

CBSE Class 12 Chemistry Question Paper 2020 with Solution PDF-Set 56-1-3

Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) This question paper comprises **four** Sections – **A, B, C** and **D**. There are **37** questions in the question paper. **All** questions are compulsory.
- (ii) **Section A** – Questions no. **1** to **20** are very short answer type questions, carrying **1** mark each. Answer these questions in one word or one sentence.
- (iii) **Section B** – Questions no. **21** to **27** are short answer type questions, carrying **2** marks each.
- (iv) **Section C** – Questions no. **28** to **34** are long answer type-I questions, carrying **3** marks each.
- (v) **Section D** – Questions no. **35** to **37** are long answer type-II questions, carrying **5** marks each.
- (vi) There is no overall choice in the question paper. However, an internal choice has been provided in 2 questions of two marks, 2 questions of three marks and all the 3 questions of five marks. You have to attempt only one of the choices in such questions.
- (vii) In addition to this, separate instructions are given with each section and question, wherever necessary.
- (viii) Use of calculators and log tables is not permitted.

Section A (20 marks)

Read the given passage and answer the questions number 1 to 5 that follow :

1–5. Read the given passage and answer the questions number 1 to 5 that follow :

The substitution reaction of alkyl halide mainly occurs by S_N1 or S_N2 mechanism. Whatever mechanism alkyl halides follow for the substitution reaction to occur, the polarity of the carbon halogen bond is responsible for these substitution reactions. The rate of S_N1 reactions are governed by the stability of carbocation whereas for S_N2 reactions steric factor is the deciding factor. If the starting material is a chiral compound, we may end up with an inverted product or racemic mixture depending upon the type of mechanism followed by alkyl halide. Cleavage of ethers with HI is also governed by steric factor and stability of carbocation, which indicates that in organic chemistry, these two major factors help us in deciding the kind of product formed. [5 marks]

1. Predict the stereochemistry of the product formed if an optically active alkyl halide undergoes substitution reaction by S_N1 mechanism. [1 mark]

Solution:

Concept:

- An S_N1 reaction occurs through a carbocation intermediate after the carbon–halogen bond breaks.
- The positively charged carbon is sp^2 -hybridised and has a trigonal planar arrangement.

Step 1: Identify the intermediate The optically active alkyl halide initially has a chiral tetrahedral carbon. Loss of the halide ion produces a planar carbocation, so the original three-dimensional arrangement at that carbon is lost.

Step 2: Consider nucleophilic attack The nucleophile can attack either face of this planar intermediate. Attack from one face produces retention of configuration, whereas attack from the opposite face produces inversion. Thus both enantiomeric forms are obtained.

Step 3: Conclusion The product shows racemisation: a mixture of the two enantiomers is formed.

Quick Tip to Solve: For S_N1 , first picture a flat carbocation; access to both faces explains racemisation.

2. What is plane polarised light? [1 mark]

Solution:

Concept:

- Light is a transverse electromagnetic wave: its electric field vibrates perpendicular to the direction of propagation.
- Polarisation describes the direction in which the electric-field vibrations are restricted.

Step 1: Contrast ordinary light In unpolarised light, the electric-field vibrations have random orientations in the plane perpendicular to the direction of travel. There is no single fixed vibration direction.

Step 2: Restrict the vibrations When these vibrations are confined to one fixed direction perpendicular

Quick Tip to Solve: In the definition, state both restrictions: one fixed plane and vibrations perpendicular to the direction of travel.

to propagation, the electric field and the propagation direction define a single fixed plane. Such light is called plane polarised light.

Step 3: Conclusion Plane polarised light is light whose vibrations are restricted to a single plane containing the direction of propagation.

Quick Tip to Solve: In the definition, state both restrictions: one fixed plane and vibrations perpendicular to the direction of travel.

3. Write the structures of the products formed when ethoxybenzene is treated with HI.

[1 mark]

Solution:

Concept:

- An aryl-alkyl ether reacts with HI by protonation of oxygen followed by cleavage of the alkyl-oxygen bond.
- The aryl-oxygen bond has partial double-bond character because of resonance and is not cleaved in this reaction.

Step 1: Identify the bond that breaks Ethoxybenzene has the structure $\text{C}_6\text{H}_5-\text{O}-\text{CH}_2-\text{CH}_3$. After protonation of its oxygen, I^- attacks the primary ethyl carbon by an $\text{S}_{\text{N}}2$ process. The bond between oxygen and the ethyl group breaks.

Step 2: Write the reaction The phenyl group remains bonded to oxygen, while iodine becomes attached to the ethyl group:



Phenyl iodide and ethanol are not the products because cleavage does not occur at the aryl carbon.

Step 3: Conclusion The products are phenol, $\text{C}_6\text{H}_5-\text{OH}$, and iodoethane, $\text{CH}_3-\text{CH}_2-\text{I}$.

Quick Tip to Solve: For phenyl-alkyl ethers with HI, keep oxygen attached to the phenyl group and attach iodine to the alkyl group.

4. Predict the major product formed when 2-Bromopentane reacts with alcoholic KOH.

[1 mark]

Solution:

Concept:

- Alcoholic KOH favours beta-elimination (dehydrohalogenation) of an alkyl halide.
- According to Saytzeff's rule, the more substituted alkene is generally the major product.

Step 1: Locate the beta-carbons In $\text{CH}_3-\text{CH}(\text{Br})-\text{CH}_2-\text{CH}_2-\text{CH}_3$, bromine is attached to carbon 2. Removal of a beta-hydrogen from carbon 1 gives pent-1-ene, whereas removal from carbon 3 gives pent-2-ene.

Step 2: Compare the alkenes The double bond in pent-2-ene has more alkyl substituents than the

Quick Tip to Solve: With alcoholic KOH, compare the possible double-bond positions and select the more substituted alkene.

double bond in pent-1-ene, making it more stable. Therefore the elimination favours formation of the internal double bond between carbons 2 and 3.

Step 3: Conclusion The major product is pent-2-ene, $\text{CH}_3 - \text{CH} = \text{CH} - \text{CH}_2 - \text{CH}_3$.

Quick Tip to Solve: With alcoholic KOH, compare the possible double-bond positions and select the more substituted alkene.

5. Give one use of CHI_3 .

[1 mark]

Solution:

Concept:

- CHI_3 is triiodomethane, commonly called iodoform, a yellow crystalline compound.
- Iodoform has been used as an antiseptic; its antiseptic action is associated with the liberation of free iodine.

Step 1: Identify the compound The formula CHI_3 represents iodoform. Its common name helps distinguish it from chloroform, CHCl_3 , which has different properties and uses.

