CBSE Class 12 Chemistry Question Paper 2014 with Solution PDF-Set 56/3 (Foreign)

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. Name the depressant which is used to separate ZnS and PbS ores in the froth floatation process.

[1 mark]

Solution:

Concept:

- A depressant selectively prevents one sulphide ore from entering the froth, allowing a mixture of sulphide ores to be separated.
- For a mixture of zinc sulphide, ZnS, and lead sulphide, PbS, sodium cyanide is the standard selective depressant.

Step 1: Identify the reagent Sodium cyanide, $NaCN$, is added during the froth floatation separation of these two sulphide ores.

Step 2: Explain its selective action It prevents ZnS particles from forming froth, while PbS continues to enter the froth and can be skimmed off. Thus the two sulphides are separated selectively.

Step 3: Conclusion The depressant is sodium cyanide, $\boxed{NaCN}$.

Quick Tip to Solve: Remember this pair: NaCN depresses ZnS, so PbS remains in the froth.

2. Based on the type of dispersed phase, what type of colloid is micelles? [1 mark]

Solution:

Concept:

- Colloids are classified by the nature of their dispersed particles as multimolecular, macromolecular or associated colloids.
- In associated colloids, small molecules or ions aggregate into colloidal-sized particles called micelles above the critical micelle concentration.

Step 1: Identify the dispersed particles A micelle is an aggregate of many surfactant molecules or ions. Individual surfactant species are smaller than colloidal particles, but their aggregates have colloidal dimensions.

Step 2: Classify the colloid Because colloidal particles arise by association of smaller species, micelles belong to the associated-colloid class. Soap solutions above their critical micelle concentration provide a typical example.

Step 3: Conclusion Micelles are $\boxed{\text{associated colloids}}$.

Quick Tip to Solve: For micelles, focus on aggregation of surfactant molecules: association gives the classification.

3. Arrange the following in the increasing order of their basic character:

NH_3, PH_3, AsH_3, SbH_3, BiH_3 [1 mark]

Solution:

Concept:

- A base accepts a proton by donating an available lone pair of electrons.
- For group 15 hydrides, basic character decreases down the group as the central atom becomes larger and its lone pair is less effectively donated to a proton.

Step 1: Apply the group trend Ammonia is the strongest base among the listed hydrides. On descending from nitrogen through phosphorus, arsenic and antimony to bismuth, the tendency to accept a proton decreases.

Step 2: Reverse the order for increasing basicity The decreasing order is

$$NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3.$$

Therefore, start with bismuth hydride and end with ammonia when writing the increasing order.

Step 3: Conclusion

$$\boxed{BiH_3 < SbH_3 < AsH_3 < PH_3 < NH_3}$$

Quick Tip to Solve: Write the group 15 elements downwards first, then reverse that sequence for increasing hydride basicity.

4. What type of isomerism is exhibited by the complex $[Co(NH_3)_5NO_2]^{2+}$? [1 mark]

Solution:

Concept:

- Linkage isomerism occurs when an ambidentate ligand can coordinate to the same metal through different donor atoms.
- The nitrite ion, NO_2^-, can bind through nitrogen or oxygen; ammonia is not ambidentate.

Step 1: Identify the ambidentate ligand In $[Co(NH_3)_5NO_2]^{2+}$, the nitrite ligand has two possible donor atoms. Coordination through nitrogen gives the nitro form.

Step 2: Describe the alternative linkage If the same nitrite ion binds through oxygen, the nitrito form, $[Co(NH_3)_5(ONO)]^{2+}$, is obtained. The composition and charge stay the same, but the metal-ligand attachment changes.

Step 3: Conclusion The complex exhibits $\boxed{\text{linkage isomerism}}$.

Quick Tip to Solve: Look for NO2 as an ambidentate ligand: nitrogen versus oxygen attachment signals linkage isomerism.

5. Write the IUPAC name of the following compound:

$HO-CH_2-CH(OH)-CH_2-OH$ [1 mark]

Solution:

Concept:

- Choose the longest carbon chain containing the hydroxyl groups and number it to give these groups the lowest possible locants.
- Three hydroxyl groups are indicated by the suffix triol, with the position of every hydroxyl group stated.

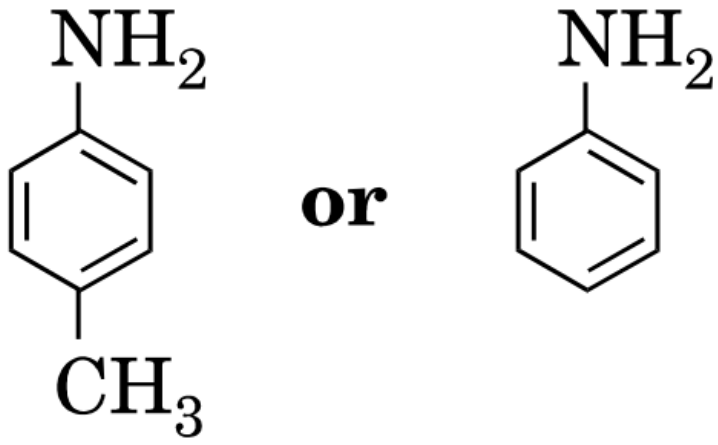
Step 1: Choose and number the parent chain The structure $HOCH_2 - CH(OH) - CH_2OH$ has three carbon atoms in an unbranched saturated chain, so its parent hydrocarbon is propane. Numbering from either end gives the same positions.

Step 2: Locate the hydroxyl groups There is one hydroxyl group on each of carbons 1, 2 and 3. Attach the suffix triol to the parent name and include all three locants; the common name glycerol is not the requested systematic name.

Step 3: Conclusion The IUPAC name is $\boxed{\text{propane-1,2,3-triol}}$.

Quick Tip to Solve: Count three carbons and three OH groups; their locants are 1, 2 and 3 from either end.

6. Which of the two is more basic and why? [1 mark]



Solution:

Concept:

- Basicity depends on the availability of the nitrogen lone pair for accepting a proton.
- A methyl group is electron releasing through its positive inductive effect and hyperconjugation, increasing electron density in a substituted aromatic amine.

Step 1: Identify the printed amines The first structure is para-toluidine, p-$CH_3C_6H_4NH_2$, and the second is aniline, $C_6H_5NH_2$. Both contain an amino group attached directly to a benzene ring.

Quick Tip to Solve: Compare the substituent on the ring: the para methyl group donates electron density and increases basicity.

Step 2: Compare lone-pair availability The para methyl group supplies electron density to the aromatic system through its electron-releasing effect. Relative to aniline, this increases the availability of the amino nitrogen lone pair for proton acceptance. Hence para-toluidine is the stronger base.

Step 3: Conclusion $\boxed{p\text{-toluidine is more basic than aniline}}$, because the methyl group is electron releasing.

Quick Tip to Solve: Compare the substituent on the ring: the para methyl group donates electron density and increases basicity.

7. What are biocatalysts? Give an example. [1 mark]

Solution:

Concept:

- Biocatalysts are catalysts produced by living organisms; they increase the rate of biochemical reactions without being consumed.
- Enzymes act specifically on their substrates and lower the activation energy of a reaction.

Step 1: Identify the biological catalysts The catalysts responsible for speeding up biochemical reactions in living systems are called biocatalysts. Enzymes perform this role: they help reactions proceed rapidly under the mild conditions found in cells and are regenerated after the reaction.

Step 2: Give a suitable example Urease is a biocatalyst. It catalyses the hydrolysis of urea to ammonia and carbon dioxide:

$$\mathrm{CO(NH_2)_2 + H_2O \xrightarrow{urease} 2NH_3 + CO_2}.$$

The enzyme facilitates this conversion without becoming a reactant in the net chemical equation.

Step 3: Conclusion Biocatalysts are biological catalysts, such as enzymes. An example is urease, which catalyses the hydrolysis of urea.

Quick Tip to Solve: Name a specific enzyme, such as urease, after defining biocatalysts; do not give only the name of a biological reaction.

8. Express the relationship between atomic radius (r) and the edge length (a) in the b.c.c. unit cell. [1 mark]

Solution:

Concept:

- In a body-centred cubic (b.c.c.) unit cell, atoms touch along a body diagonal.
- The body diagonal of a cube of edge length a is $\sqrt{3}a$; the atomic radius is denoted by r.

Step 1: Identify the line along which atoms touch A b.c.c. unit cell has atoms at its corners and one atom at the body centre. Along a body diagonal, the corner atom, the central atom and the opposite corner atom are in contact. Atoms do not touch along a cube edge.

Step 2: Equate the geometric length to the radii The distance from one corner atom centre to the

Quick Tip to Solve: For b.c.c., use contact along the body diagonal: its length equals four atomic radii.

body-centred atom centre is $2r$, and the distance from the body centre to the opposite corner atom centre is also $2r$. The complete body diagonal therefore measures $4r$. From cube geometry, this length is $\sqrt{3}a$, giving $4r = \sqrt{3}a$.

Step 3: Conclusion The required relationship is $\boxed{r = \frac{\sqrt{3}}{4}a}$, or equivalently $\boxed{a = \frac{4r}{\sqrt{3}}}$.

Quick Tip to Solve: For b.c.c., use contact along the body diagonal: its length equals four atomic radii.

9. Write the role of the following:

(i) Iodine in the refining of zirconium

(ii) Silica in the extraction of copper from copper matte [2 marks]

Solution:

Concept:

- In the van Arkel process, a metal forms a volatile iodide which can be separated from non-volatile impurities and then decomposed.
- An acidic flux such as silica combines with a basic impurity such as iron(II) oxide to form a fusible slag.

Step 1: Explain the role of iodine in zirconium refining Iodine converts impure zirconium into volatile zirconium tetraiodide:

$$\mathrm{Zr} + 2\mathrm{I_2} \longrightarrow \mathrm{ZrI_4}.$$

The volatile iodide is separated from the impurities. On contact with a very hot tungsten filament it decomposes, depositing pure zirconium and liberating iodine:

$$\mathrm{ZrI_4} \longrightarrow \mathrm{Zr} + 2\mathrm{I_2}.$$

Thus iodine serves as the reagent for volatile-compound formation in the van Arkel refining process.

