conclusion The molar conductivity at 25°C is $\Lambda_m = 500 \text{ S cm}^2 \text{ mol}^{-1}$, equivalent to

Quick Tip to Solve: For a unity cell constant in centimetre units, use $\Lambda_m = 1000/(Rc)$; retain the factor 1000 when concentration is in mol per litre.

$$0.050 \text{ S m}^2 \text{ mol}^{-1}.$$

Quick Tip to Solve: For a unity cell constant in centimetre units, use $\Lambda_m = 1000/(Rc)$; retain the factor 1000 when concentration is in mol per litre.

22. Give reasons for the following:

- (i) Transition metals exhibit a wide range of oxidation states.
- (ii) Cobalt(II) is very stable in aqueous solutions but gets easily oxidised in the presence of strong ligands.
- (iii) Actinoids exhibit a greater range of oxidation states than lanthanoids. [3 marks]

Solution:

Concept:

- Variable oxidation states occur when electrons in orbitals of similar energy can participate in bonding or be removed successively.
- The stability of an oxidation state depends on its environment: ligands can stabilise a particular electronic configuration through crystal-field splitting and complex formation.

Step 1: (i) Variable oxidation states of transition metals The energies of the outer ns and inner $(n-1)d$ orbitals are close. Consequently, besides the ns electrons, different numbers of d electrons can also participate in bonding. This produces several oxidation states. For example, manganese exhibits oxidation states from +2 to +7 in its compounds, with different numbers of valence electrons involved. The availability of both sets of orbitals explains the wide range.

Step 2: (ii) Stability of cobalt(II) and oxidation with strong ligands In aqueous solution, cobalt(II) is relatively stable, whereas cobalt(III) is a strong oxidising species and tends to be reduced to cobalt(II). Thus simple oxidation of aqueous Co^{2+} to Co^{3+} is unfavourable. Strong-field ligands, such as CN^- , strongly stabilise the cobalt(III) complex. Cobalt(III) is $3d^6$; in a strong octahedral field it has the low-spin configuration $t_{2g}^6 e_g^0$, with a large crystal-field stabilisation. This preferential stabilisation of the higher oxidation state makes oxidation of cobalt(II) much easier in the presence of such ligands.

Step 3: (iii) Wider range of oxidation states in actinoids The $5f$, $6d$ and $7s$ orbitals of actinoids have comparable energies, especially in the earlier members. Different numbers of their electrons can therefore participate in bonding. In lanthanoids, the $4f$ electrons are more deeply buried and are less available for bonding; the +3 state consequently predominates, with only limited occurrence of other states. Actinoids therefore display a greater range of oxidation states than lanthanoids.

Step 4: Conclusion The reasons are: (i) similar energies of ns and $(n-1)d$ orbitals, (ii) strong-ligand stabilisation of low-spin d^6 cobalt(III), and (iii) the comparable energies and greater bonding availability of $5f$, $6d$ and $7s$ electrons in actinoids.

Quick Tip to Solve: Link variable oxidation states to orbital energies; for cobalt, explicitly explain how a strong ligand stabilises the oxidation product, cobalt(III).

23(a). Giving appropriate examples, explain how the two types of processes of adsorption (physisorption and chemisorption) are influenced by the prevailing temperature, the surface area of adsorbent and the activation energy of the process?

[3 marks]

Solution:

Concept:

- Physisorption holds the adsorbate on the surface by weak van der Waals forces, whereas chemisorption involves the formation of chemical bonds with the surface.
- Both processes are generally exothermic and occur at the surface. The accessible surface area controls the number of sites, while an activation barrier controls how readily adsorption begins.

Step 1: Influence of temperature Physisorption is favoured at low temperature. As temperature increases, weakly held molecules escape from the surface, so the extent of physisorption decreases at fixed gas pressure. For example, gases such as nitrogen are physically adsorbed more readily on charcoal at low temperature. Chemisorption often requires an initial rise in temperature to overcome its activation barrier; its rate and observed uptake can therefore initially increase. Once adsorption equilibrium is established, sufficiently high temperature favours desorption because adsorption is exothermic. For example, the chemisorption of hydrogen on nickel requires activation and is promoted initially by warming.

Step 2: Influence of the surface area of the adsorbent For both types, a larger accessible surface area provides more adsorption sites and increases adsorption for a given mass of adsorbent under comparable conditions. Finely divided or porous solids therefore adsorb more than compact pieces. Activated charcoal has a large surface area and physically adsorbs gases efficiently. Finely divided nickel supplies more exposed sites for the chemisorption of hydrogen than a compact nickel piece of the same mass.

Step 3: Influence of activation energy Physisorption normally needs no appreciable activation energy because it does not involve forming chemical bonds; it can occur readily even at low temperature. Chemisorption usually has an appreciable activation energy associated with bond rearrangement or dissociation of adsorbate molecules. For example, hydrogen can dissociate on nickel and form surface bonds. Heating helps molecules overcome this barrier, explaining the initial temperature dependence of activated chemisorption.

Step 4: Conclusion Physisorption is favoured by low temperature and has negligible activation energy. Chemisorption usually requires activation and may increase initially on warming. Both are enhanced by increasing the accessible surface area; at sufficiently high temperature, exothermic adsorption is opposed by desorption.

Quick Tip to Solve: Separate the initial kinetic effect of warming on chemisorption from the equilibrium effect: overcoming a barrier helps initially, but high temperature favours desorption.