Step 2: Connect its property to its use Iodine released from iodoform on contact with the skin provides antiseptic action. This accounts for the traditional use of iodoform in antiseptic preparations and wound dressings. The question asks for only one use of this compound.

Step 3: Conclusion Iodoform, CHI_3 , is used as an antiseptic.

Quick Tip to Solve: Associate CHI_3 with iodoform and iodine release; this directly recalls its antiseptic use.

6. Identify which liquid will have lower vapour pressure at 90°C if the boiling points of two liquids A and B are 140°C and 180°C respectively.

[1 mark]

Solution:

Concept:

- A liquid boils when its vapour pressure becomes equal to the external pressure.
- In the usual comparison at the same temperature, a higher boiling point indicates lower volatility and lower vapour pressure.

Step 1: Compare the boiling points Liquid A boils at 140°C , while liquid B boils at 180°C . Thus B requires a higher temperature for its vapour pressure to reach the same external pressure.

Step 2: Apply the comparison at the given temperature The temperature 90°C is below both boiling points. Using the boiling-point and volatility relationship, B is less volatile than A and hence has the lower vapour pressure at this common temperature.

Step 3: Conclusion Liquid B has the lower vapour pressure at 90°C .

Quick Tip to Solve: For this boiling-point comparison, select the liquid with the higher boiling point for the lower vapour pressure.

7. Which structural unit present in a detergent makes it non-biodegradable?

[1 mark]

Solution:

Concept:

- Biodegradation is the breakdown of a substance by microorganisms and their enzymes.
- The structure of the hydrocarbon part of a detergent affects how readily microorganisms can break it down.

Step 1: Identify the structural feature The relevant feature is branching in the long hydrocarbon chain of the detergent. The question concerns the structure of this chain, rather than merely the presence of the polar head group.

Step 2: Relate branching to breakdown Highly branched hydrocarbon chains resist microbial degradation because they are less readily attacked by the enzymes responsible for breakdown. Detergents with straight hydrocarbon chains are more readily biodegradable by comparison.

Step 3: Conclusion A highly branched hydrocarbon chain makes a detergent non-biodegradable.

Quick Tip to Solve: Look at the detergent's hydrocarbon chain: extensive branching signals resistance to biodegradation.

8. Give the structure of the monomer of Teflon.

[1 mark]

Solution:

Concept:

- An addition polymer forms by joining unsaturated monomers through opening their carbon-carbon double bonds.
- Teflon is polytetrafluoroethene: its repeating unit contains two carbon atoms, each bonded to two fluorine atoms.

Step 1: Identify the repeating unit The repeating backbone segment of Teflon is $-\text{CF}_2-\text{CF}_2-$. The carbon-fluorine bonds remain intact during addition polymerisation; only the bonding between successive carbon atoms changes.

Step 2: Recover the unsaturated molecule Restore the double bond between the two carbon atoms of one repeat unit. This gives $\text{CF}_2=\text{CF}_2$, which has two fluorine atoms on each carbon and can open its double bond to join other identical molecules.

Step 3: Conclusion The monomer of Teflon is tetrafluoroethene (tetrafluoroethylene), with structure $\text{CF}_2=\text{CF}_2$.

Quick Tip to Solve: For Teflon, take one $-\text{CF}_2-\text{CF}_2-$ repeat unit and restore the carbon-carbon double bond to find the monomer.

9. Out of zinc and tin, whose coating is better to protect iron objects?

[1 mark]

Solution:

Concept:

- A metal coating protects iron by preventing contact with air and moisture; a more readily oxidised metal also gives sacrificial protection.
- Zinc is more reactive than iron, whereas tin is less reactive than iron, so their behaviour differs if the protective layer is damaged.

Step 1: Examine a damaged zinc coating If a scratch exposes iron in contact with zinc, zinc acts as the anode and oxidises preferentially: $\text{Zn} \longrightarrow \text{Zn}^{2+} + 2\text{e}^-$. Iron is protected as the cathode even where the coating is broken.

Step 2: Compare a damaged tin coating Tin can provide a physical barrier while its coating is intact. When it is scratched, however, the more reactive iron becomes the anode and is oxidised in preference to tin. Tin therefore does not provide sacrificial protection to the exposed iron.

Step 3: Conclusion Zinc coating is better for protecting iron objects because zinc provides sacrificial protection even when the coating is scratched.

Quick Tip to Solve: Compare the coating metal with iron in reactivity: zinc sacrifices itself, while a scratched tin coating leaves iron as the anode.

10. Will the rate constant of the reaction depend upon T if the E_{act} (activation energy) of the reaction is zero?

[1 mark]

Solution:

Concept:

- The Arrhenius equation is $k = A \exp[-E_{\text{act}}/(RT)]$, where k is the rate constant, A the pre-exponential factor, R the gas constant and T the absolute temperature.
- In the usual Arrhenius treatment of this question, A is taken as constant over the temperature range considered.

Step 1: Substitute the given activation energy The question gives $E_{\text{act}} = 0$. Hence the exponent in the Arrhenius factor vanishes for any nonzero absolute temperature:

$$k = A \exp\left(-\frac{0}{RT}\right) = A \exp(0).$$

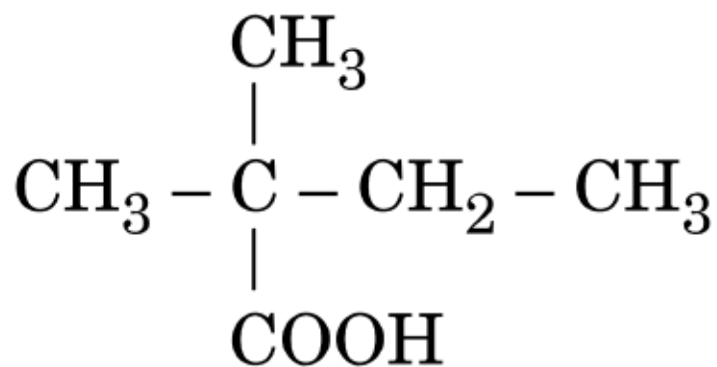
Step 2: Examine the temperature factor Since $\exp(0) = 1$, varying T does not change the exponential factor. With the pre-exponential factor treated as constant, there is no temperature-dependent factor left in the expression for k .

Step 3: Conclusion No. For zero activation energy, $k = A$, so the rate constant is independent of temperature in the Arrhenius model with constant A .

Quick Tip to Solve: Put zero activation energy into the Arrhenius exponent first: the exponential becomes unity, not zero.