Step 2: Explain the role of silica during copper extraction Iron sulphide present in copper matte is oxidised to iron(II) oxide during air blowing. Silica acts as an acidic flux and reacts with this basic oxide:

$$\mathrm{FeO} + \mathrm{SiO_2} \longrightarrow \mathrm{FeSiO_3}.$$

The iron silicate formed is a fusible slag that can be removed from the copper-containing melt. Hence silica removes the iron oxide impurity rather than acting as the reducing agent for copper.

Step 3: Conclusion (i) Iodine forms volatile $\mathrm{ZrI_4}$, whose thermal decomposition deposits pure zirconium. (ii) Silica removes FeO as iron silicate slag, $\mathrm{FeSiO_3}$.

Quick Tip to Solve: Remember the reagent roles: iodine makes a volatile iodide; silica traps basic FeO as silicate slag.

10(a). Name the two most important allotropes of sulphur. Which one of the two is stable at room temperature? What happens when the stable form is heated above 370 K? [2 marks]

Solution:

Concept:

- Rhombic sulphur and monoclinic sulphur are the two most important crystalline allotropes of sulphur. Both contain S_8 molecules but differ in their crystal arrangements.
- The transition temperature between these forms is approximately $369\,K$: rhombic sulphur is stable below it and monoclinic sulphur above it.

Step 1: Name the forms and identify the room-temperature form The two important allotropes are rhombic sulphur, also called α-sulphur, and monoclinic sulphur, also called β-sulphur. At room temperature, about $298\,K$, rhombic sulphur is thermodynamically stable because this temperature lies below the transition temperature.

Step 2: Describe the change on heating above 370 K When the stable room-temperature form, rhombic sulphur, is heated just above $370\,K$, it changes into monoclinic sulphur. The heating crosses the transition temperature, approximately $369\,K$, and monoclinic sulphur becomes the stable crystalline form. This is an allotropic change in crystal structure, not a chemical conversion to a different element; both forms contain puckered S_8 rings.

Step 3: Conclusion The allotropes are rhombic and monoclinic sulphur. Rhombic sulphur is stable at room temperature; on heating above $370\,K$, it changes into monoclinic sulphur.

Quick Tip to Solve: Compare the temperature with about 369 K: below it use rhombic sulphur; just above it use monoclinic sulphur.

OR

10(b). (i) Write the conditions to maximize the yield of H_2SO_4 by contact process.
(ii) Why is $K_{a2} << K_{a1}$ for H_2SO_4 in water? [2 marks]

Solution:

Concept:

- The contact process involves the reversible exothermic oxidation $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$. Le Chatelier's principle relates the yield to temperature, pressure and reactant concentration.
- Successive dissociation of a polyprotic acid becomes less favourable when a proton must be removed from a negatively charged ion.

Step 1: Conditions for the contact process Low temperature and increased pressure favour SO_3 formation because the forward reaction is exothermic and reduces the number of gas molecules from three to two. In practice, use about $720\,K$, about $2\,bar$, a V_2O_5 catalyst and excess oxygen. The moderate temperature gives a useful reaction rate; the catalyst speeds attainment of equilibrium without changing its position. Absorb the SO_3 in concentrated sulphuric acid to form oleum, then dilute it to obtain sulphuric acid.

Quick Tip to Solve: Separate conditions that favour equilibrium from the catalyst, which only increases the rate.

Step 2: Compare the two acid dissociations The first stage is $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$, which is nearly complete in water. The second is $HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$. The remaining proton is attracted more strongly by the negatively charged HSO_4^- ion. Its removal, producing a doubly negative ion, is therefore much less favourable than removal from neutral H_2SO_4.

Step 3: Conclusion (i) Use about $720\,K$, $2\,bar$, V_2O_5 and excess oxygen. (ii) The stronger attraction of the second proton to HSO_4^- makes $K_{a2} \ll K_{a1}$.

Quick Tip to Solve: Separate conditions that favour equilibrium from the catalyst, which only increases the rate.

11. Complete the following equations:

(i) $2MnO_4^- + 5SO_3^{2-} + 6H^+ \longrightarrow$

(ii) $2CrO_4^{2-} + 2H^+ \longrightarrow$ [2 marks]

Solution:

Concept:

- In acidic solution, permanganate is reduced from Mn(VII) to Mn(II), while sulphite is oxidised from S(IV) to S(VI). Balance both atoms and total charge.
- Acidification converts yellow chromate to orange dichromate by a condensation equilibrium; chromium remains in oxidation state $+6$.

Step 1: Complete the permanganate reaction The half-reactions are

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O,$$
$$SO_3^{2-} + H_2O \longrightarrow SO_4^{2-} + 2H^+ + 2e^-.$$

Multiply the first by 2 and the second by 5. Add, cancel ten electrons, and cancel common water and hydrogen ions. Thus

$$2MnO_4^- + 5SO_3^{2-} + 6H^+ \longrightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O.$$

Both sides have total charge -6.

Step 2: Complete the chromate reaction Two chromate ions combine on acidification, losing one oxygen atom as water:

$$2CrO_4^{2-} + 2H^+ \longrightarrow Cr_2O_7^{2-} + H_2O.$$

There are two chromium atoms, eight oxygen atoms and two hydrogen atoms on each side. The charge is -2 on each side, confirming the equation.

Step 3: Conclusion (i) Products: $2Mn^{2+} + 5SO_4^{2-} + 3H_2O$. (ii) Products: $Cr_2O_7^{2-} + H_2O$.

Quick Tip to Solve: For each ionic equation, check net charge after balancing the oxygen and hydrogen atoms.

12. Write the state of hybridization, shape and IUPAC name of the complex $[Co(NH_3)_6]^{3+}$. (Atomic no. of Co = 27) [2 marks]

Solution:

Concept:

- Neutral ammonia ligands contribute no charge, so cobalt has oxidation state $+3$ in $[\mathrm{Co(NH_3)_6}]^{3+}$.
- Coordination number six gives an octahedral arrangement. For low-spin d^6 cobalt(III), two inner $3d$ orbitals participate in d^2sp^3 hybridisation.

Step 1: Find the metal configuration and hybridisation Cobalt, with atomic number 27, has ground-state configuration $[\mathrm{Ar}]3d^7 4s^2$. Remove the two $4s$ electrons and one $3d$ electron to obtain Co^{3+} : $[\mathrm{Ar}]3d^6$. With ammonia and the high charge of cobalt(III), the six $3d$ electrons pair in three orbitals. Two $3d$ orbitals are then available to combine with one $4s$ and three $4p$ orbitals, giving d^2sp^3 hybridisation.

Step 2: Assign geometry and the systematic name The six equivalent hybrid orbitals accept six ammonia lone pairs and point towards the vertices of an octahedron. The complex therefore has octahedral shape. Ammonia is named ammine as a ligand; six such ligands give the prefix hexaammine. As this is a cationic complex, the metal retains the name cobalt, followed by its oxidation state in Roman numerals.

Step 3: Conclusion Hybridisation: d^2sp^3; shape: octahedral; IUPAC name: hexaamminecobalt(III) ion.

Quick Tip to Solve: For cobalt(III), remove 4s electrons first, then use the resulting d6 configuration to assign the inner-orbital complex.

13. Write chemical equations when

(i) ethyl chloride is treated with alcoholic KOH.

(ii) chlorobenzene is treated with CH_3Cl in the presence of anhydrous $AlCl_3$. [2 marks]

Solution:

Concept:

- Hot alcoholic KOH favours β-elimination of hydrogen halide from a haloalkane, producing an alkene.
- Chlorine deactivates benzene but directs electrophilic substitution to the ortho and para positions through resonance donation.

Step 1: Ethyl chloride with alcoholic potassium hydroxide On heating, the base removes a hydrogen from the carbon adjacent to the carbon bearing chlorine. Chloride leaves and a carbon-carbon double bond forms. The dehydrohalogenation equation is

$$\mathrm{CH_3CH_2Cl + KOH \xrightarrow[\Delta]{\text{alcohol}} CH_2{=}CH_2 + KCl + H_2O.}$$

The organic product is ethene. The alcoholic medium is significant because it favours elimination;

Quick Tip to Solve: Use the reagent medium to distinguish elimination, and use chlorine's ortho/para direction for ring methylation.

aqueous hydroxide instead favours substitution to an alcohol.

Step 2: Chlorobenzene with methyl chloride and anhydrous aluminium chloride Under the stated Friedel–Crafts alkylation conditions, methyl substitution occurs at positions ortho and para to chlorine. The equation showing both positional products is

$$C_6H_5Cl + CH_3Cl \xrightarrow{\text{anhydrous } AlCl_3} o\text{–}ClC_6H_4CH_3 \text{ or } p\text{–}ClC_6H_4CH_3 + HCl.$$

Each product corresponds to replacement of one ring hydrogen by a methyl group. The para isomer predominates because it has less steric crowding between chlorine and the incoming methyl group.

Step 3: Conclusion (i) Ethene is formed by elimination. (ii) A mixture of 1-chloro-2-methylbenzene and 1-chloro-4-methylbenzene is formed, with the para isomer as the major product.

Quick Tip to Solve: Use the reagent medium to distinguish elimination, and use chlorine's ortho/para direction for ring methylation.

14. Write the mechanism of the following reaction:

$CH_3CH_2OH \xrightarrow{HBr} CH_3CH_2Br + H_2O$ [2 marks]

Solution:

Concept:

- The hydroxyl group of an alcohol is a poor leaving group. Protonation by the acid converts it into water, which is a good leaving group.
- Ethanol is a primary alcohol. Bromide ion, Br^-, attacks its primary carbon by an S_N2 displacement; a free primary carbocation is not required.

Step 1: Protonate the alcohol The oxygen lone pair accepts a proton from hydrogen bromide. This activates the carbon–oxygen bond by forming the ethyloxonium ion:

$$CH_3CH_2OH + HBr \rightleftharpoons CH_3CH_2OH_2^+ + Br^-.$$

The positive charge is on oxygen, which now has three bonds.