23(b). Explain clearly how the phenomenon of adsorption finds application in

(i) production of vacuum in a vessel

(ii) heterogeneous catalysis

(iii) froth floatation process in metallurgy

[3 marks]

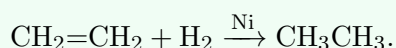
Solution:

Concept:

- Adsorption is the accumulation of molecules at the surface of a solid or liquid; a porous solid has a large surface area and can therefore adsorb appreciable quantities of a gas.
- Selective adsorption changes the concentration or wetting properties at a surface. This accounts for surface catalysis and the separation of sulphide ores from gangue.

Step 1: (i) Production of vacuum A vessel is first partially evacuated with a vacuum pump. Activated charcoal is then exposed to the residual gas in the vessel. Its large porous surface adsorbs the remaining gas molecules, reducing the number of molecules in the gas phase and hence the pressure. Cooling the charcoal increases physical adsorption, so a higher vacuum can be obtained.

Step 2: (ii) Heterogeneous catalysis Reactant molecules are adsorbed on the surface of a solid catalyst. Adsorption brings them close together and weakens their bonds; reaction then occurs by a pathway of lower activation energy. The products desorb, freeing the active sites for further reaction. For example, hydrogen and ethene adsorb on finely divided nickel, which catalyses their conversion into ethane:



Step 3: (iii) Froth floatation In concentrating sulphide ores, the powdered ore is agitated with water and a small quantity of pine oil, and air is blown through the mixture. Oil is preferentially adsorbed on the sulphide ore particles, while gangue is preferentially wetted by water. The oil-wetted ore particles attach to air bubbles and rise with the froth, which is skimmed off; the water-wetted gangue remains behind and settles.

Step 4: Conclusion Adsorption removes residual gases to produce a high vacuum, provides active sites for heterogeneous catalytic reactions, and enables the selective flotation of sulphide ore particles away from gangue.

Quick Tip to Solve: For each application, identify what is adsorbed and explain the resulting change: gas removal, surface reaction, or selective wetting.

24. Write down the IUPAC names of the following complexes and also give stereochemistry and magnetic moment of the complexes:



(At. Nos. Cr = 24, Mn = 25, Co = 27, py = pyridine)

[3 marks]

Solution:

Concept:

- Find the metal oxidation state using the ligand charges: NH_3 and pyridine are neutral, while Cl^- and CN^- carry charge -1 . All three complexes have coordination number six and octahedral geometry.
- The spin-only magnetic moment is $\mu = \sqrt{n(n+2)} \text{ BM}$, where n is the number of unpaired electrons. In an octahedral field the lower orbitals are t_{2g} , and the higher orbitals are e_g .

Step 1: (i) Pentaamminechloridocobalt(III) chloride The two outer chloride ions show that the complex ion is $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$. Thus $x - 1 = +2$, giving cobalt oxidation state $+3$ and configuration $3d^6$. The complex is low spin, with configuration $t_{2g}^6 e_g^0$; all electrons are paired. It is octahedral ($d^2 sp^3$ hybridisation in valence-bond terminology), diamagnetic, and

$$\mu = \sqrt{0(0+2)} = 0 \text{ BM.}$$

Its IUPAC name is pentaamminechloridocobalt(III) chloride.

Step 2: (ii) Trichloridotris(pyridine)chromium(III) This complex is neutral, so $x + 3(-1) = 0$, giving chromium oxidation state $+3$. Chromium(III) is $3d^3$, and its octahedral configuration is $t_{2g}^3 e_g^0$, with three unpaired electrons. Its geometry is octahedral ($d^2 sp^3$); the formula permits facial and meridional isomers, but does not specify one. It is paramagnetic:

$$\mu = \sqrt{3(3+2)} = \sqrt{15} \approx 3.87 \text{ BM.}$$

The IUPAC name is trichloridotris(pyridine)chromium(III).

Step 3: (iii) Potassium hexacyanidomanganate(II) The four potassium ions require an anion of charge -4 . Hence $x + 6(-1) = -4$, giving manganese oxidation state $+2$ and configuration $3d^5$. Cyanide is a strong-field ligand, so the octahedral complex is low spin: $t_{2g}^5 e_g^0$, with one unpaired electron. Its geometry is octahedral ($d^2 sp^3$), and it is paramagnetic:

$$\mu = \sqrt{1(1+2)} = \sqrt{3} \approx 1.73 \text{ BM.}$$

The anionic complex takes the metal ending manganate; its IUPAC name is potassium hexacyanido-manganate(II).

Step 4: Conclusion All three complexes are octahedral. Their spin-only magnetic moments, in the printed order, are 0, 3.87 and 1.73 BM, respectively; their names are given in the corresponding steps.

Quick Tip to Solve: Determine oxidation state before counting d electrons; cyanide makes the manganese(II) complex low spin, despite its d^5 configuration.

25. How are the following conversions carried out?

(i) Propene to Propan-2-ol

(ii) Ethylmagnesium chloride to Propan-1-ol

(iii) Benzyl chloride to Benzyl alcohol

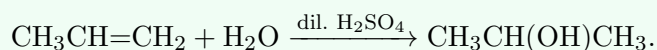
[3 marks]

Solution:

Concept:

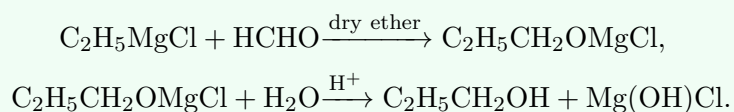
- Acid-catalysed hydration adds water across an unsymmetrical alkene according to Markovnikov orientation: hydrogen enters the carbon already bearing more hydrogen atoms.
- A Grignard reagent reacts with methanal to give, after acidic hydrolysis, a primary alcohol with one carbon more than its alkyl group. Aqueous hydroxide converts a benzyl halide into benzyl alcohol by nucleophilic substitution.