11. What is the correct IUPAC name of the given compound?

[1 mark]



- (A) 2,2-Dimethylbutanoic acid
(B) 2-Carboxyl-2-methylbutane
(C) 2-Ethyl-2-methylpropanoic acid
(D) 3-Methylbutane carboxylic acid

Correct Answer: (A) 2,2-Dimethylbutanoic acid

Solution:

Concept:

- The carbon of the principal carboxyl group, $-\text{COOH}$, is included in the parent chain and numbered 1.
- Choose the longest carbon chain containing this carbon; name alkyl substituents with their locants before the acid name.

Step 1: Select and number the parent chain The printed structure is $\text{HOOC}-\text{C}(\text{CH}_3)_2-\text{CH}_2-\text{CH}_3$. Starting at the carboxyl carbon gives a four-carbon chain, so the parent is butanoic acid. The carbon adjacent to $-\text{COOH}$ is carbon 2.

Step 2: Identify the substituents and compare the options Two methyl groups are attached to carbon 2, giving the prefix 2,2-dimethyl. Option (B) incorrectly treats the principal acid group as a carboxyl substituent. Option (C) chooses a shorter three-carbon parent. Option (D) does not describe the two methyl groups on carbon 2 of the required parent chain.

Step 3: Conclusion The IUPAC name is 2,2-dimethylbutanoic acid. Hence, the correct option is (A).

Quick Tip to Solve: Begin numbering at the carbon of $-\text{COOH}$, then trace the longest chain through the ethyl arm before counting the methyl branches.

12. Hardening of leather in tanning industry is based on

[1 mark]

- (A) Electrophoresis
- (B) Electro-osmosis
- (C) Mutual coagulation
- (D) Tyndall effect

Correct Answer: (C) Mutual coagulation

Solution:

Concept:

- Colloidal particles carry an electric charge that helps prevent their aggregation.
- Oppositely charged colloids can neutralise each other's charges and precipitate together; this is mutual coagulation.

Step 1: Identify the oppositely charged colloids Animal hide contains positively charged colloidal protein particles. Tannin has negatively charged colloidal particles. When the hide is treated with tannin, their opposite charges are neutralised and the particles coagulate, hardening the hide into leather.

Step 2: Distinguish the other colloidal phenomena Electrophoresis is the movement of colloidal particles in an electric field, while electro-osmosis is movement of the dispersion medium when particles are held fixed. The Tyndall effect is scattering of light by colloidal particles. None of these describes the charge neutralisation responsible for tanning.

Step 3: Conclusion Hardening of leather is based on mutual coagulation. Hence, the correct option is (C).

Quick Tip to Solve: In tanning questions, pair positively charged hide proteins with negatively charged tannin; opposite charges suggest mutual coagulation.

13. Out of the following, the strongest base in aqueous solution is

[1 mark]

- (A) Methylamine
- (B) Dimethylamine
- (C) Trimethylamine
- (D) Aniline

Correct Answer: (B) Dimethylamine

Solution:

Concept:

- Amines accept a proton using the nitrogen lone pair. Alkyl groups increase electron density on nitrogen by their positive inductive effect.
- In aqueous solution, basic strength also depends on hydration of the conjugate acid and steric hindrance around nitrogen.

Step 1: Compare the methylamines in water Dimethylamine combines the electron-releasing effect

Quick Tip to Solve: For methylamines in water, remember secondary greater than primary greater than tertiary; include hydration rather than counting methyl groups alone.

of two methyl groups with effective hydration of its conjugate acid, $(\text{CH}_3)_2\text{NH}_2^+$. Methylamine has a weaker electron-releasing effect. Although trimethylamine has three methyl groups, steric crowding and poorer hydration of its conjugate acid reduce its aqueous basic strength. The aqueous order is dimethylamine greater than methylamine greater than trimethylamine.

Step 2: Compare aniline with the alkylamines In aniline, the nitrogen lone pair is delocalised into the benzene ring by resonance, making it less available for protonation. Aniline is therefore weaker than the listed aliphatic amines. Comparing all four options places dimethylamine first.

Step 3: Conclusion Dimethylamine is the strongest base in aqueous solution. Hence, the correct option is (B).

Quick Tip to Solve: For methylamines in water, remember secondary greater than primary greater than tertiary; include hydration rather than counting methyl groups alone.

14. Iodoform test is given by

[1 mark]

- (A) Pentan-2-one
- (B) Ethanoic acid
- (C) Pentan-3-one
- (D) Methoxymethane

Correct Answer: (A) Pentan-2-one

Solution:

Concept:

- Methyl ketones containing the group $\text{CH}_3-\text{CO}-\text{R}$ give the iodoform test with iodine and alkali, producing yellow CHI_3 .
- The carbonyl must be that of a methyl ketone; merely containing a methyl group or an oxygen atom is insufficient.

Step 1: Locate the methyl ketone group Pentan-2-one has the structure $\text{CH}_3-\text{CO}-\text{CH}_2-\text{CH}_2-\text{CH}_3$. Its carbonyl carbon is directly bonded to a methyl group, so it undergoes the haloform reaction and gives a yellow precipitate of iodoform, CHI_3 .

Step 2: Check the remaining compounds Ethanoic acid, CH_3COOH , is a carboxylic acid and does not behave as a methyl ketone in this test. Pentan-3-one, $\text{CH}_3\text{CH}_2-\text{CO}-\text{CH}_2\text{CH}_3$, has ethyl groups on both sides of its carbonyl and lacks $\text{CH}_3-\text{CO}-$. Methoxymethane, $\text{CH}_3-\text{O}-\text{CH}_3$, is an ether with no carbonyl group. These three compounds therefore give a negative test.

Step 3: Conclusion Pentan-2-one gives the iodoform test. Hence, the correct option is (A).

Quick Tip to Solve: Expand each ketone around its carbonyl: a directly attached CH_3 identifies pentan-2-one, whereas two ethyl groups rule out pentan-3-one.

15. Out of the following transition elements, the maximum number of oxidation states are shown by
- (A) Sc ($Z = 21$)
(B) Cr ($Z = 24$)
(C) Mn ($Z = 25$)
(D) Fe ($Z = 26$)

[1 mark]

Solution:

Concept:

- Transition metals show variable oxidation states because their $(n - 1)d$ and ns electrons have similar energies and can participate in bonding.
- In the first transition series, the range of common oxidation states increases towards manganese, whose configuration is $[\text{Ar}] 3d^5 4s^2$.

Step 1: Compare the available valence electrons Mn has five $3d$ electrons and two $4s$ electrons. It exhibits oxidation states from +2 to +7, including +2, +3, +4, +5, +6 and +7. Thus both its d and s electrons contribute to a particularly wide range of oxidation states.