Step 2: Displace water with bromide Bromide attacks the carbon bonded to oxygen from the side opposite the leaving group. Formation of the carbon–bromine bond and cleavage of the carbon–oxygen bond occur in the same step:

$$Br^- + CH_3CH_2OH_2^+ \longrightarrow CH_3CH_2Br + H_2O.$$

The departing oxygen takes the bonding electron pair and leaves as neutral water. Since the carbon is primary, formation of an unstable ethyl carbocation is avoided.

Step 3: Conclusion Thus ethanol gives bromoethane by protonation followed by S_N2 attack of bromide: $CH_3CH_2OH + HBr \rightarrow CH_3CH_2Br + H_2O$.

Quick Tip to Solve: First convert OH into OH2+; for ethanol show bromide displacement without a free ethyl carbocation.

15. Name the different reagents needed to perform the following reactions:

(i) Phenol to Benzene

(ii) Dehydration of propan-2-ol to propene

(iii) Friedel–Crafts acetylation of anisole

(iv) Dehydrogenation of ethanol to ethanal [2 marks]

Solution:

Concept:

- Choose the reagent according to the bond change: removal of phenolic oxygen, loss of water, aromatic acylation or removal of hydrogen.
- The temperature and catalyst distinguish dehydration of an alcohol to an alkene from dehydrogenation to a carbonyl compound.

Step 1: (i) Phenol to benzene Heat phenol with zinc dust. Zinc removes oxygen as zinc oxide:

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

Thus the required reagent is zinc dust, with heating.

Step 2: (ii) Propan-2-ol to propene Heat propan-2-ol with concentrated sulphuric acid at about $443\,K$. The acid promotes elimination of water:

$$CH_3CH(OH)CH_3 \xrightarrow[443\,K]{\text{conc. } H_2SO_4} CH_3CH{=}CH_2 + H_2O.$$

Step 3: (iii) Friedel–Crafts acetylation of anisole Use acetyl chloride, CH_3COCl, with anhydrous $AlCl_3$. The Lewis acid generates the acetyl electrophile for substitution on the aromatic ring. Anisole gives mainly the para-acetyl derivative together with the ortho derivative.

Step 4: (iv) Ethanol to ethanal Pass ethanol vapours over heated copper at $573\,K$:

$$CH_3CH_2OH \xrightarrow[573\,K]{Cu} CH_3CHO + H_2.$$

Copper catalyses dehydrogenation, removing hydrogen without removing the oxygen atom.

Step 5: Conclusion The reagents are: (i) heated zinc dust; (ii) concentrated H_2SO_4, $443\,K$; (iii) CH_3COCl/anhydrous $AlCl_3$; (iv) heated Cu, $573\,K$.

Quick Tip to Solve: Associate zinc with phenol reduction, acid with dehydration and hot copper with dehydrogenation.

16. A solution of $Ni(NO_3)_2$ is electrolysed between platinum electrodes using a current of 5.0 ampere for 20 minutes. What mass of nickel will be deposited at the cathode?
(Given: At. mass of Ni = 58.7 g mol^{-1}, 1 F = 96500 C mol^{-1}) [2 marks]

Solution:

Concept:

- Faraday law gives $m = \dfrac{MIt}{nF}$, where m is deposited mass, M molar mass, I current, t time in seconds and F charge per mole of electrons.
- For nickel(II), the cathode reaction is $Ni^{2+} + 2e^- \rightarrow Ni$; hence two moles of electrons deposit one mole of nickel, so $n = 2$.

Step 1: Find the total charge The nitrate solution supplies Ni^{2+} ions. Platinum is an inert electrode; nickel deposition is reduction at the cathode. Convert the duration into seconds before using the current:

$$t = 20 \times 60 = 1200\,\text{s}, \qquad Q = It = 5.0 \times 1200 = 6000\,\text{C}.$$

Step 2: Apply the electron-to-metal ratio The amount of electrons passed is $6000/96500$ mol. Since each nickel ion gains two electrons, the amount of nickel deposited is half this value:

$$n(\text{Ni}) = \frac{6000}{2 \times 96500}\,\text{mol}.$$

Multiplication by the given molar mass gives

$$m = \frac{58.7 \times 6000}{2 \times 96500}\,\text{g} = 1.8249\,\text{g}.$$

The factor of two comes from the charge on nickel, not from the two nitrate ions acting as reducible species.

Step 3: Conclusion The mass of nickel deposited at the cathode is approximately $\boxed{1.82\,\text{g}}$.

Quick Tip to Solve: Write Ni2+ + 2e- -> Ni first, so the factor 2 is included before substituting into Faraday law.

17. Define half-life of a reaction. Write the expression of half-life for
(i) zero order reaction and
(ii) first order reaction. [2 marks]

Solution:

Concept:

- The half-life, $t_{1/2}$, is the time required for the concentration of a reactant to fall to half its initial value: $[A] = [A]_0/2$.
- The integrated rate equation depends on reaction order. Here $[A]_0$ is the initial reactant concentration and k is the rate constant for the specified order.

Quick Tip to Solve: Substitute [A] = [A]0/2 into the integrated law; initial concentration cancels only for first order.

Step 1: (i) Half-life of a zero order reaction For a zero order reaction, the integrated rate law is

$$[A] = [A]_0 - kt.$$

At the half-life put $[A] = [A]_0/2$:

$$\frac{[A]_0}{2} = [A]_0 - kt_{1/2} \quad \Rightarrow \quad t_{1/2} = \frac{[A]_0}{2k}.$$

Thus the half-life is proportional to the initial concentration. A larger initial amount takes longer to decrease by half because the rate is constant.

Step 2: (ii) Half-life of a first order reaction The integrated first order law is

$$kt = \ln \frac{[A]_0}{[A]}.$$

Substituting the half-life condition gives

$$kt_{1/2} = \ln \frac{[A]_0}{[A]_0/2} = \ln 2.$$

Hence $t_{1/2} = \ln 2/k = 0.693/k$. The initial concentration cancels, so the first order half-life is independent of $[A]_0$. Each successive halving therefore takes the same time under fixed conditions.

Step 3: Conclusion Half-life is the time for reactant concentration to become half its initial value. For zero order, $\boxed{t_{1/2} = [A]_0/(2k)}$; for first order, $\boxed{t_{1/2} = 0.693/k}$.

Quick Tip to Solve: Substitute [A] = [A]0/2 into the integrated law; initial concentration cancels only for first order.

18. (a) Which alkyl halide from the following pair would you expect to react more rapidly by an S_N2 mechanism and why?

$CH_3-CH_2-CH(Br)-CH_3$ and $CH_3-CH_2-CH_2-CH_2-Br$

(b) Racemisation occurs in S_N1 reactions. Why? [2 marks]

Solution:

Concept:

- An S_N2 reaction occurs in one concerted step: the nucleophile attacks from the side opposite to the leaving group. Steric crowding around the carbon bearing the halogen slows this attack.
- An S_N1 reaction proceeds through a trigonal planar carbocation. At a chiral reaction centre, attack on either face produces the two enantiomers.

Step 1: Part (a): compare the reacting carbons In $CH_3CH_2CH(Br)CH_3$, the carbon bonded to bromine is secondary and is surrounded by two alkyl groups. In $CH_3CH_2CH_2CH_2Br$, this carbon is primary and has only one alkyl group. The primary halide therefore offers less steric hindrance to the incoming nucleophile and reacts more rapidly by the S_N2 mechanism.

Step 2: Part (b): explain the loss of optical purity When an optically active alkyl halide undergoes

Quick Tip to Solve: For S_N2, inspect the carbon carrying Br, not the total number of carbons in the molecule.

S_N1 substitution, the leaving group first departs to form an sp^2-hybridised, planar carbocation. The nucleophile can approach its empty orbital from either face. One face gives a product with retention of configuration and the other gives inversion, so both enantiomers are obtained and racemisation occurs. Equal attack gives an optically inactive racemic mixture; ion-pair effects can make racemisation incomplete in practice.

Step 3: Conclusion (a) $CH_3CH_2CH_2CH_2Br$ reacts faster by S_N2 because it is less sterically hindered. (b) The planar carbocation in S_N1 allows attack from both faces, producing both enantiomers.

Quick Tip to Solve: For S_N2, inspect the carbon carrying Br, not the total number of carbons in the molecule.

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19. The following data were obtained during the first order thermal decomposition of SO_2Cl_2 at a constant volume:

$SO_2Cl_2(g) \rightarrow SO_2(g) + Cl_2(g)$

Experiment 1: Time = 0 s, Total pressure = 0.4 atm

Experiment 2: Time = 100 s, Total pressure = 0.7 atm

Calculate the rate constant.

(Given: log 4 = 0.6021, log 2 = 0.3010) [3 marks]

Solution:

Concept:

- For a first-order reaction, $k = \dfrac{2.303}{t}\log_{10}\left(\dfrac{[A]_0}{[A]_t}\right)$, where k is the rate constant and t is elapsed time.
- At fixed temperature and volume, gas partial pressure is proportional to its amount. For $A(g) \rightarrow B(g)+C(g)$, the increase in total pressure equals the pressure-equivalent amount of A decomposed.

Step 1: Relate total pressure to decomposition Initially only SO_2Cl_2 is present, with pressure $P_0 = 0.4$ atm. Let x atm be the pressure-equivalent amount decomposed after 100 s. The partial pressures are then $P_{SO_2Cl_2} = 0.4 - x$, $P_{SO_2} = x$, and $P_{Cl_2} = x$. Hence

$$P_t = (0.4 - x) + x + x = 0.4 + x.$$

Since $P_t = 0.7$ atm, $x = 0.3$ atm.

Step 2: Find the remaining reactant pressure The partial pressure of undecomposed sulphuryl chloride is therefore

$$P_A = 0.4 - 0.3 = 0.1 \text{ atm}.$$

Equivalently, $P_A = 2P_0 - P_t = 0.8 - 0.7 = 0.1$ atm. The total pressure must not be substituted for the remaining reactant pressure: it includes both product gases.