Step 1: (i) Propene to propan-2-ol Treat propene with water in the presence of dilute sulphuric acid. Protonation of the double bond favours the more stable secondary carbocation, followed by attack of water and loss of a proton. Thus the hydroxyl group enters the middle carbon:



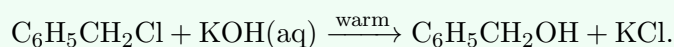
The product is propan-2-ol, as required by Markovnikov addition.

Step 2: (ii) Ethylmagnesium chloride to propan-1-ol React ethylmagnesium chloride with methanal in dry ether. The ethyl group adds to the carbonyl carbon to form a magnesium alkoxide; subsequent treatment with dilute acid gives the alcohol:



Methanal supplies the extra carbon, so the two-carbon ethyl group becomes three-carbon propan-1-ol. Keep the addition step dry because water destroys a Grignard reagent; add water or dilute acid only during work-up.

Step 3: (iii) Benzyl chloride to benzyl alcohol Warm benzyl chloride with aqueous potassium hydroxide. Hydroxide replaces chlorine at the benzylic carbon, producing benzyl alcohol:



This is hydrolysis by nucleophilic substitution. The hydroxyl group attaches to the side-chain carbon, so the product is benzyl alcohol, not phenol.

Step 4: Conclusion Use (i) acid-catalysed hydration, (ii) methanal in dry ether followed by acidic hydrolysis, and (iii) warm aqueous KOH, to obtain the three specified alcohols.

Quick Tip to Solve: Count carbons first: converting an ethyl Grignard reagent into a three-carbon primary alcohol requires methanal, followed by hydrolysis.

26. What are essential and non-essential amino acids? Give two examples of each.

[3 marks]

Solution:

Concept:

- Amino acids are the building units of proteins. Their classification as essential or non-essential depends on whether the human body can synthesise them in sufficient amounts.
- Essential amino acids must be obtained from food, whereas non-essential amino acids can be synthesised in the body. Both groups are required for normal protein synthesis.

Step 1: Define essential amino acids and give examples Essential amino acids are amino acids which the human body cannot synthesise in adequate quantities to meet its needs. They must therefore be supplied through the diet, for example through suitable protein-containing foods. Two examples are valine and leucine. Their description as essential refers specifically to their dietary requirement.

Step 2: Define non-essential amino acids and give examples Non-essential amino acids are amino acids which the human body can synthesise in amounts adequate for its normal requirements. It is therefore not necessary to obtain their entire requirement directly from the diet. Two examples are glycine and alanine. The term non-essential does not mean that these amino acids are unimportant: they too take part in the formation of proteins and in metabolism.

Step 3: Conclusion Essential amino acids must be provided in the diet: examples are valine and leucine. Non-essential amino acids can be synthesised in the human body: examples are glycine and alanine.

Quick Tip to Solve: Classify amino acids by the body's ability to make them; remember valine and leucine as dietary essentials, and glycine and alanine as non-essential examples.

27. Answer the following:

(i) Why is the use of aspartame limited to cold foods and drinks?

(ii) How do antiseptics differ from disinfectants?

(iii) Why do soaps not work in hard water?

[3 marks]

Solution:

Concept:

- An artificial sweetener must remain chemically stable under the conditions in which the food or drink is prepared and consumed.
- Antiseptics and disinfectants control microorganisms, but their suitability for living tissue differs. Hard water contains Ca^{2+} and Mg^{2+} ions that form insoluble salts with soap.

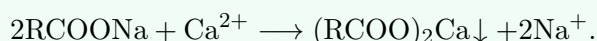
Step 1: (i) Stability of aspartame Aspartame is unstable at cooking temperatures and decomposes on heating. This destroys its useful sweetening action. Its use is consequently limited to cold foods and drinks, where such thermal decomposition is avoided.

Step 2: (ii) Antiseptics and disinfectants Antiseptics kill microorganisms or inhibit their growth and are suitable, in the appropriate concentration, for application to living tissues such as skin, cuts and wounds. Disinfectants are used to kill microorganisms on non-living objects such as floors, drains and

Quick Tip to Solve: Link the three answers to heat stability, safe site of application, and precipitation of calcium or magnesium soaps, respectively.

instruments; they are generally harmful to living tissues at the concentrations used for disinfection. Thus the distinction concerns safe application and concentration, not simply whether a substance kills microbes. For example, dilute phenol can act as an antiseptic, while a stronger phenol solution acts as a disinfectant.

Step 3: (iii) Action of soap in hard water Soap consists of sodium or potassium salts of higher fatty acids. Calcium and magnesium ions in hard water precipitate these as insoluble calcium and magnesium soaps, producing scum. For a sodium soap, with R denoting a long hydrocarbon chain,

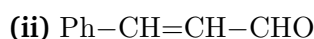
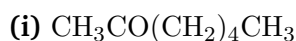


A similar reaction occurs with Mg^{2+} . Soap is consumed in forming the precipitate, so less is available for lather formation and effective cleansing.

Step 4: Conclusion (i) Aspartame decomposes on heating. (ii) Antiseptics are suitable for living tissues, whereas disinfectants are applied to non-living surfaces. (iii) Soap forms insoluble scum with calcium and magnesium ions in hard water and therefore cleans poorly.

Quick Tip to Solve: Link the three answers to heat stability, safe site of application, and precipitation of calcium or magnesium soaps, respectively.

28(a). Write the IUPAC names of the following compounds:



[2 marks]

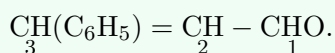
Solution:

Concept:

- Select the parent carbon chain containing the principal carbonyl group and number it to give that group the lowest possible locant. Ketones use the suffix -one and aldehydes use -al.
- In an unsaturated aldehyde, the aldehyde carbon is carbon 1. Specify the double-bond position and the positions of substituents relative to this carbon.