Step 2: Eliminate the other elements Sc predominantly exhibits +3. Cr commonly exhibits +2, +3 and +6, whereas Fe mainly exhibits +2 and +3. Although less common states also occur, none of these elements shows as wide a range as manganese in the standard first-row transition-element comparison.

Step 3: Conclusion Manganese, Mn with $Z = 25$, shows the maximum number of oxidation states among the given elements. Hence, the correct option is (C).

Quick Tip to Solve: For this first-row comparison, remember the central element Mn: its $3d^5 4s^2$ configuration supports oxidation states up to +7.

16. Assertion (A): The molecularity of the reaction $\text{H}_2 + \text{Br}_2 \rightarrow 2\text{HBr}$ appears to be 2.

Reason (R): Two molecules of the reactants are involved in the given elementary reaction.

- (i) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
(ii) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
(iii) Assertion (A) is correct, but Reason (R) is incorrect statement.
(iv) Assertion (A) is incorrect, but Reason (R) is correct statement.

[1 mark]

Solution:

Concept:

- Molecularity counts the reacting species taking part in a single elementary step; it is a positive integer.
- The overall stoichiometric equation of a multistep reaction does not by itself determine molecularity. An apparent count from that equation must be distinguished from an elementary-step count.

Quick Tip to Solve: In this question, notice “appears” in A and “elementary” in R: the overall hydrogen-bromine reaction is a multistep chain reaction.

Step 1: Evaluate the assertion The equation $\text{H}_2 + \text{Br}_2 \longrightarrow 2\text{HBr}$ shows one molecule each of hydrogen and bromine on the reactant side. Counting these gives $1 + 1 = 2$, so the molecularity appears to be two. With the word “appears”, the assertion is correct.

Step 2: Evaluate the reason The hydrogen-bromine reaction proceeds by a chain mechanism involving several elementary steps and radical intermediates. The displayed overall equation is therefore not an elementary reaction. The reason incorrectly describes it as elementary and is false, even though two reactant molecules occur in the stoichiometric equation.

Step 3: Test the explanation An apparent sum of stoichiometric coefficients cannot establish a simultaneous bimolecular elementary event. The reason therefore cannot explain an actual molecularity for the overall reaction. Codes (i) and (ii) require a true reason, while code (iv) requires a false assertion; these conditions are not met.

Step 4: Conclusion Assertion (A) is correct, but Reason (R) is incorrect. Hence, the correct option is (iii).

Quick Tip to Solve: In this question, notice “appears” in A and “elementary” in R: the overall hydrogen-bromine reaction is a multistep chain reaction.

17. Assertion (A): Linkage isomerism arises in coordination compounds because of ambidentate ligand.

Reason (R): Ambidentate ligand like NO_2 has two different donor atoms i.e., N and O.

(i) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

(ii) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

(iii) Assertion (A) is correct, but Reason (R) is incorrect statement.

(iv) Assertion (A) is incorrect, but Reason (R) is correct statement.

[1 mark]

Solution:

Concept:

- An ambidentate ligand has two different possible donor atoms, but coordinates through only one of them at a time.
- Linkage isomers have the same composition and ligand, but differ in which donor atom of an ambidentate ligand binds to the central metal.

Step 1: Evaluate the assertion An ambidentate ligand can attach to a metal through either of its alternative donor atoms. The resulting coordination compounds differ in the metal-ligand linkage, so the assertion about the origin of linkage isomerism is correct.

Step 2: Evaluate the reason The nitrite ligand can donate through nitrogen or oxygen. The N-bound form is called nitro, whereas the O-bound form is called nitrito. Thus the reason correctly identifies the two different donor atoms, N and O, available in this ambidentate ligand.

Step 3: Connect the donor choice with the isomerism Binding the same ligand through N instead of O

Quick Tip to Solve: For linkage isomerism, keep the ligand unchanged and switch its donor atom: nitro is N-bound, while nitrito is O-bound.

changes its point of attachment to the metal. This is precisely the change defining linkage isomerism. Therefore the reason explains the assertion; code (ii) incorrectly denies that link, and codes (iii) and (iv) incorrectly make one statement false.

Step 4: Conclusion Both Assertion (A) and Reason (R) are correct, and Reason (R) correctly explains Assertion (A). Hence, the correct option is (i).

Quick Tip to Solve: For linkage isomerism, keep the ligand unchanged and switch its donor atom: nitro is N-bound, while nitrito is O-bound.

18. Assertion (A): Au and Ag are extracted by leaching their ores with a dil. solution of NaCN.

Reason (R): Impurities associated with these ores dissolve in NaCN.

(i) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

(ii) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

(iii) Assertion (A) is correct, but Reason (R) is incorrect statement.

(iv) Assertion (A) is incorrect, but Reason (R) is correct statement.

[1 mark]

Solution:

Concept:

- Leaching selectively dissolves the desired metal-bearing constituent using a suitable reagent, leaving much of the gangue undissolved.
- Cyanide ions form soluble complexes with gold and silver, such as $[\text{Au}(\text{CN})_2]^-$ and $[\text{Ag}(\text{CN})_2]^-$.

Step 1: Evaluate the assertion Gold and silver can be extracted using dilute aqueous NaCN. Cyanide leaching brings the desired metal into solution as a soluble cyanide complex; the metal can subsequently be recovered by displacement with zinc. Thus the assertion is correct.

Step 2: Evaluate the reason The useful separation occurs because the gold- or silver-bearing material forms the soluble complex, whereas the principal insoluble impurities remain as residue. The reason reverses this role by claiming that dissolution of the associated impurities is the basis of the process. It is incorrect.

Step 3: Test the proposed explanation Formation of the soluble metal-cyanide complex, rather than dissolution of the impurities, explains the extraction. Since the reason is false, it cannot explain the true assertion. Codes (i) and (ii) both require a true reason, and code (iv) would require a false assertion.

Step 4: Conclusion Assertion (A) is correct, but Reason (R) is incorrect. Hence, the correct option is (iii).

Quick Tip to Solve: In cyanide leaching, track the valuable metal: Au or Ag enters the filtrate as a complex, while insoluble gangue is filtered off.

19. Assertion (A): F–F bond in F_2 molecule is weak.

Reason (R): F atom is small in size.

(i) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

(ii) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

(iii) Assertion (A) is correct, but Reason (R) is incorrect statement.

(iv) Assertion (A) is incorrect, but Reason (R) is correct statement.