Step 3: Apply the first-order rate equation Using the ratio of reactant partial pressures in place of

Quick Tip to Solve: For one gaseous reactant forming two gaseous products, first calculate its remaining pressure as $2P_0 - P_t$.

concentrations,

$$\begin{aligned} k &= \frac{2.303}{100} \log_{10}\left(\frac{0.4}{0.1}\right) \\ &= \frac{2.303}{100} \log_{10} 4 \\ &= \frac{2.303 \times 0.6021}{100} \\ &= 0.013866\,\text{s}^{-1}. \end{aligned}$$

The pressure ratio is dimensionless, and the first-order rate constant has units of inverse time.

Step 4: Conclusion The rate constant is $\boxed{k = 1.387 \times 10^{-2}\,\text{s}^{-1}}$.

Quick Tip to Solve: For one gaseous reactant forming two gaseous products, first calculate its remaining pressure as $2P_0 - P_t$.

20. (i) What type of stoichiometric defect is shown by KCl and why?
(ii) What type of semiconductor is formed when silicon is doped with As?
(iii) Which one of the following is an example of molecular solid: CO_2 or SiO_2
(iv) What type of substances would make better magnets, ferromagnetic or ferrimagnetic? [3 marks]

Solution:

Concept:

- Stoichiometric defects preserve the cation-to-anion ratio of an ionic crystal. A Schottky defect consists of paired cation and anion vacancies.
- Doping silicon with a pentavalent element supplies donor electrons, while magnetic strength depends on the resultant alignment of magnetic moments.
- A molecular solid contains discrete molecules held together by intermolecular forces; a covalent network solid has an extended bonded framework.

Step 1: Part (i): defect in potassium chloride KCl exhibits a Schottky defect. Its cations and anions have comparable sizes and the crystal has a high coordination number. Equal numbers of K^+ and Cl^- ions can be absent from their lattice sites, maintaining electrical neutrality and the $1:1$ stoichiometric ratio. The vacancies decrease the density of the crystal.

Step 2: Part (ii): arsenic-doped silicon Arsenic has five valence electrons, whereas silicon has four. An arsenic atom replacing a silicon atom uses four electrons to form four covalent bonds with neighbouring atoms; its fifth electron is available for conduction. Electrons are the majority charge carriers, so the material is an n-type semiconductor.

Step 3: Part (iii): identify the molecular solid Solid CO_2 is a molecular solid because it contains discrete carbon dioxide molecules held together by dispersion forces. In contrast, SiO_2 has an extended three-dimensional network of strong Si–O covalent bonds and is a covalent network solid.

Step 4: Part (iv): compare magnetic substances Ferromagnetic substances make better magnets. Their magnetic moments align parallel within domains, producing a large resultant magnetisation when the domains align. Ferrimagnetic substances have oppositely aligned, unequal magnetic moments, so

Quick Tip to Solve: Remember: equal ionic vacancies preserve stoichiometry, and a group 15 dopant gives silicon an extra conduction electron.

partial cancellation produces a smaller net magnetisation.

Step 5: Conclusion (i) Schottky defect; (ii) n-type semiconductor; (iii) CO_2; (iv) ferromagnetic substances.

Quick Tip to Solve: Remember: equal ionic vacancies preserve stoichiometry, and a group 15 dopant gives silicon an extra conduction electron.

21. (i) Write two advantages of $H_2 - O_2$ fuel cell over ordinary cell.
(ii) Equilibrium constant (K_c) for the given cell reaction is 10. Calculate E°_{cell}.

$$A(s) + B^{2+}(aq) \rightleftharpoons A^{2+}(aq) + B(s)$$

[3 marks]

Solution:

Concept:

- A fuel cell converts the chemical energy of continuously supplied fuel and oxidant directly into electrical energy.
- The equilibrium constant and standard cell potential are related by $\Delta G^\circ = -nFE^\circ_{cell} = -RT\ln K$, where n is the number of electrons transferred per cell reaction.

Step 1: (i) Advantages of the hydrogen-oxygen fuel cell First, the cell has high efficiency because it converts chemical energy directly into electrical energy. Second, it is environmentally clean during operation: its reaction product is water, so it does not produce the polluting combustion gases associated with conventional fuels. The net reaction is $2H_2 + O_2 \rightarrow 2H_2O$. Continuous fuel supply also permits sustained operation without the exhaustion characteristic of an ordinary primary cell.

Step 2: (ii) Determine the electron transfer and cell potential For the printed reaction, the half-reactions are

$$A(s) \rightarrow A^{2+}(aq) + 2e^-, \qquad B^{2+}(aq) + 2e^- \rightarrow B(s).$$

Thus $n = 2$. At 298 K, use the usual equilibrium-constant relation

$$E^\circ_{cell} = \frac{0.0591}{n}\log_{10} K_c = \frac{0.0591}{2}\log_{10} 10 = 0.02955\,V.$$

Since $K_c > 1$, the standard cell potential is positive, consistent with the forward reaction being thermodynamically favoured under standard conditions.

Step 3: Conclusion The fuel cell offers high efficiency and clean operation producing water. At 298 K, $\boxed{E^\circ_{cell} \approx +0.0296\,V}$.

Quick Tip to Solve: Count electrons from the oxidation-state change before using the equilibrium constant; here the divalent ions make n equal to 2.

22. After the ban on plastic bags, students of one school decided to create awareness among the people about the harmful effects of plastic bags on the environment and the Yamuna river. To make it more impactful, they organized a rally by joining hands with other schools and distributed paper bags to vegetable vendors, shopkeepers and departmental stores. All students pledged not to use polythene bags in future to save the Yamuna river.

After reading the above passage, answer the following questions:

(i) What values are shown by the students?

(ii) What are biodegradable polymers? Give one example.

(iii) Is polythene a homopolymer or copolymer? [3 marks]

Solution:

Concept:

- Biodegradable polymers can be broken down by microorganisms through enzymatic action into simpler products.
- A homopolymer is formed from one type of monomer; a copolymer is formed from two or more different types of monomers.

Step 1: (i) Identify the values reflected in the action The students show environmental awareness and concern for the protection of the Yamuna river. Their rally reflects social responsibility, cooperation and teamwork with students of other schools. Distributing paper bags shows initiative and a willingness to offer a practical alternative. Their pledge to avoid polythene demonstrates commitment to responsible habits rather than merely asking others to change.

Step 2: (ii) Define biodegradable polymers and give an example Biodegradable polymers are polymers that undergo degradation by microorganisms, such as bacteria, through enzyme-catalysed reactions. Their chains break into smaller, simpler substances, reducing the persistence of discarded material in the environment. One example is poly(β-hydroxybutyrate-co-β-hydroxyvalerate), abbreviated PHBV, a biodegradable polyester.

Step 3: (iii) Classify polythene by its monomer Polythene is prepared by the addition polymerisation of ethene alone:

$$n\,CH_2{=}CH_2 \longrightarrow [-CH_2 - CH_2-]_n\,.$$

All its repeating units arise from the same monomer, ethene. The presence of two carbon atoms in the repeating unit does not mean two different monomers were used.

Step 4: Conclusion (i) Environmental concern, social responsibility and cooperation; (ii) polymers degradable by microorganisms, for example PHBV; (iii) polythene is a homopolymer.

Quick Tip to Solve: Classify a polymer by the number of different starting monomers, not the number of atoms or groups in its repeating unit.

23. (i) Define Antihistamine with an example.

(ii) Which one of the following drugs is an antibiotic: Morphine, Equanil, Chloramphenicol, Aspirin.

(iii) Why is use of aspartame limited to cold food and drink? [3 marks]

Solution:

Concept:

- Drugs are classified by their therapeutic action; antihistamines counter histamine-mediated allergy, while antibiotics inhibit or kill susceptible microorganisms.
- The suitability of an artificial sweetener for cooking depends on its stability at elevated temperature as well as its sweetness.

Step 1: (i) Antihistamines: definition and example Antihistamines are drugs that counteract the action of histamine, especially its effects in allergic reactions, by blocking histamine receptors. Synthetic antihistamines interfere with the natural action of histamine by competing with it for receptor binding sites. An example is brompheniramine (Dimetapp); terfenadine is another example. Such drugs help relieve allergic symptoms arising from histamine release.

Step 2: (ii) Identify the antibiotic from the given drugs Chloramphenicol is the antibiotic. It is a broad-spectrum antibiotic that acts against susceptible microorganisms by inhibiting bacterial protein synthesis. The remaining drugs belong to other therapeutic classes: morphine is a narcotic analgesic, Equanil is a tranquiliser, and aspirin is a non-narcotic analgesic and antipyretic. Therefore their presence in the list does not make them antibiotics.

Step 3: (iii) Explain the temperature restriction for aspartame Aspartame is an artificial sweetener derived from a dipeptide. It is unstable at cooking temperatures and decomposes on heating, so its sweetening action is lost or reduced. Consequently, it is suitable for cold foods and drinks, where it can provide sweetness without being subjected to the heat that causes its breakdown.

Step 4: Conclusion (i) Antihistamines oppose histamine action; brompheniramine is an example. (ii) Chloramphenicol is the antibiotic. (iii) Aspartame is used in cold preparations because it decomposes on heating.

Quick Tip to Solve: For aspartame, connect the use in cold drinks directly to thermal instability; artificial sweetness alone does not explain the restriction.

24. Define the following terms:

(a) Invert sugar

(b) Vitamins

(c) Nucleoside [3 marks]

Solution:

Concept:

- Carbohydrates can undergo hydrolysis to simpler sugars; sucrose gives one molecule each of glucose and fructose.
- Vitamins regulate normal biological functions in small amounts. A nucleoside contains a sugar and

Quick Tip to Solve: To distinguish nucleoside from nucleotide, check for phosphate: only the nucleotide contains it.

a nitrogenous base.

Step 1: Define invert sugar Invert sugar is the equimolar mixture of D-glucose and D-fructose obtained by hydrolysis of sucrose with dilute acid or the enzyme invertase.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 \text{ (glucose)} + C_6H_{12}O_6 \text{ (fructose)}.$$

Sucrose is dextrorotatory, whereas the mixture is laevorotatory because the negative rotation of fructose exceeds the positive rotation of glucose. This reversal of rotation gives the name invert sugar.