Step 1: (i) Name the ketone Expand the formula as $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$. The longest chain containing the carbonyl carbon has seven carbon atoms, giving the parent heptane. Numbering from the end nearer the carbonyl gives the ketone group locant 2; numbering from the other end would give locant 6. Replacing the final -e of heptane by -2-one gives **heptan-2-one**.

Step 2: (ii) Name the unsaturated aldehyde In the printed formula $\text{Ph}-\text{CH}=\text{CH}-\text{CHO}$, Ph denotes the phenyl group C_6H_5 . Number the three-carbon aldehyde chain from CHO:



The parent is prop-2-enal, because the double bond begins at carbon 2. The phenyl substituent is at carbon 3, giving **3-phenylprop-2-enal**. No geometric descriptor is added because the condensed formula does not specify the alkene geometry.

Quick Tip to Solve: Count the carbonyl carbon in the parent chain; for an aldehyde, assign the CHO carbon position 1 before locating the double bond and phenyl group.

Step 3: Conclusion (i) Heptan-2-one.
(ii) 3-Phenylprop-2-enal.

Quick Tip to Solve: Count the carbonyl carbon in the parent chain; for an aldehyde, assign the CHO carbon position 1 before locating the double bond and phenyl group.

28(b). Describe the following conversions in not more than two steps:

(i) Ethanol to 3-Hydroxybutanal

(ii) Benzoic acid to m-Nitrobenzyl alcohol

(iii) Propanone to Propene

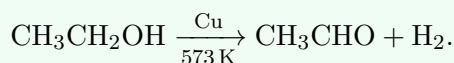
[3 marks]

Solution:

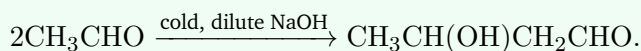
Concept:

- An aldol addition joins two molecules of an aldehyde containing an α -hydrogen, giving a β -hydroxy aldehyde in cold dilute alkali.
- The $-\text{COOH}$ group directs electrophilic substitution mainly to the meta position. Borane selectively reduces a carboxyl group to $-\text{CH}_2\text{OH}$.
- Reduction of a ketone gives a secondary alcohol; acid-catalysed dehydration of that alcohol gives an alkene.

Step 1: (i) Ethanol to 3-hydroxybutanal First dehydrogenate ethanol by passing its vapour over heated copper at 573 K:

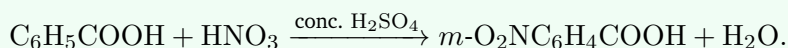


Then treat ethanal with cold dilute aqueous NaOH:

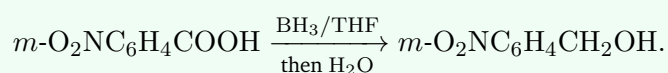


Ethanal undergoes aldol addition. Keep it cold to avoid dehydration of the hydroxy product.

Step 2: (ii) Benzoic acid to m-nitrobenzyl alcohol Nitrate benzoic acid first with concentrated nitric acid and concentrated sulphuric acid:



The carboxyl group is meta-directing. Selectively reduce this carboxyl group using borane in THF, followed by aqueous work-up:

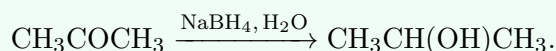


Borane preserves the nitro group. Nitrate first to establish the meta relationship.

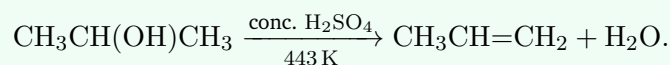
Step 3: (iii) Propanone to propene Reduce propanone with sodium borohydride, followed by aqueous

Quick Tip to Solve: Nitrate benzoic acid before reducing its carboxyl group; keep the ethanal aldol addition cold to retain the hydroxyl group.

work-up, to form propan-2-ol:



Dehydrate the alcohol by heating with concentrated sulphuric acid:



Step 4: Conclusion The intermediates are ethanal in (i), m-nitrobenzoic acid in (ii), and propan-2-ol in (iii). Each route gives the specified product in two steps.

Quick Tip to Solve: Nitrate benzoic acid before reducing its carboxyl group; keep the ethanal aldol addition cold to retain the hydroxyl group.

OR

28(a). Draw the structures of the following compounds:

(i) 4-Chloropentan-2-one

(ii) p-Nitropropiophenone

[2 marks]

Solution:

Concept:

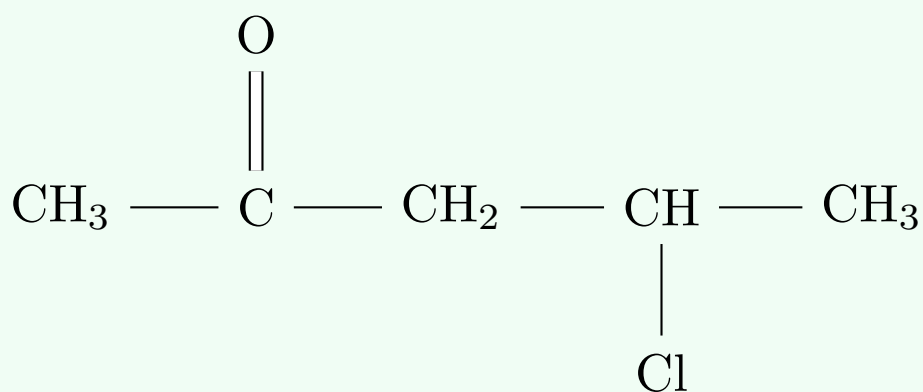
- In a ketone, the carbonyl carbon is bonded to two carbon groups. Number the parent chain to give the carbonyl group the lowest possible locant.
- Propiophenone is $\text{C}_6\text{H}_5\text{COCH}_2\text{CH}_3$. The prefix para (*p*) places a ring substituent opposite the carbonyl-containing substituent, at position 4.