[1 mark]

Solution:

Concept:

- Bond strength depends on the balance between bonding attraction and repulsions involving nonbonding electrons.
- Each atom in F_2 has three lone pairs. The very small size of fluorine brings the nonbonding electron pairs on the two bonded atoms close together.

Step 1: Evaluate the assertion The F–F bond has an anomalously low bond dissociation enthalpy, particularly compared with the Cl–Cl bond. Thus the assertion that the bond in F_2 is weak is correct.

Step 2: Evaluate the reason Fluorine is a very small atom, with its valence electrons occupying the compact second shell. The reason is therefore correct. On bonding, three lone pairs on each fluorine atom occupy a small region around the short bond.

Step 3: Explain the connection The short interatomic separation produces strong lone-pair–lone-pair repulsions between the two fluorine atoms. These repulsions weaken the bond despite effective orbital overlap. Small atomic size therefore explains the anomalous weakness. Code (ii) misses this causal connection, while codes (iii) and (iv) incorrectly make one statement false.

Step 4: Conclusion Both Assertion (A) and Reason (R) are correct, and Reason (R) correctly explains Assertion (A). Hence, the correct option is (i).

Quick Tip to Solve: For the weak F–F bond, link fluorine's small size to crowding of its three lone pairs on each atom and the resulting repulsion.

20. Assertion (A): Sucrose is a non-reducing sugar.

Reason (R): Reducing groups of glucose and fructose are involved in glycosidic bond formation.

(i) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

(ii) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

(iii) Assertion (A) is correct, but Reason (R) is incorrect statement.

(iv) Assertion (A) is incorrect, but Reason (R) is correct statement.

[1 mark]

Solution:

Concept:

- A reducing sugar has a free anomeric centre that can open to a carbonyl form and reduce suitable reagents such as Tollens' or Fehling's reagent.
- In sucrose, the glycosidic linkage joins C-1 of the glucose unit to C-2 of the fructose unit; both are anomeric carbon atoms.

Step 1: Evaluate the assertion Sucrose does not have a free hemiacetal or hemiketal group and does not show the usual reducing-sugar tests. Thus the assertion that sucrose is a non-reducing sugar is correct.

Step 2: Evaluate the reason Sucrose contains an α -D-glucose unit and a β -D-fructose unit joined through a (1 $\rightarrow$ 2) glycosidic bond. The anomeric centres corresponding to the aldehyde group of glucose and the ketone group of fructose both participate in this bond. Hence the reason is correct.

Step 3: Relate the bond to reducing behaviour Because both anomeric centres are tied up in the linkage, neither unit can open to a free carbonyl form without hydrolysis of sucrose. The reason therefore directly explains the absence of reducing behaviour. Code (ii) wrongly denies this explanation; codes (iii) and (iv) wrongly label a true statement as false.

Step 4: Conclusion Both Assertion (A) and Reason (R) are correct, and Reason (R) correctly explains Assertion (A). Hence, the correct option is (i).

Quick Tip to Solve: Check both anomeric carbons: in sucrose, glucose C-1 and fructose C-2 are both bonded, leaving no free reducing end.

Section B (14 marks)

21(a). For a 5% solution of urea (Molar mass = 60 g/mol), calculate the osmotic pressure at 300 K.

[$R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$]

[2 marks]

Solution:

Concept:

- For a dilute solution, osmotic pressure is $\pi = CRT = (n/V)RT$, where C is molarity, n is solute amount, V is solution volume and T is absolute temperature.
- Urea, $\text{CO}(\text{NH}_2)_2$, is a non-electrolyte, so its van't Hoff factor is $i = 1$. The stated percentage is used

Quick Tip to Solve: For a mass-by-volume percentage, first use grams per 100 mL, then convert that volume to litres before applying $\pi = CRT$.

as mass by volume: 5 g in 100 mL of solution.

Step 1: Convert percentage into molarity Take 100 mL = 0.100 L of solution. It contains 5 g of urea, whose molar mass is 60 g mol⁻¹.

$$n = \frac{5}{60} \text{ mol}, \quad C = \frac{5/60}{0.100} = \frac{5}{6} \text{ mol L}^{-1}.$$

Step 2: Substitute into the osmotic-pressure equation Use the solution volume, not the solvent mass, in the molarity calculation. Since the given gas constant uses litres and atmospheres, no conversion to cubic metres is needed.

$$\pi = \frac{5}{6} \times 0.0821 \times 300 = 20.525 \text{ atm}.$$

The litre, mole and kelvin factors cancel, leaving pressure in atmospheres.

Step 3: Conclusion The osmotic pressure at 300 K is 20.525 atm $\approx$ 20.5 atm.

Quick Tip to Solve: For a mass-by-volume percentage, first use grams per 100 mL, then convert that volume to litres before applying $\pi = CRT$.

OR

21(b). Visha took two aqueous solutions – one containing 7.5 g of urea (Molar mass = 60 g/mol) and the other containing 42.75 g of substance Z in 100 g of water, respectively. It was observed that both the solutions froze at the same temperature. Calculate the molar mass of Z. [2 marks]

Solution:

Concept:

- Depression in freezing point is $\Delta T_f = K_f m$ for a non-electrolyte, where K_f is the solvent's molal depression constant and m is solute molality.
- Two solutions in the same solvent with equal freezing points have equal freezing-point depressions. For non-associating, non-dissociating solutes, their molalities are therefore equal.

Step 1: Equate the two molalities Each solution contains 100 g = 0.100 kg of water. The common solvent gives the same K_f , which cancels when the equal depressions are compared. Thus

$$\frac{7.5/60}{0.100} = \frac{42.75/M_Z}{0.100},$$

where M_Z is the molar mass of Z in g mol⁻¹. Equal solvent masses mean that equal molality also means equal amounts of the two solutes in moles.

Step 2: Calculate the molar mass of Z The amount of urea is 7.5/60 = 0.125 mol. Hence 42.75 g of Z also represents 0.125 mol, giving

$$M_Z = \frac{42.75 \text{ g}}{0.125 \text{ mol}} = 342 \text{ g mol}^{-1}.$$

Quick Tip to Solve: With the same solvent mass and equal freezing points, cancel both K_f and the solvent mass; directly equate the solute moles.

Substitution gives 1.25 mol kg^{-1} for both solutions, confirming equal freezing-point depressions.

Step 3: Conclusion The molar mass of substance Z is 342 g mol^{-1} .