Step 2: Define vitamins Vitamins are organic compounds required in small quantities in the diet for normal growth, maintenance of health and metabolism. The body generally cannot synthesise them in sufficient amounts, so they must be supplied through food. Their deficiency causes characteristic disorders; for example, vitamin C deficiency causes scurvy.

Step 3: Define nucleoside A nucleoside consists of a nitrogenous base linked to a pentose sugar, ribose or 2-deoxyribose, through a β-N-glycosidic bond. It contains no phosphate group. For example, adenine linked to ribose forms adenosine; addition of phosphate to a nucleoside gives a nucleotide.

Step 4: Conclusion Invert sugar: glucose-fructose mixture from sucrose hydrolysis; vitamins: essential organic dietary micronutrients; nucleoside: nitrogenous base plus pentose sugar.

Quick Tip to Solve: To distinguish nucleoside from nucleotide, check for phosphate: only the nucleotide contains it.

25(a). What are the different oxidation states exhibited by the lanthanoids?

(b) Write two characteristics of the transition elements.

(c) Which of the 3d-block elements may not be regarded as the transition elements and why? [3 marks]

Solution:

Concept:

- A transition element has an incompletely filled d subshell in its atom or in at least one of its oxidation states.
- The energies of the outer s and inner d electrons are close, allowing variable oxidation states.

Step 1: State the oxidation states of lanthanoids Lanthanoids predominantly exhibit the $+3$ oxidation state. Some also show $+2$ and $+4$, particularly when these give favourable empty, half-filled or filled 4f configurations. Examples include Eu^{2+} with $4f^7$, Yb^{2+} with $4f^{14}$, and Ce^{4+} with $4f^0$. Thus the oxidation states generally listed are $+2, +3, +4$.

Step 2: Give two characteristics of transition elements First, they exhibit variable oxidation states because both the outer ns and inner $(n-1)d$ electrons can participate in bonding. For example, iron commonly forms Fe^{2+} and Fe^{3+}. Second, they commonly form coloured ions or compounds: a partially filled d subshell can permit absorption of visible light during transitions between split d levels. This is a general characteristic, with exceptions for ions having d^0 or d^{10} configurations.

Step 3: Identify the exception in the 3d series Zinc is not regarded as a transition element. Its atom has configuration $[Ar]3d^{10}4s^2$, and its common ion Zn^{2+} has $[Ar]3d^{10}$; both have completely filled d

Quick Tip to Solve: Apply the transition-element definition to both the neutral atom and its ions; a d-zero ion alone does not exclude Sc.

subshells. Scandium is a transition element because its neutral atom has $[\mathrm{Ar}]3d^1 4s^2$, even though Sc^{3+} itself is d^0.

Step 4: Conclusion Lanthanoids exhibit mainly +3, with +2 and +4 also found. Transition elements show variable oxidation states and commonly coloured compounds. Zn is the non-transition element of the 3d series.

Quick Tip to Solve: Apply the transition-element definition to both the neutral atom and its ions; a d-zero ion alone does not exclude Sc.

OR

25(b). Assign suitable reasons for the following:

(a) The Mn^{2+} compounds are more stable than Fe^{2+} towards oxidation to their +3 state.

(b) In the 3d series from Sc (Z = 21) to Zn (Z = 30), the enthalpy of atomization of Zn is the lowest.

(c) Sc^{3+} is colourless in aqueous solution whereas Ti^{3+} is coloured. [3 marks]

Solution:

Concept:

- Half-filled d^5 and completely filled d^{10} subshells have enhanced stability.
- Metallic bonding controls atomization enthalpy; visible d-d transitions require partially occupied d levels.

Step 1: Compare oxidation of manganese(II) and iron(II) Mn^{2+} has the stable half-filled $[\mathrm{Ar}]3d^5$ configuration. Oxidation to Mn^{3+} gives $3d^4$, destroying that half-filled configuration, and is therefore less favourable. In contrast, Fe^{2+} is $[\mathrm{Ar}]3d^6$; oxidation to Fe^{3+} produces the stable half-filled $3d^5$ configuration. Hence Mn(II) compounds resist oxidation to +3 more strongly than Fe(II) compounds.

Step 2: Explain the low atomization enthalpy of zinc Zinc has configuration $[\mathrm{Ar}]3d^{10}4s^2$, with no unpaired d electrons. Its filled d subshell contributes little to metallic bonding compared with the partially filled d subshells of the other 3d metals. Consequently zinc has relatively weak metallic bonding, so the energy needed to separate its solid into gaseous atoms is the lowest in this series.

Step 3: Explain the colours of the aqueous ions Sc^{3+} has configuration $[\mathrm{Ar}]3d^0$. With no d electron, it cannot undergo a d-d transition and its aqueous solution is colourless. Ti^{3+} has $[\mathrm{Ar}]3d^1$. In the field of water ligands its d orbitals split into different energy levels; the d electron absorbs visible light to reach a higher d level. The transmitted complementary light gives the solution its colour.

Step 4: Conclusion Mn(II) retains a stable half-filled d subshell; Zn has weak metallic bonding with a filled d subshell; Sc(III) is d-zero, whereas Ti(III) is d-one and undergoes visible d-d absorption.

Quick Tip to Solve: Write the ionic d-electron counts first: Mn(II) d5, Fe(II) d6, Sc(III) d0 and Ti(III) d1.

26. (a) Write the expression for the Freundlich adsorption isotherm for the adsorption of gases on solids, in the form of an equation.

(b) What are the dispersed phase and dispersion medium of butter?

(c) A delta is formed at the meeting place of sea and river water. Why? [3 marks]

Solution:

Concept:

- Freundlich adsorption isotherm relates the mass of gas adsorbed per unit mass of solid to the equilibrium pressure at a fixed temperature.
- In a colloid, the dispersed phase is distributed throughout the continuous dispersion medium. Electrolytes can coagulate a charged colloidal sol.

Step 1: Write the adsorption equation For adsorption of a gas on a solid at a fixed temperature, the Freundlich equation is

$$\frac{x}{m} = kP^{1/n}, \qquad 0 < \frac{1}{n} < 1.$$

Here x is the mass of gas adsorbed, m is the mass of the adsorbent, P is the equilibrium gas pressure, and k, n are constants for the particular gas and solid at that temperature. Equivalently, $\log(x/m) = \log k + (1/n)\log P$. The empirical relation applies over a limited pressure range.

Step 2: Identify the phases of butter Butter is a water-in-oil type emulsion: small droplets of water form the dispersed phase, while the continuous fat (oil) forms the dispersion medium. The phases are identified by which material forms droplets and which surrounds those droplets.

Step 3: Explain delta formation River water carries fine clay particles as a colloidal sol. When the river meets sea water, electrolytes present in sea water supply ions that neutralise the charge on the clay particles. The particles lose their electrostatic stabilisation, coagulate into larger aggregates and settle. Continued deposition of this coagulated material near the river mouth builds up a delta.

Step 4: Conclusion Thus $x/m = kP^{1/n}$; butter has water dispersed in fat (oil); and a delta forms through electrolyte-induced coagulation and deposition of river clay.

Quick Tip to Solve: For an emulsion, name the droplets first and the continuous surrounding phase second; sea-water salts destabilise river clay.

27. Give the structures of A, B and C in the following reactions:

(i) $CH_3Br \xrightarrow{KCN} A \xrightarrow{LiAlH_4} B \xrightarrow[273\,K]{HNO_2} C$

(ii) $CH_3COOH \xrightarrow[\Delta]{NH_3} A \xrightarrow{Br_2+KOH} B \xrightarrow{CHCl_3+NaOH} C$ [3 marks]

Solution:

Concept:

- Ionic KCN attacks an alkyl halide through carbon, giving a nitrile with one more carbon atom; reduction converts its $-C \equiv N$ group into $-CH_2NH_2$.
- Heating a carboxylic acid with ammonia produces an amide. Hofmann bromamide degradation

Quick Tip to Solve: Count carbons: KCN adds one carbon, nitrile reduction retains it, and Hofmann degradation removes the amide carbonyl carbon.

converts the amide to a primary amine containing one carbon fewer.

- An aliphatic primary amine reacts with nitrous acid to give an alcohol; the carbylamine reaction converts a primary amine into an isocyanide.

Step 1: Identify the first sequence Cyanide displaces bromide from methyl bromide, so A is ethanenitrile (acetonitrile):

$$CH_3Br + KCN \longrightarrow CH_3C \equiv N + KBr.$$

Lithium aluminium hydride reduces the nitrile carbon to a methylene group without losing a carbon atom. Thus B is ethanamine, $CH_3CH_2NH_2$. Treatment of this primary aliphatic amine with nitrous acid at $273\,K$ gives ethanol:

$$CH_3CH_2NH_2 + HNO_2 \longrightarrow CH_3CH_2OH + N_2 + H_2O.$$

Therefore $C = CH_3CH_2OH$.

Step 2: Identify the second sequence Ethanoic acid first forms ammonium ethanoate with ammonia; heating dehydrates the salt to ethanamide:

$$CH_3COOH + NH_3 \xrightarrow{\Delta} CH_3CONH_2 + H_2O.$$

Thus $A = CH_3CONH_2$. Hofmann degradation removes the carbonyl carbon, giving $B = CH_3NH_2$, methylamine:

$$CH_3CONH_2 + Br_2 + 4KOH \longrightarrow CH_3NH_2 + 2KBr + K_2CO_3 + 2H_2O.$$

Methylamine then undergoes the carbylamine reaction:

$$CH_3NH_2 + CHCl_3 + 3NaOH \longrightarrow CH_3N \equiv C + 3NaCl + 3H_2O.$$

Hence C is methyl isocyanide; its methyl group is bonded to nitrogen, not to the terminal carbon.

Step 3: Conclusion (i) $A = CH_3C \equiv N$, $B = CH_3CH_2NH_2$, $C = CH_3CH_2OH$. (ii) $A = CH_3CONH_2$, $B = CH_3NH_2$, $C = CH_3N \equiv C$.