Step 1: (i) Draw 4-chloropentan-2-one Use a five-carbon parent chain. Place the ketone group on carbon 2, then place chlorine on carbon 4. The condensed structure is



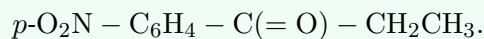
Counting from the left gives the carbonyl carbon locant 2 and chlorine locant 4, exactly as required. The carbonyl carbon is included among the five carbons; it is not an extra carbon appended to pentane.

Quick Tip to Solve: Locate $\text{C}=\text{O}$ before numbering the chain; in propiophenone retain the ethyl group and put the nitro group opposite the acyl group.

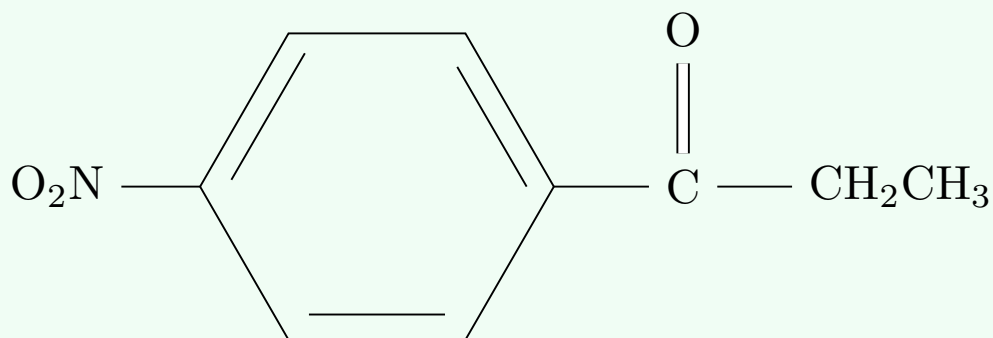


4-Chloropentan-2-one

Step 2: (ii) Draw p-nitropropiophenone Attach the carbonyl carbon of $-\text{COCH}_2\text{CH}_3$ directly to a benzene-ring carbon. Place $-\text{NO}_2$ at the opposite ring carbon, giving the 1,4 relationship:



The ethyl group on the other side of the carbonyl distinguishes propiophenone from acetophenone, which has a methyl group there. The nitro group is bonded through nitrogen to the aromatic ring.



p-Nitropropiophenone: the ring substituents occupy opposite positions.

Step 3: Conclusion The structures are $\text{CH}_3\text{COCH}_2\text{CH}(\text{Cl})\text{CH}_3$ and $p\text{-O}_2\text{NC}_6\text{H}_4\text{COCH}_2\text{CH}_3$, respectively, as drawn.

Quick Tip to Solve: Locate $\text{C}=\text{O}$ before numbering the chain; in propiophenone retain the ethyl group and put the nitro group opposite the acyl group.

28(b). Give tests to distinguish between the following pairs of compounds:

(i) Ethanal and Propanal

(ii) Phenol and Benzoic acid

(iii) Benzaldehyde and Acetophenone

[3 marks]

Solution:

Concept:

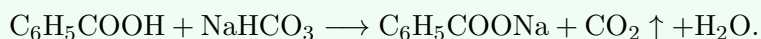
- The iodoform test detects the group $\text{CH}_3\text{CO}-$, and ethanal also responds. Warm the sample with iodine and aqueous sodium hydroxide; yellow CHI_3 is a positive result.
- Carboxylic acids liberate CO_2 from sodium hydrogencarbonate. Phenol is too weak an acid to do so.
- Tollens' reagent (ammoniacal silver nitrate) oxidises aldehydes and deposits silver; ordinary ketones do not give this test.

Step 1: (i) Ethanal and propanal: iodoform test Warm separate samples with I_2/NaOH . Ethanal gives a yellow precipitate of iodoform, whereas propanal gives no yellow precipitate because it lacks the required methyl carbonyl group. The positive reaction is



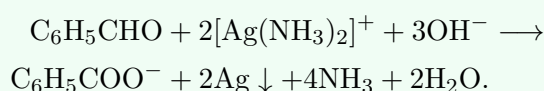
Both compounds are aldehydes, so an ordinary aldehyde test would not distinguish this pair.

Step 2: (ii) Phenol and benzoic acid: bicarbonate test Add aqueous sodium hydrogencarbonate to separate samples. Benzoic acid gives brisk effervescence of carbon dioxide, while phenol gives no effervescence. The gas turns limewater milky.



The stronger carboxylic acid displaces carbonic acid, which decomposes into water and carbon dioxide.

Step 3: (iii) Benzaldehyde and acetophenone: Tollens' test Warm the samples gently with freshly prepared Tollens' reagent in a water bath. Benzaldehyde gives a silver mirror; acetophenone gives no silver mirror.



The aldehyde is oxidised to benzoate as silver ions are reduced to silver metal.

Step 4: Conclusion Ethanal: yellow iodoform; propanal: none. Benzoic acid: CO_2 with NaHCO_3 ; phenol: none. Benzaldehyde: silver mirror with Tollens' reagent; acetophenone: none.

Quick Tip to Solve: For each pair choose a test that only one member passes: methyl carbonyl, carboxylic acidity, then aldehyde oxidation.

29(a). What is van't Hoff factor? What types of values can it have if in forming the solution the solute molecules undergo

(i) Dissociation?