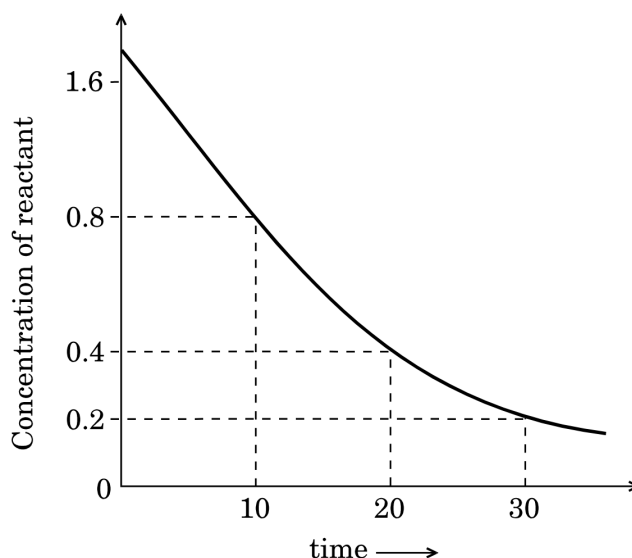
Quick Tip to Solve: With the same solvent mass and equal freezing points, cancel both K_f and the solvent mass; directly equate the solute moles.

22. Analyse the given graph, drawn between concentration of reactant vs. time.

(a) Predict the order of reaction.

(b) Theoretically, can the concentration of the reactant reduce to zero after infinite time? Explain.

[2 marks]



Solution:

Concept:

- A first-order reaction follows $[A]_t = [A]_0 e^{-kt}$, where $[A]_t$ is reactant concentration at time t , $[A]_0$ is its initial concentration and $k > 0$ is the rate constant.
- Its half-life, $t_{1/2} = \ln 2/k$, is independent of concentration: equal time intervals produce equal fractional decreases, rather than equal absolute decreases.

Step 1: Identify the order from successive halvings In the graph, concentration falls from 0.8 at $t = 10$ to 0.4 at $t = 20$, and then to 0.2 at $t = 30$. Each halving takes the same interval of 10 time units. This constant half-life identifies a first-order reaction. A zero-order reaction would instead give a straight concentration-time line with a constant slope.

Step 2: Examine the infinite-time limit For every finite time, the exponential factor e^{-kt} is positive, so the concentration never becomes exactly zero in a finite time. However,

$$\lim_{t \rightarrow \infty} [A]_t = [A]_0 \lim_{t \rightarrow \infty} e^{-kt} = 0.$$

Quick Tip to Solve: Read successive halvings from the graph: equal half-lives imply first order. Distinguish zero in the infinite-time limit from zero at a finite time.

Thus, in the theoretical infinite-time limit asked about, the concentration tends to zero. The time axis is an asymptote of the decay curve; it is approached indefinitely rather than crossed at a finite time.

Step 3: Conclusion (a) The reaction is first order. (b) Yes, the concentration tends to zero in the theoretical limit $t \rightarrow \infty$; it does not reach exactly zero at any finite time.

Quick Tip to Solve: Read successive halvings from the graph: equal half-lives imply first order. Distinguish zero in the infinite-time limit from zero at a finite time.

23(a). Define the following terms:

(a) Tranquilizers

(b) Antiseptic

[2 marks]

Solution:

Concept:

- Drugs are classified by their therapeutic effects. Tranquilizers act on the nervous system, whereas antiseptics act against microorganisms on living tissues.
- An antiseptic must be suitable for application to living tissue at its working concentration. Disinfectants are used on non-living objects and need not be safe for tissue.

Step 1: Define tranquilizers (a) Tranquilizers are a class of chemical compounds used in the treatment of stress and mild or severe mental diseases. They relieve anxiety, tension and irritability and induce a sense of well-being by acting on the central nervous system. Diazepam is an example. Their calming action distinguishes them from analgesics, whose principal use is relieving pain.

Step 2: Define an antiseptic (b) An antiseptic is a chemical substance that kills microorganisms or inhibits their growth and can be applied to living tissues such as wounds, cuts, ulcers and diseased skin. Its purpose is to prevent or control infection without harming the tissue at the concentration used. Tincture of iodine is an example. Suitability for living tissue is the key distinction from a disinfectant used on floors or instruments.

Step 3: Conclusion Tranquilizers relieve stress and anxiety through their action on the nervous system. Antiseptics kill or inhibit microorganisms on living tissues and help prevent infection.

Quick Tip to Solve: In these definitions, pair tranquilizers with stress and anxiety, and antiseptics with microorganisms on living tissues.

23(b). Explain the cleansing action of soaps.

[2 marks]

Solution:**Concept:**

- Soap is a sodium or potassium salt of a long-chain fatty acid, represented by RCOO^-Na^+ . The long hydrocarbon group R is hydrophobic, whereas the ionic carboxylate head is hydrophilic.
- A micelle is an aggregate in which the nonpolar tails point towards an oily interior and the charged heads remain in contact with water.

Step 1: Attach the soap molecules to greasy dirt Grease does not dissolve in water. When soap is added, its hydrocarbon tails dissolve in the grease, while the $-\text{COO}^-$ heads project into the surrounding water. Thus, a soap molecule can interact with both the oily dirt and water.

Step 2: Disperse the grease as micelles On rubbing or agitation, the grease breaks into small droplets surrounded by soap molecules. Their tails remain embedded in the grease and their charged heads face outward into water. Repulsion between these similarly charged surfaces prevents the droplets from joining again; the grease stays emulsified and is carried away during rinsing.

Step 3: Conclusion Soap cleans by trapping greasy dirt inside micelles, dispersing it in water and allowing it to be washed away.

Quick Tip to Solve: Describe the orientation explicitly: hydrocarbon tails towards grease, ionic heads towards water, followed by removal on rinsing.

24. Write the names and structures of monomers in the following polymers:

(a) Buna-N

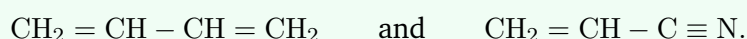
(b) Nylon 6

[2 marks]

Solution:**Concept:**

- A monomer is a small molecule from which a polymer is formed. Buna-N is a copolymer because it is prepared from two different monomers.
- Nylon 6 is prepared by ring-opening polymerisation of caprolactam, a cyclic amide containing six carbon atoms.

Step 1: Identify the two monomers of Buna-N The monomers are buta-1,3-diene and acrylonitrile (prop-2-enenitrile). Their structures are, respectively,

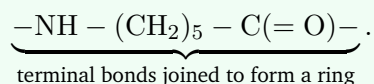


Both contain carbon-carbon double bonds that participate in addition polymerisation. The nitrile group of acrylonitrile accounts for the letter N in Buna-N.