Quick Tip to Solve: Count carbons: KCN adds one carbon, nitrile reduction retains it, and Hofmann degradation removes the amide carbonyl carbon.

28(a). Account for the following:

(i) Bi is a strong oxidizing agent in the +5 state.

(ii) PCl_5 is known but NCl_5 is not known.

(iii) Iron dissolves in HCl to form $FeCl_2$ and not $FeCl_3$. [3 marks]

Solution:

Concept:

- The inert-pair effect stabilises the lower oxidation state of heavy p-block elements; bismuth therefore favours $+3$ over $+5$.
- Nitrogen is a second-period element and cannot expand its octet. Phosphorus can form a five-coordinate chloride.
- Hydrochloric acid is a non-oxidising acid; iron normally dissolves in it in the $+2$ oxidation state.

Step 1: Explain the oxidising action of Bi(V) Bismuth has valence configuration $6s^2 6p^3$. Due to the inert-pair effect, its $6s^2$ pair is relatively reluctant to participate in bonding. Consequently, $+3$ is much more stable than $+5$. Bismuth in the $+5$ state therefore readily accepts two electrons and is reduced to the stable $+3$ state:

$$\mathrm{Bi(V)} + 2\mathrm{e}^- \longrightarrow \mathrm{Bi(III)}.$$

By accepting electrons it oxidises the other reactant, so Bi(V) acts as a strong oxidising agent.

Step 2: Explain the existence of phosphorus pentachloride In PCl_5, phosphorus forms five P–Cl bonds and has ten electrons around it in the conventional covalent representation. Phosphorus can accommodate this expanded valence shell (traditionally described using available vacant $3d$ orbitals). Nitrogen has only $2s$ and $2p$ valence orbitals and no vacant $2d$ orbitals, so it cannot expand its octet to form five N–Cl bonds. Hence PCl_5 is known but NCl_5 is not.

Step 3: Explain the chloride obtained with HCl Iron displaces hydrogen from dilute hydrochloric acid:

$$\mathrm{Fe} + 2\mathrm{HCl} \longrightarrow \mathrm{FeCl_2} + \mathrm{H_2}\uparrow.$$

HCl does not provide an oxidising agent capable of converting the resulting Fe^{2+} into Fe^{3+}. Moreover, any ferric ions in contact with excess iron are reduced:

$$2\mathrm{Fe}^{3+} + \mathrm{Fe} \longrightarrow 3\mathrm{Fe}^{2+}.$$

Thus the product under these conditions is ferrous chloride rather than ferric chloride.

Step 4: Conclusion Bi(V) gains electrons to attain stable Bi(III); nitrogen cannot expand its octet to form NCl_5; and non-oxidising HCl gives $FeCl_2$.

Quick Tip to Solve: Link each reason to a distinct principle: inert pair for Bi, octet restriction for N, and non-oxidising acid for iron.

28(b). Draw the structures of the following:

(i) $XeOF_4$

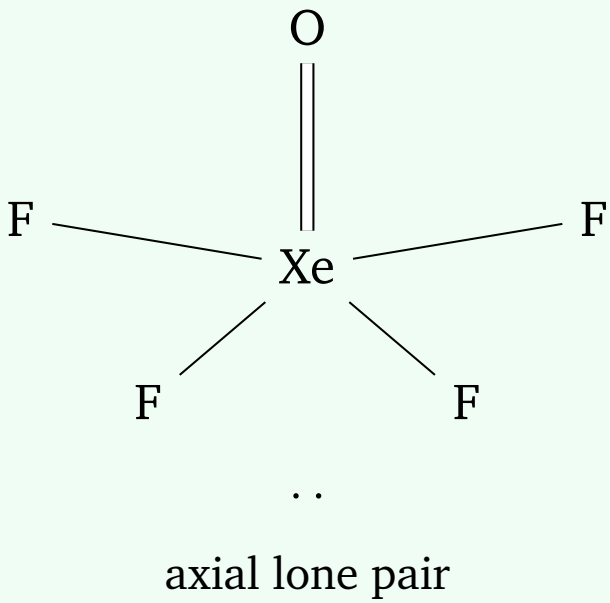
(ii) $HClO_4$ [2 marks]

Solution:

Concept:

- VSEPR theory predicts molecular shape from the repulsions between electron domains around the central atom; a multiple bond counts as one domain.
- In a structural formula, single and double lines represent single and double covalent bonds respectively; a lone pair is shown as two dots.

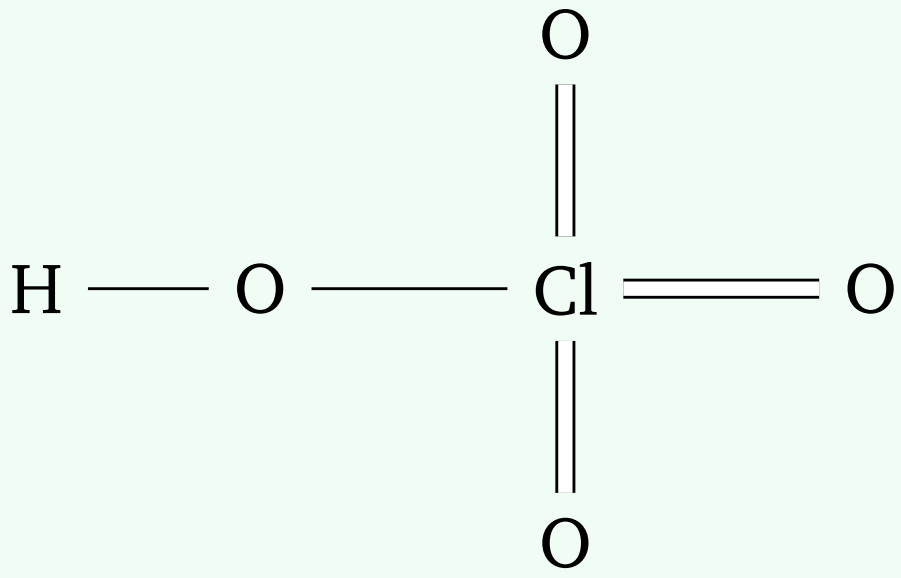
Step 1: (i) Structure of xenon oxytetrafluoride In $XeOF_4$, xenon has four Xe–F single bonds, one Xe=O double bond and one lone pair. Thus six electron domains surround Xe, giving an octahedral electron-pair arrangement. The four fluorine atoms occupy a square plane. Oxygen is above that plane and the lone pair occupies the opposite axial position. Hence the molecular shape is square pyramidal.



Square pyramidal XeOF4; the lone pair is opposite oxygen.

Step 2: (ii) Structure of perchloric acid Perchloric acid has the connectivity $HO-Cl(=O)_3$. Chlorine is bonded to four oxygen atoms: three terminal oxygen atoms by double bonds and one hydroxyl oxygen by a single bond. The hydrogen atom is attached to oxygen, not directly to chlorine. The four oxygen atoms are arranged approximately tetrahedrally around chlorine; the formula below shows the conventional expanded-valence structure.

Quick Tip to Solve: For XeOF4 count the lone pair as the sixth domain; for HClO4 put the acidic H on oxygen.



Conventional structure of HClO4; the oxygen coordination is tetrahedral.

Step 3: Conclusion $XeOF_4$ is square pyramidal with the lone pair opposite Xe=O; $HClO_4$ is $HO-Cl(=O)_3$, tetrahedral around Cl.

Quick Tip to Solve: For XeOF4 count the lone pair as the sixth domain; for HClO4 put the acidic H on oxygen.

OR

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

(i) $H_2S_2O_8$

(ii) Red P_4 [2 marks]

Solution:

Concept:

- Peroxodisulphuric acid contains a peroxide linkage, $-O-O-$, joining two sulphur-containing groups.
- Red phosphorus is polymeric: linked phosphorus units form an extended network, rather than isolated P_4 molecules.

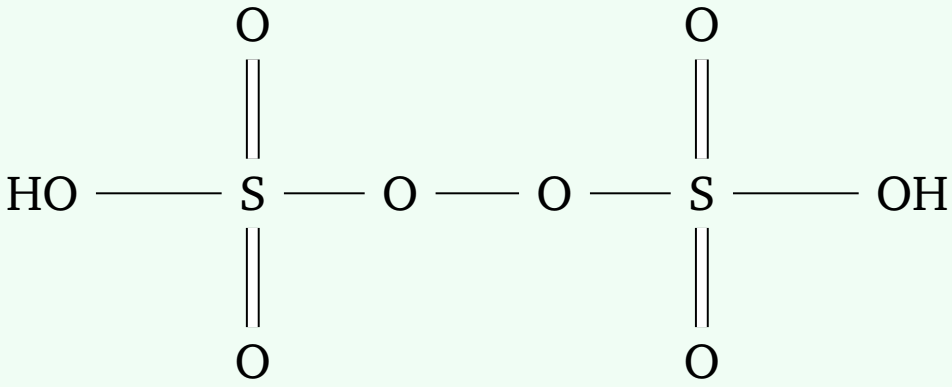
Step 1: (i) Structure of peroxodisulphuric acid The structure is shown below. Its connectivity is

$$HO-S(=O)_2-O-O-S(=O)_2-OH.$$

Each sulphur atom is bonded to two terminal oxygen atoms through double bonds, to one hydroxyl oxygen and to one peroxide oxygen through single bonds. The central O–O bond is essential: it distinguishes this acid from an acid having an S–O–S bridge. Counting the atoms gives two H, two S

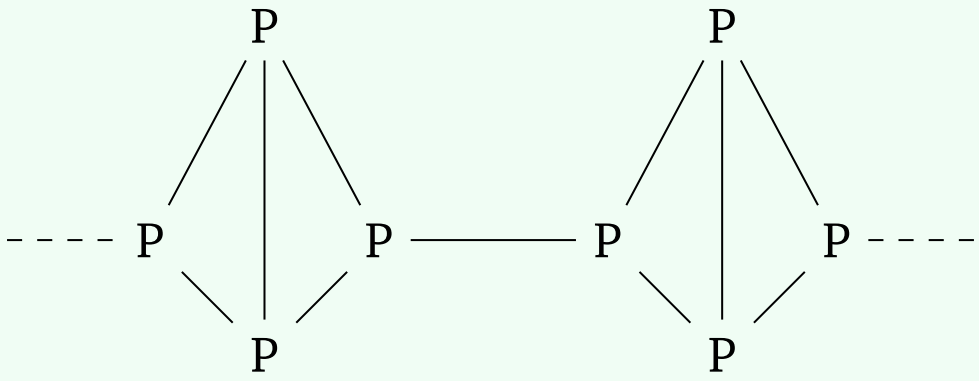
Quick Tip to Solve: Include the O–O bond in H2S2O8 and show continuing P–P links when drawing red phosphorus.

and eight O atoms.