(ii) Association?

[2 marks]

Solution:

Concept:

- Van't Hoff factor i measures the change in the effective number of solute particles on dissolution; colligative properties depend on particle number, not chemical identity.
- For the same solute amount, solvent and temperature, $i = P_{\text{obs}}/P_{\text{normal}}$. Here P_{obs} is the observed colligative property; P_{normal} is its calculated value when each solute formula unit remains one particle.

Step 1: Define van't Hoff factor It is the ratio of the actual number of solute particles present in solution to the number of particles expected if each solute formula unit remained a single particle:

$$i = \frac{\text{actual number of solute particles}}{\text{number of solute formula units dissolved}}$$

It is dimensionless. Without association or dissociation, the particle count is unchanged and $i = 1$.

Step 2: (i) Dissociation Dissociation splits one solute formula unit into two or more particles, increasing the particle count. Therefore $i > 1$. For example, ideal complete dissociation $\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-$ gives $i = 2$; partial dissociation gives a value between 1 and 2 for this example.

Step 3: (ii) Association Association combines two or more solute molecules into one larger particle, reducing the particle count. Therefore $0 < i < 1$. For example, complete dimerisation $2\text{A} \rightleftharpoons \text{A}_2$ halves the number of particles, giving $i = 1/2$.

Step 4: Conclusion Van't Hoff factor is the actual-to-expected solute particle-number ratio. Dissociation gives $i > 1$; association gives $0 < i < 1$.

Quick Tip to Solve: Count particles after dissolution: splitting raises i above 1; joining molecules lowers i below 1.

29(b). How many mL of a 0.1 M HCl solution are required to react completely with 1 g of a mixture of Na_2CO_3 and NaHCO_3 containing equimolar amounts of both? (Molar mass: $\text{Na}_2\text{CO}_3 = 106$ g, $\text{NaHCO}_3 = 84$ g)

[3 marks]

Solution:

Concept:

- Equimolar means equal numbers of moles, not equal masses. Let the mixture contain x mol of each salt.
- For complete neutralisation, one mole of Na_2CO_3 consumes two moles of HCl, while one mole of NaHCO_3 consumes one mole of HCl.
- Molarity is $M = n/V$, with V in litres. Thus $V = n/M$.

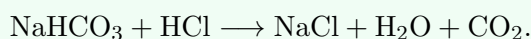
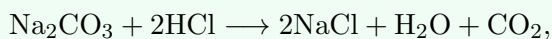
Quick Tip to Solve: For an equimolar carbonate-bicarbonate mixture, pair 190 g of mixture with 3 mol HCl, then scale to 1 g.

Step 1: Find the moles of each salt The molar masses are 106 g mol^{-1} for Na_2CO_3 and 84 g mol^{-1} for NaHCO_3 . If each contributes x moles, their masses are $106x$ and $84x$ grams. Since the total mixture has mass 1 g,

$$106x + 84x = 1, \quad x = \frac{1}{190} \text{ mol.}$$

Equimolar proportions therefore do not imply 0.5 g of each component.

Step 2: Use the complete neutralisation equations The balanced reactions are



Hence the total amount of HCl required is

$$n(\text{HCl}) = 2x + x = 3x = \frac{3}{190} \text{ mol.}$$

Carbonate is neutralised all the way to carbon dioxide and water; stopping at bicarbonate would underestimate the acid requirement.

Step 3: Convert the acid amount to volume Using the specified HCl concentration $M = 0.1 \text{ mol L}^{-1}$,

$$\begin{aligned} V &= \frac{n}{M} = \frac{3/190}{0.1} \text{ L} \\ &= 0.15789 \text{ L} = 157.89 \text{ mL.} \end{aligned}$$

This volume supplies 0.015789 mol of acid, exactly matching the combined two-to-one and one-to-one acid requirements.

Step 4: Conclusion The required volume of 0.1 M HCl is 157.9 mL (approximately 158 mL).

Quick Tip to Solve: For an equimolar carbonate-bicarbonate mixture, pair 190 g of mixture with 3 mol HCl, then scale to 1 g.

OR

29(a). Define

(i) Mole fraction

(ii) Molality

(iii) Raoult's law

[3 marks]

Solution:

Concept:

- Composition can be expressed using moles of a component relative to total moles, or moles of solute relative to the mass of solvent.
- Raoult's law relates the partial vapour pressure of a volatile component of an ideal solution to its mole fraction in the liquid.

Quick Tip to Solve: Check the denominator: mole fraction uses total moles, whereas molality uses kilograms of solvent. In Raoult's law use the mole fraction of the volatile component.

Step 1: Define mole fraction The mole fraction of a component is the ratio of the number of moles of that component to the total number of moles of all components in the solution. For component i ,

$$x_i = \frac{n_i}{\sum_j n_j}.$$

Here n_i is the amount of component i in moles. For a binary solution, $x_1 = n_1/(n_1 + n_2)$ and $x_2 = n_2/(n_1 + n_2)$, so $x_1 + x_2 = 1$. Mole fraction has no unit.

Step 2: Define molality Molality is the number of moles of solute dissolved in one kilogram of solvent:

$$m = \frac{n_{\text{solute}}}{w_{\text{solvent in kg}}}.$$

Its unit is mol kg^{-1} . The denominator is the mass of solvent, not the mass or volume of the solution. Since masses do not change with temperature, molality is independent of temperature.

Step 3: State Raoult's law At a given temperature, the partial vapour pressure p_i of each volatile component of an ideal solution equals the vapour pressure p_i^0 of that pure component multiplied by its mole fraction x_i in the liquid:

$$p_i = x_i p_i^0.$$

For a non-volatile solute in a volatile solvent, only the solvent contributes appreciably to the vapour pressure, so $p = x_{\text{solvent}} p_{\text{solvent}}^0$.