Step 2: Identify the cyclic monomer of Nylon 6 The monomer is caprolactam (also called ϵ -

Quick Tip to Solve: For Nylon 6, count five methylene carbons plus one carbonyl carbon; show that caprolactam is cyclic, not an open-chain amide.

caprolactam). Its cyclic structure is represented as



The terminal carbonyl carbon is bonded back to the nitrogen, forming a seven-membered ring with six carbon atoms and one nitrogen atom. Opening this ring gives the polyamide repeating unit $[-\text{NH} - (\text{CH}_2)_5 - \text{CO}-]_n$.

Step 3: Conclusion (a) Buna-N: buta-1,3-diene, $\text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2$, and acrylonitrile, $\text{CH}_2 = \text{CH} - \text{C} \equiv \text{N}$.

(b) Nylon 6: caprolactam, the cyclic amide $-\text{NH} - (\text{CH}_2)_5 - \text{C}(=\text{O})-$, with its terminal bonds joined.

Quick Tip to Solve: For Nylon 6, count five methylene carbons plus one carbonyl carbon; show that caprolactam is cyclic, not an open-chain amide.

25. Draw the shape of the following molecules:

(a) $\text{H}_2\text{S}_2\text{O}_8$

(b) XeF_2

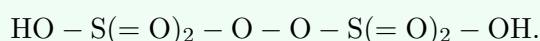
[2 marks]

Solution:

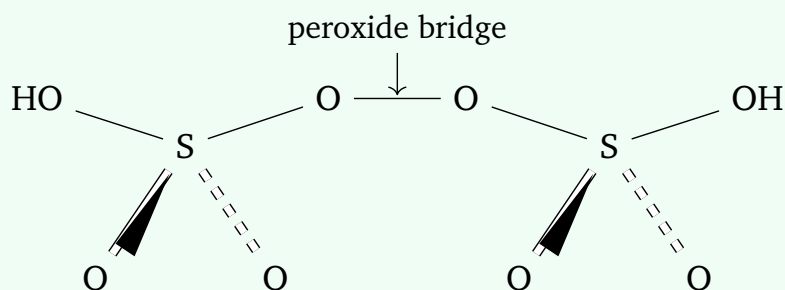
Concept:

- Peroxodisulphuric acid, $\text{H}_2\text{S}_2\text{O}_8$, has an $-\text{O}-\text{O}-$ peroxide bridge connecting two sulphur-containing groups. Each sulphur has four surrounding oxygen atoms in a tetrahedral arrangement.
- In VSEPR theory, XeF_2 has five electron pairs around xenon: two bond pairs and three lone pairs. Molecular shape depends on the positions of the bonded atoms.

Step 1: Draw peroxodisulphuric acid Each sulphur is bonded to one hydroxyl oxygen, two doubly bonded oxygens and one oxygen of the peroxide bridge. Its connectivity is



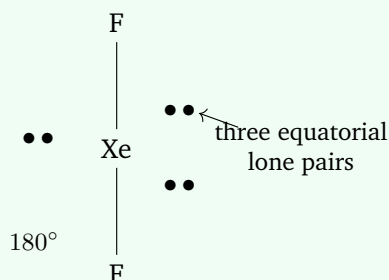
Each sulphur is tetrahedral: solid wedges project out of the plane, while dashed bonds project behind it. The peroxide oxygens are joined by a single bond.



Peroxodisulphuric acid: peroxide bridge and tetrahedral arrangement around each sulphur (schematic)

Quick Tip to Solve: Keep the O-O bridge in peroxodisulphuric acid; for XeF_2 , put all three lone pairs equatorial so the fluorines remain opposite.

Step 2: Draw xenon difluoride Xenon forms two Xe–F bonds and retains three lone pairs. In the trigonal-bipyramidal electron-pair arrangement, all three lone pairs occupy equatorial positions to reduce repulsions. The two fluorine atoms occupy the opposite axial positions, giving a linear molecule with $\angle \text{F} - \text{Xe} - \text{F} = 180^\circ$.



Linear XeF_2 ; three lone pairs occupy equatorial positions

Step 3: Conclusion $\text{H}_2\text{S}_2\text{O}_8$ contains a peroxide bridge and tetrahedral geometry about each sulphur. XeF_2 is linear, with an F–Xe–F angle of 180° .

Quick Tip to Solve: Keep the O–O bridge in peroxodisulphuric acid; for XeF_2 , put all three lone pairs equatorial so the fluorines remain opposite.

26. Give the formulae of the following compounds:

(a) Pentaamminecarbonatocobalt (III) chloride

(b) Potassium tetracyanonickelate (II)

[2 marks]

Solution:

Concept:

- The oxidation state of the central metal plus the charges of all ligands gives the charge on a coordination entity. Counterions outside the square brackets make the complete compound electrically neutral.
- Ammine, NH_3 , is neutral; carbonate, CO_3^{2-} , has charge -2 ; cyanido, CN^- , has charge -1 .

Step 1: Form pentaamminecarbonatocobalt(III) chloride Pentaammine denotes five NH_3 ligands, and carbonate denotes one CO_3^{2-} ligand. Cobalt(III) has oxidation state $+3$, so the coordination entity has charge

$$+3 + 5(0) + (-2) = +1.$$

One chloride counterion of charge -1 is therefore needed outside the square brackets. The ligand counts are unchanged by this charge-balancing step.

Step 2: Form potassium tetracyanonickelate(II) Tetracyanido denotes four CN^- ligands attached to nickel(II). The charge of the coordination entity is

$$+2 + 4(-1) = -2.$$

Hence, two potassium ions, each with charge $+1$, are required outside the square brackets. The suffix

Quick Tip to Solve: First total metal and ligand charges inside the brackets; this gives one chloride for the cobalt complex and two potassium ions for the nickel complex.

nickelate is consistent with an anionic nickel coordination entity.

Step 3: Conclusion (a) Pentaamminecarbonatocobalt(III) chloride: $[\text{Co}(\text{NH}_3)_5(\text{CO}_3)]\text{Cl}$.

(b) Potassium tetracyanonickelate(II): $\text{K}_2[\text{Ni}(\text{CN})_4]$.

Quick Tip to Solve: First total metal and ligand charges inside the brackets; this gives one chloride for the cobalt complex and two potassium ions for the nickel complex.

27. What happens when

(a) Acetone is treated with $\text{Zn}(\text{Hg})$ / Conc. HCl , and

(b) Ethanal is treated with methylmagnesium bromide and then hydrolysed?