Peroxodisulphuric acid with the central peroxide bond.

Step 2: (ii) Structure of red phosphorus Red phosphorus consists of an extended polymeric structure, commonly represented by linked opened P_4 tetrahedral units. Opening a P–P bond in a tetrahedron allows neighbouring units to join by P–P bonds. The sketch shows a representative segment; the dotted end connections indicate continuation of the network. Each phosphorus atom has three covalent bonds and one lone pair. Unlike white phosphorus, red phosphorus does not consist of discrete tetrahedral P_4 molecules.



Representative polymeric segment of red phosphorus (network continues at both ends).

Step 3: Conclusion The structures are $HO-S(=O)_2-O-O-S(=O)_2-OH$ and the extended linked phosphorus network shown below.

Quick Tip to Solve: Include the O–O bond in H2S2O8 and show continuing P–P links when drawing red phosphorus.

28(b). Account for the following:

(i) Sulphur in vapour state exhibits paramagnetism.

(ii) Unlike xenon, no distinct chemical compound of helium is known.

(iii) H_3PO_2 is a stronger reducing agent than H_3PO_3. [3 marks]

Solution:

Concept:

- Paramagnetism arises from unpaired electrons; a species with only paired electrons is diamagnetic.
- Noble-gas reactivity depends on the energy required to disturb the closed-shell configuration. The reducing behaviour of phosphorus oxyacids is associated with their $\mathrm{P-H}$ bonds.

Step 1: Explain sulphur vapour At high temperature, sulphur vapour contains diatomic S_2 molecules. Like O_2, an S_2 molecule has two unpaired electrons in its degenerate antibonding π^* molecular orbitals. These unpaired electrons are attracted by a magnetic field, so sulphur vapour exhibits paramagnetism. The explanation concerns the diatomic species present in the vapour, rather than the usual ring structure of solid sulphur.

Step 2: Compare helium and xenon Helium has the compact, completely filled $1s^2$ shell and an exceptionally high ionisation enthalpy. Its electrons are very tightly held, making ordinary chemical bond formation extremely unfavourable. Xenon is larger and has a much lower ionisation enthalpy; strong oxidising elements such as fluorine and oxygen can therefore form compounds with xenon. Thus, unlike xenon, helium has no distinct ordinary chemical compound.

Step 3: Compare the phosphorus oxyacids The structures are $\mathrm{HOP(=O)H_2}$ for hypophosphorous acid, H_3PO_2, and $\mathrm{(HO)_2P(=O)H}$ for phosphorous acid, H_3PO_3. The former has two $\mathrm{P-H}$ bonds, whereas the latter has only one. Since their reducing character is due to these $\mathrm{P-H}$ bonds, H_3PO_2 is the stronger reducing agent. The number of $\mathrm{O-H}$ bonds instead determines basicity and must not be used to compare reducing character.

Step 4: Conclusion Sulphur vapour is paramagnetic because S_2 has two unpaired electrons; helium is chemically inert because of its tightly held $1s^2$ shell; and H_3PO_2 is more strongly reducing because it has two $\mathrm{P-H}$ bonds compared with one in H_3PO_3.

Quick Tip to Solve: For phosphorus oxyacids, draw the connectivity first: count P-H bonds for reducing power and O-H bonds for basicity.

29(a). Write the products formed when ethanal reacts with the following reagents:

(i) CH_3MgBr and then H_3O^+

(ii) Zn–Hg / conc. HCl

(iii) C_6H_5CHO in the presence of dilute NaOH [3 marks]

Solution:

Concept:

- A Grignard reagent adds its alkyl group to the carbonyl carbon; acidic hydrolysis converts the resulting magnesium alkoxide into an alcohol.

Quick Tip to Solve: Track the carbonyl carbon: Grignard addition adds a methyl group, Clemmensen reduction removes its oxygen, and aldol condensation makes a new C-C bond.

- Clemmensen reduction converts $C = O$ into CH_2. In dilute alkali, ethanal forms an enolate that can undergo crossed aldol reaction with benzaldehyde.

Step 1: Add methylmagnesium bromide and hydrolyse The methyl group of CH_3MgBr adds to the electrophilic carbonyl carbon of ethanal. The alkoxide obtained in dry ether gives propan-2-ol on acidic hydrolysis:

$$CH_3CHO + CH_3MgBr \longrightarrow CH_3CH(OMgBr)CH_3$$

$$CH_3CH(OMgBr)CH_3 \xrightarrow{H_3O^+} CH_3CH(OH)CH_3.$$

A secondary alcohol results because the aldehyde already contains one methyl group and gains a second one.

Step 2: Carry out Clemmensen reduction Zinc amalgam and concentrated hydrochloric acid reduce the aldehyde group completely to a methyl group without changing the carbon skeleton:

$$CH_3CHO + 4[H] \xrightarrow{Zn-Hg/\text{conc. } HCl} CH_3CH_3 + H_2O.$$

The organic product is ethane; the product is not ethanol, which would require reduction only to the alcohol stage.

Step 3: Carry out the crossed aldol reaction Ethanal has alpha-hydrogen atoms and forms an enolate in dilute sodium hydroxide. Benzaldehyde has no alpha-hydrogen and acts as the carbonyl electrophile. Their crossed aldol addition first gives the beta-hydroxy aldehyde:

$$C_6H_5CHO + CH_3CHO \xrightarrow{\text{dil. NaOH}} C_6H_5CH(OH)CH_2CHO.$$

This is 3-hydroxy-3-phenylpropanal. On dehydration, the conjugated condensation product is cinnamaldehyde, or 3-phenylprop-2-enal:

$$C_6H_5CH(OH)CH_2CHO \xrightarrow{-H_2O} C_6H_5CH{=}CHCHO.$$

The conjugated aldehyde is the usual product written for this crossed aldol condensation.

Step 4: Conclusion The products are (i) propan-2-ol, $CH_3CH(OH)CH_3$; (ii) ethane, CH_3CH_3; and (iii) the crossed aldol product $C_6H_5CH(OH)CH_2CHO$, which dehydrates to cinnamaldehyde, $C_6H_5CH{=}CHCHO$.

Quick Tip to Solve: Track the carbonyl carbon: Grignard addition adds a methyl group, Clemmensen reduction removes its oxygen, and aldol condensation makes a new C-C bond.

29(b). Give simple chemical tests to distinguish between the following pairs of compounds:

(i) Benzoic acid and Ethyl benzoate

(ii) Propanal and Butan-2-one [2 marks]

Solution:

Concept:

- A carboxylic acid liberates carbon dioxide from aqueous sodium hydrogen carbonate, whereas an ester does not.
- Tollens' reagent oxidises an aliphatic aldehyde to a carboxylate ion while silver(I) is reduced to metallic silver. An ordinary ketone does not give this test.

Step 1: Distinguish benzoic acid from ethyl benzoate Add aqueous sodium hydrogen carbonate separately to small portions of the two samples. Benzoic acid gives brisk effervescence of carbon dioxide:

$$C_6H_5COOH + NaHCO_3 \longrightarrow C_6H_5COONa + CO_2 \uparrow + H_2O.$$

Ethyl benzoate gives no effervescence under these conditions because it has no acidic carboxyl hydrogen. The gas from benzoic acid turns limewater milky, confirming carbon dioxide.

Step 2: Distinguish propanal from butan-2-one Warm each sample separately with freshly prepared Tollens' reagent in a clean test tube. Propanal gives a silver mirror or a deposit of metallic silver, while butan-2-one gives no silver mirror. The ionic equation for propanal is

$$CH_3CH_2CHO + 2[Ag(NH_3)_2]^+ + 3OH^- \longrightarrow CH_3CH_2COO^- + 2Ag \downarrow + 4NH_3 + 2H_2O.$$

Propanal is oxidised because it is an aldehyde; butan-2-one is a ketone and is not oxidised by this mild reagent.

Step 3: Conclusion Use aqueous $NaHCO_3$: benzoic acid evolves CO_2, ethyl benzoate does not. Use Tollens' reagent: propanal gives a silver mirror, butan-2-one does not.

Quick Tip to Solve: Always report the positive observation and the negative observation for each pair, rather than naming only the reagent.

OR

29(a). Account for the following:

(i) CH_3CHO is more reactive than CH_3COCH_3 towards reaction with HCN.

(ii) There are two $-NH_2$ groups in semicarbazide ($H_2NNHCONH_2$). However, only one is involved in the formation of semicarbazone. [2 marks]

Solution:

Concept:

- Nucleophilic addition to a carbonyl group begins with attack on its electron-deficient carbon; lower steric hindrance and greater electrophilicity increase the rate.
- A nitrogen lone pair conjugated with a carbonyl group is less available for nucleophilic attack than a free amino nitrogen lone pair.

Step 1: (i) Compare addition of HCN In cyanohydrin formation, CN^- attacks the carbonyl carbon. Ethanal has one methyl group and one small hydrogen atom, whereas propanone has two methyl groups. The second methyl group in propanone increases crowding around the carbonyl carbon and donates electron density by its $+I$ effect. This reduces the positive character of that carbon. Thus both the steric effect and the electronic effect make ethanal more reactive towards HCN.

Step 2: (ii) Identify the reactive amino group Write semicarbazide as $H_2N-NH-C(=O)-NH_2$. The lone pair on the terminal H_2N- nitrogen, attached to another nitrogen, is available for attack on an aldehyde or ketone. The lone pair on the $-CONH_2$ nitrogen is delocalised into the adjacent carbonyl group by resonance, so this amino group is much less nucleophilic. Condensation therefore occurs through the terminal hydrazino amino group, giving $R_2C=N-NH-CO-NH_2$ and water.