Step 4: Conclusion Mole fraction is $n_i / \sum_j n_j$; molality is moles of solute per kilogram of solvent; Raoult's law is $p_i = x_i p_i^0$ at a fixed temperature.

Quick Tip to Solve: Check the denominator: mole fraction uses total moles, whereas molality uses kilograms of solvent. In Raoult's law use the mole fraction of the volatile component.

29(b). Assuming complete dissociation, calculate the expected freezing point of a solution prepared by dissolving 6.00 g of Glauber's salt, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ in 0.100 kg of water. (K_f for water = $1.86 \text{ K kg mol}^{-1}$, Atomic masses: Na = 23, S = 32, O = 16, H = 1) [2 marks]

Solution:

Concept:

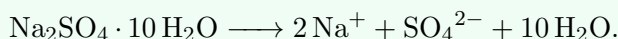
- Freezing-point depression is $\Delta T_f = i K_f m$, where i is the van't Hoff factor and m is moles of solute per kilogram of solvent.
- On dissolving a hydrated salt, its water of crystallisation joins the solvent; complete dissociation of Na_2SO_4 gives three ions per formula unit.

Step 1: Find the amount of salt and the particle factor The molar mass of $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ is

$$M = 2(23) + 32 + 4(16) + 10(18) = 322 \text{ g mol}^{-1}.$$

Quick Tip to Solve: For Glauber's salt, use 322 g per mole, count three ions, and add its ten waters of crystallisation to the solvent mass before calculating molality.

Hence $n = 6.00/322 = 0.01863$ mol. The dissolution and complete dissociation give



The dissolved electrolyte produces two sodium ions and one sulphate ion, so $i = 3$.

Step 2: Calculate the molality and freezing point The water supplied by the crystals has mass $0.01863 \times 180 = 3.354$ g. The total solvent mass is therefore $100 + 3.354 = 103.354$ g, or 0.103354 kg. Thus

$$m = \frac{0.01863}{0.103354} = 0.1803 \text{ mol kg}^{-1}.$$

$$\Delta T_f = 3(1.86)(0.1803) = 1.006 \text{ K}.$$

Since the freezing point of pure water is 273.15 K, the solution freezes at $273.15 - 1.006 = 272.144$ K.

Step 3: Conclusion The expected freezing point is approximately $\boxed{272.14 \text{ K}}$, or $\boxed{-1.01^\circ \text{C}}$.

Quick Tip to Solve: For Glauber's salt, use 322 g per mole, count three ions, and add its ten waters of crystallisation to the solvent mass before calculating molality.

30(a). Write the formula and describe the structure of a noble gas species which is isostructural with

(i) IBr_2^-

(ii) BrO_3^-

[2 marks]

Solution:

Concept:

- Isostructural species have the same molecular geometry. VSEPR theory predicts geometry from bonding regions and lone pairs around the central atom.
- A multiple bond counts as one electron-density region when determining molecular shape; lone pairs occupy space but are not included as atoms in the named shape.

Step 1: Match the linear species In IBr_2^- , the iodine atom has two bonding pairs and three lone pairs, giving an AX_2E_3 arrangement. The electron-pair geometry is trigonal bipyramidal. The three lone pairs occupy equatorial positions, leaving the two bromine atoms in axial positions. The ion is therefore linear. The corresponding noble gas species is XeF_2 : xenon also has two bonding pairs and three lone pairs, with a linear $\text{F}-\text{Xe}-\text{F}$ arrangement and bond angle 180° .

Step 2: Match the trigonal pyramidal species In BrO_3^- , bromine is surrounded by three bonding regions and one lone pair, giving an AX_3E arrangement. The electron-pair geometry is tetrahedral and the molecular shape is trigonal pyramidal. The corresponding noble gas species is XeO_3 . It has three xenon-oxygen bonding regions and one lone pair on xenon, with the three oxygen atoms forming the base of a trigonal pyramid and xenon at the apex.

Step 3: Conclusion (i) $\boxed{\text{XeF}_2}$: linear, with three lone pairs on xenon. (ii) $\boxed{\text{XeO}_3}$: trigonal pyramidal, with one lone pair on xenon.

Quick Tip to Solve: Match the central-atom pattern: two bonds plus three lone pairs gives linear XeF_2 ; three bonding regions plus one lone pair gives pyramidal XeO_3 .

30(b). Assign reasons for the following:

(i) SF_6 is kinetically inert.

(ii) NF_3 is an exothermic compound whereas NCl_3 is not.

(iii) HCl is a stronger acid than HF though fluorine is more electronegative than chlorine. [3 marks]

Solution:

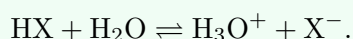
Concept:

- Kinetic inertness means that reaction is extremely slow because the activation barrier is high; it does not merely describe the energy of the products.
- The enthalpy of formation depends on the energy consumed in breaking reactant bonds and the energy released in forming product bonds.
- For hydrogen halides in aqueous solution, ease of breaking the hydrogen–halogen bond strongly influences acid strength.

Step 1: (i) Explain the kinetic inertness of sulphur hexafluoride In SF_6 , six fluorine atoms surround the sulphur atom in an octahedral arrangement. The strong $\text{S} - \text{F}$ bonds are difficult to break, and this compact shell of fluorine atoms shields sulphur from attack by reagents such as water. Thus, attack on the central atom and bond cleavage require a high activation energy. Consequently, ordinary reactions, including hydrolysis, occur extremely slowly and SF_6 is kinetically inert.