Step 3: Conclusion Ethanal reacts faster because its carbonyl carbon is less hindered and more electrophilic. Only the terminal hydrazino $-NH_2$ group forms the semicarbazone.

Quick Tip to Solve: In semicarbazide, locate the amino nitrogen directly bonded to C=O: its lone pair is resonance-delocalised.

29(b). Write the chemical equation to illustrate each of the following name reactions:

(i) Rosenmund reduction

(ii) Hell–Volhard–Zelinsky reaction

(iii) Cannizzaro reaction [3 marks]

Solution:

Concept:

- Rosenmund reduction converts an acyl chloride into an aldehyde using hydrogen and a poisoned palladium catalyst.
- The Hell–Volhard–Zelinsky reaction halogenates the alpha carbon of a carboxylic acid containing an alpha hydrogen.
- An aldehyde without alpha hydrogen undergoes Cannizzaro disproportionation in concentrated alkali: one molecule is oxidised and another is reduced.

Quick Tip to Solve: For Cannizzaro, use two aldehyde molecules and show a carboxylate salt because the medium is strongly alkaline.

Step 1: (i) Rosenmund reduction An illustrative equation is

$$CH_3COCl + H_2 \xrightarrow{Pd/BaSO_4} CH_3CHO + HCl.$$

The catalyst is poisoned to limit its activity, allowing the reaction to stop at the aldehyde rather than reducing it further to an alcohol. Thus ethanoyl chloride gives ethanal.

Step 2: (ii) Hell–Volhard–Zelinsky reaction Ethanoic acid has alpha hydrogen atoms and undergoes alpha bromination in the presence of red phosphorus:

$$CH_3COOH + Br_2 \xrightarrow{\text{red P}} BrCH_2COOH + HBr.$$

The usual procedure includes hydrolysis of the intermediate acyl bromide, restoring the carboxylic acid group. The product is 2-bromoethanoic acid; bromine replaces an alpha hydrogen, not the acidic hydrogen.

Step 3: (iii) Cannizzaro reaction Benzaldehyde has no alpha hydrogen and reacts with concentrated aqueous sodium hydroxide:

$$2C_6H_5CHO + NaOH \xrightarrow{\text{conc.}} C_6H_5CH_2OH + C_6H_5COONa.$$

One aldehyde molecule is reduced to benzyl alcohol while the other is oxidised to sodium benzoate. The salt, rather than free benzoic acid, is obtained in the alkaline reaction mixture.

Step 4: Conclusion The equations illustrate acyl chloride reduction to an aldehyde, alpha bromination of a carboxylic acid, and aldehyde disproportionation, respectively.

Quick Tip to Solve: For Cannizzaro, use two aldehyde molecules and show a carboxylate salt because the medium is strongly alkaline.

30(a). State Raoult's law for a solution containing volatile components. Name the solution which follows Raoult's law at all concentrations and temperatures. [2 marks]

Solution:

Concept:

- Raoult's law relates the equilibrium partial vapour pressure of each volatile component to its mole fraction in the liquid solution.
- For an ideal solution, each volatile component obeys $p_i = x_i p_i^0$, where p_i^0 is its pure-component vapour pressure at the same temperature.

Step 1: State the law for each volatile component At a given temperature, the partial vapour pressure p_i of a volatile component i above a solution equals its mole fraction x_i in the liquid multiplied by its vapour pressure p_i^0 in the pure state:

$$p_i = x_i p_i^0.$$

For a binary solution of volatile components A and B, $p_A = x_A p_A^0$ and $p_B = x_B p_B^0$. By Dalton's law, the total vapour pressure is $p = p_A + p_B = x_A p_A^0 + x_B p_B^0$, with $x_A + x_B = 1$.

Quick Tip to Solve: Apply Raoult's law separately to every volatile component, then add their partial pressures for the total.

Step 2: Name the solution A solution obeying Raoult's law over the entire range of concentrations and temperatures is called an ideal solution. Its unlike molecular interactions are comparable to the corresponding like interactions; mixing therefore has $\Delta H_{\text{mix}} = 0$ and $\Delta V_{\text{mix}} = 0$. The mole fractions used in the law refer to the liquid phase, while p_i is the component's pressure in the vapour phase.

Step 3: Conclusion Raoult's law is $\boxed{p_i = x_i p_i^0}$. The solution described is an $\boxed{\text{ideal solution}}$.

Quick Tip to Solve: Apply Raoult's law separately to every volatile component, then add their partial pressures for the total.

30(b). Calculate the boiling point elevation for a solution prepared by adding 10 g of $CaCl_2$ to 200 g of water. (K_b for water = 0.512 K kg mol^{-1}, Molar mass of $CaCl_2$ = 111 g mol^{-1}) [3 marks]

Solution:

Concept:

- Boiling point elevation is a colligative property: $\Delta T_b = iK_b m$, where i is the van't Hoff factor, K_b is the molal elevation constant and m is the molality.
- Molality is the amount of solute in moles per kilogram of solvent. Dissociation increases the number of solute particles and therefore increases the boiling point elevation.

Step 1: Find the amount of calcium chloride The given mass of calcium chloride is $10\,\text{g}$ and its molar mass is $111\,\text{g mol}^{-1}$. Therefore,

$$n(\text{CaCl}_2) = \frac{10}{111} = 0.09009\,\text{mol}.$$

The solvent mass is $200\,\text{g} = 0.200\,\text{kg}$. Hence the molality before accounting for dissociation is

$$m = \frac{0.09009}{0.200} = 0.45045\,\text{mol kg}^{-1}.$$

Step 2: Account for dissociation and calculate the elevation For the usual complete-dissociation treatment in water, calcium chloride produces three ions per formula unit:

$$\text{CaCl}_2(\text{aq}) \longrightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{Cl}^-(\text{aq}).$$

Thus $i = 3$. Substituting the solvent constant and the calculated molality gives

$$\begin{aligned}\Delta T_b &= iK_b m \\ &= 3 \times 0.512 \times 0.45045 \\ &= 0.6919\,\text{K}.\end{aligned}$$

Using $i = 1$ would neglect the additional particles produced by the electrolyte and underestimate the elevation by a factor of three.

Step 3: Conclusion The boiling point elevation is $\boxed{\Delta T_b \simeq 0.692\,\text{K}}$, taking complete dissociation of $CaCl_2$ in water.

Quick Tip to Solve: Count the ions first: one formula unit of calcium chloride gives three ions, so multiply the ordinary molal elevation by three.

OR

30(a). Define the following terms:

(i) Azeotrope

(ii) Osmotic pressure

(iii) Colligative properties [3 marks]

Solution:

Concept:

- A solution property can depend on vapour-liquid equilibrium, on solvent flow through a semipermeable membrane, or simply on the number of dissolved particles.
- In defining colligative behaviour, compare dilute solutions at the same temperature and count solute particles after any association or dissociation.

Step 1: Define azeotrope An azeotrope is a liquid mixture that boils at a constant temperature and has the same composition in the vapour phase as in the liquid phase. Consequently, its composition does not change on boiling, and its components cannot be separated by fractional distillation at that pressure. Azeotropes occur at a particular composition in non-ideal solutions; they may be minimum-boiling or maximum-boiling mixtures.

Step 2: Define osmotic pressure Osmotic pressure, π, is the minimum excess pressure that must be applied to a solution to prevent the net flow of solvent into it through a semipermeable membrane separating it from pure solvent. The membrane permits solvent molecules to pass but prevents solute particles from passing. For a dilute ideal solution, $\pi = CRT$, where C is the solute particle concentration, R the gas constant and T the absolute temperature.

Step 3: Define colligative properties Colligative properties are properties of dilute solutions that depend on the number of solute particles relative to the number of solvent particles, and not on the chemical identity of the solute. They include relative lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure. Association or dissociation must be included when counting the effective solute particles.

Step 4: Conclusion An azeotrope has identical liquid and vapour compositions at its constant boiling point; osmotic pressure stops osmosis; colligative properties depend on the number of solute particles.

Quick Tip to Solve: For azeotropes state both constant boiling and equal phase compositions; for osmotic pressure explicitly mention the semipermeable membrane.

30(b). Calculate the molarity of 9.8% (w/w) solution of H_2SO_4 if the density of the solution is 1.02 g mL^{-1}. (Molar mass of H_2SO_4 = 98 g mol^{-1}) [2 marks]

Solution:

Concept:

- Molarity is the number of moles of solute per litre of solution: $M = n/V$, with V expressed in litres.

Quick Tip to Solve: For a mass-percent solution choose 100 g of solution, then divide that full mass by density before converting the volume to litres.

- A 9.8% mass-by-mass solution contains $9.8\,\text{g}$ solute per $100\,\text{g}$ solution. Density converts solution mass to solution volume.

Step 1: Choose a convenient mass and find solute moles Take $100\,\text{g}$ of the solution. By the given mass percentage, this contains $9.8\,\text{g}$ of H_2SO_4. Using its molar mass,

$$n(H_2SO_4) = \frac{9.8\,\text{g}}{98\,\text{g mol}^{-1}} = 0.100\,\text{mol}.$$

The percentage is by mass, so it does not directly mean grams per $100\,\text{mL}$.

Step 2: Convert solution mass to volume and calculate molarity The density is $\rho = 1.02\,\text{g mL}^{-1}$. Thus the volume of the selected solution sample is

$$V = \frac{100\,\text{g}}{1.02\,\text{g mL}^{-1}} = 98.039\,\text{mL} = 0.098039\,\text{L}.$$

Therefore,

$$M = \frac{0.100}{0.098039} = 1.02\,\text{mol L}^{-1}.$$

Use the total solution mass in the density conversion, because molarity is based on solution volume rather than solvent volume.

Step 3: Conclusion The molarity of the sulphuric acid solution is $\boxed{1.02\,\text{mol L}^{-1}}$.

Quick Tip to Solve: For a mass-percent solution choose 100 g of solution, then divide that full mass by density before converting the volume to litres.