Step 2: (ii) Compare the energetics of the nitrogen trihalides The $\text{N} - \text{F}$ bonds in NF_3 are much stronger than the $\text{N} - \text{Cl}$ bonds in NCl_3 . Formation of the strong $\text{N} - \text{F}$ bonds releases sufficient energy to compensate for the energy required to break the bonds in elemental nitrogen and fluorine. Hence the enthalpy of formation of NF_3 is negative: it is an exothermic compound. The weaker $\text{N} - \text{Cl}$ bonds do not provide enough energy on formation to offset the energy needed to break the reactant bonds. Thus NCl_3 has a positive enthalpy of formation and is endothermic.

Step 3: (iii) Compare hydrochloric and hydrofluoric acids Although fluorine is more electronegative, the $\text{H} - \text{F}$ bond is very short and strong. The longer $\text{H} - \text{Cl}$ bond has a lower bond dissociation enthalpy and is more readily broken during ionisation in water:



Consequently, HCl ionises almost completely in dilute aqueous solution, whereas HF ionises only partially. The effect of the weaker $\text{H} - \text{Cl}$ bond outweighs the electronegativity difference, so HCl is the stronger acid.

Step 4: Conclusion SF_6 is inert because of strong bonds and shielding of sulphur; NF_3 is exothermic because strong $\text{N} - \text{F}$ bonds make its formation energetically favourable; and HCl is more acidic than HF because its hydrogen–halogen bond is weaker.

Quick Tip to Solve: For hydrogen halide acidity down Group 17, compare bond strength before comparing electronegativity.

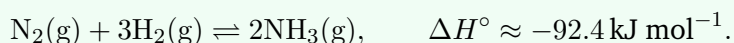
30(a). How is ammonia prepared on a large scale? Name the process and mention the optimum conditions for the production of ammonia by this process. [2 marks]

Solution:

Concept:

- Haber's process synthesises ammonia from nitrogen and hydrogen in the molar ratio 1 : 3.
- High pressure favours the side with fewer gas molecules; a moderate temperature balances equilibrium yield and reaction rate for an exothermic reaction.

Step 1: State the process and reaction Ammonia is manufactured on a large scale by Haber's process. Purified nitrogen and hydrogen, mixed in the ratio 1 : 3 by volume, are compressed and passed over an iron catalyst:



The gases must be free of catalyst poisons. The ammonia formed is cooled and liquefied, and unreacted nitrogen and hydrogen are recycled.

Step 2: Give the optimum operating conditions The usual optimum conditions are a temperature of about 700 K, a pressure of about 200 atm, and finely divided iron as catalyst with small amounts of K_2O and Al_2O_3 as promoters. High pressure favours ammonia because four moles of gaseous reactants form two moles of gaseous product. A lower temperature favours the exothermic forward reaction but makes it too slow; about 700 K provides a practical compromise. The catalyst speeds the approach to equilibrium without changing the equilibrium composition.

Step 3: Conclusion Ammonia is produced by Haber's process using $\text{N}_2 : \text{H}_2 = 1 : 3$, about 700 K, about 200 atm, and promoted finely divided iron catalyst.

Quick Tip to Solve: Remember the Haber conditions together: 1:3 gases, high pressure, moderate temperature, and promoted iron.

30(b). Assign reasons for the following:

(i) H_2S is more acidic than H_2O .

(ii) NH_3 is more basic than PH_3 .

(iii) Sulphur has a greater tendency for catenation than oxygen.

[3 marks]

Solution:

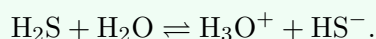
Concept:

- Acidity of Group 16 hydrides depends strongly on the ease of cleavage of the element-hydrogen bond.
- Basicity depends on the availability of a lone pair of electrons for donation to a proton.
- Catenation is the formation of chains or rings by bonds between atoms of the same element; stronger element-element bonds favour it.

Step 1: (i) Compare the acidities of hydrogen sulphide and water Sulphur is larger than oxygen,

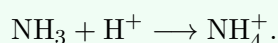
Quick Tip to Solve: Match each comparison to its controlling factor: hydride bond strength, lone-pair availability, or element-element bond strength.

so the S – H bond is longer and weaker than the O – H bond. Its lower bond dissociation enthalpy makes release of a proton easier. Thus, in aqueous solution, hydrogen sulphide undergoes acid ionisation more readily than water:



Hence H_2S is more acidic than H_2O , even though oxygen is more electronegative than sulphur.

Step 2: (ii) Compare the basicities of ammonia and phosphine Both molecules have a lone pair on the central atom. Nitrogen is smaller than phosphorus, so the lone-pair electron density in NH_3 is concentrated in a smaller region and is more readily available for donation to a proton. The lone pair in PH_3 is less readily donated. Therefore ammonia accepts a proton more readily:



Consequently, NH_3 is more basic than PH_3 .

Step 3: (iii) Explain the greater catenation of sulphur The small size of oxygen brings the lone pairs on two bonded oxygen atoms close together, causing substantial lone-pair repulsion. This weakens the O – O single bond. Sulphur atoms are larger, so lone-pair repulsion is less severe, and the S – S single bond is stronger than the O – O single bond. Sulphur can therefore form stable chains and rings, such as the S_8 ring, more readily than oxygen. Thus sulphur shows a greater tendency for catenation.

Step 4: Conclusion The weaker S – H bond makes H_2S more acidic; the more available lone pair makes NH_3 more basic; and the stronger S – S single bond gives sulphur greater catenation.

Quick Tip to Solve: Match each comparison to its controlling factor: hydride bond strength, lone-pair availability, or element–element bond strength.