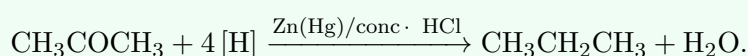
[2 marks]

Solution:

Concept:

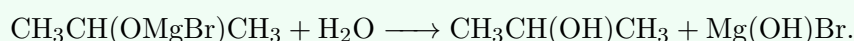
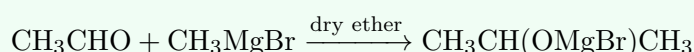
- Clemmensen reduction converts the carbonyl group of an aldehyde or ketone to a methylene group using zinc amalgam and concentrated hydrochloric acid.
- A Grignard reagent adds its alkyl group to a carbonyl carbon. Hydrolysis of the resulting magnesium alkoxide gives an alcohol.

Step 1: Reduce acetone by the Clemmensen reaction In acetone, the carbonyl carbon is bonded to two methyl groups. Treatment with $\text{Zn}(\text{Hg})$ and concentrated HCl replaces the carbonyl oxygen by two hydrogen atoms, without changing the carbon skeleton:



Thus the ketone is reduced all the way to the corresponding hydrocarbon; the product is propane.

Step 2: Add the Grignard reagent and hydrolyse Methylmagnesium bromide supplies a methyl group which attacks the electrophilic carbonyl carbon of ethanal in dry ether. The magnesium alkoxide then undergoes hydrolysis:



The carbon bearing the hydroxyl group is attached to two methyl groups, so the product is the secondary alcohol propan-2-ol.

Step 3: Conclusion (a) Acetone gives propane, $\text{CH}_3\text{CH}_2\text{CH}_3$. (b) Ethanal gives propan-2-ol, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$, after methylmagnesium bromide addition and hydrolysis.

Quick Tip to Solve: Clemmensen reduction preserves the carbon count; methylmagnesium bromide adds one carbon before hydrolysis gives the alcohol.

Section C (21 marks)

28(a). Account for the following:

(a) Sulphurous acid is a reducing agent.

(b) Fluorine forms only one oxoacid.

(c) Boiling point of noble gases increases from He to Rn.

[3 marks]

Solution:

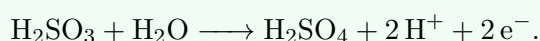
Concept:

- A reducing agent donates electrons and is itself oxidised to a higher oxidation state.
- Fluorine has the highest electronegativity and does not exhibit positive oxidation states in its compounds.
- Noble-gas atoms attract one another through London dispersion forces, whose strength increases with the polarisability of their electron clouds.

Step 1: Explain the reducing action of sulphurous acid In H_2SO_3 , let the oxidation state of sulphur be x . Then

$$2(+1) + x + 3(-2) = 0, \quad x = +4.$$

Sulphur can increase its oxidation state from +4 to +6, giving sulphuric acid. The corresponding oxidation half-reaction is



By supplying these electrons to another substance, sulphurous acid reduces that substance and is itself oxidised. This explains its reducing nature.

Step 2: Explain the single oxoacid of fluorine Fluorine is very small and the most electronegative element. Unlike the other halogens, it cannot attain the positive oxidation states needed for their series of higher oxoacids. The only oxoacid of fluorine is hypofluorous acid, HOF, with the linkage $\text{H}-\text{O}-\text{F}$. Here fluorine still has oxidation state -1 ; oxygen has oxidation state 0 . Thus this one acid does not require fluorine to have a positive oxidation state.

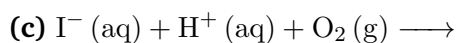
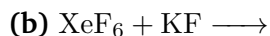
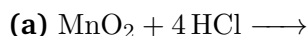
Step 3: Relate boiling points to dispersion forces Noble gases are monatomic and nonpolar. On going from helium to radon, the number of electrons and atomic size increase. Their larger electron clouds are more readily distorted, so instantaneous and induced dipoles produce stronger London dispersion forces. More thermal energy is then needed to separate the atoms into the gaseous state. Consequently, their boiling points rise down the group:



Step 4: Conclusion Sulphurous acid reduces other substances as sulphur is oxidised from +4 to +6. Fluorine forms only HOF because its high electronegativity prevents positive oxidation states. Noble-gas boiling points increase from helium to radon because increasing polarisability strengthens dispersion forces.

Quick Tip to Solve: For these explanations, track sulphur's oxidation state, fluorine's inability to become positive, and the increasing polarisability of noble-gas atoms.

28(b). Complete the following chemical reactions:



[3 marks]

Solution:

Concept:

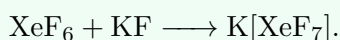
- A balanced chemical reaction conserves the number of atoms of each element and the total electric charge. Redox reactions also require equal electron loss and gain.
- Xenon hexafluoride can accept a fluoride ion from an alkali-metal fluoride, forming a complex fluoroanion.

Step 1: Complete the reaction of manganese dioxide with hydrochloric acid Manganese in MnO_2 is reduced from +4 to +2, while chloride ions are oxidised to chlorine. The manganese product is manganese(II) chloride, and the oxygen combines with hydrogen to form water:



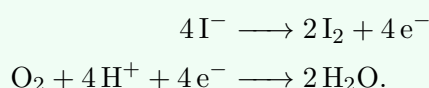
Manganese gains two electrons, while two chloride ions together lose two electrons to form Cl_2 .

Step 2: Add fluoride to xenon hexafluoride The fluoride ion supplied by KF is accepted by XeF_6 , producing the heptafluoroxenate(VI) ion, $[\text{XeF}_7]^-$. Potassium is the counterion:

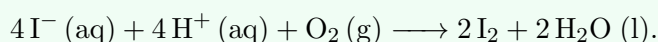


Six fluorine atoms in xenon hexafluoride plus the one in potassium fluoride give seven in the product. Xenon retains oxidation state +6, since $x + 7(-1) = -1$.

Step 3: Balance oxidation of iodide by oxygen in acid Iodide is oxidised to iodine and oxygen is reduced to water. Write and combine the half-reactions:



Cancelling the four electrons gives



The left side has net charge zero, as does the right side, and all iodine, hydrogen and oxygen atoms are conserved.

Step 4: Conclusion The products are (a) $\text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$, (b) $\text{K}[\text{XeF}_7]$, and (c) $2\text{I}_2 + 2\text{H}_2\text{O}$ when four iodide ions react with four hydrogen ions and one oxygen molecule, as balanced above.

Quick Tip to Solve: In the iodide reaction, one oxygen molecule consumes four electrons; therefore use four iodide ions and four hydrogen ions.

29. Calculate the mass of ascorbic acid (Molar mass = 176 g mol^{-1}) to be dissolved in 75 g of acetic acid, to lower its freezing point by 1.5°C . ($K_f = 3.9 \text{ K kg mol}^{-1}$) [3 marks]

Solution:

Concept:

- Depression in freezing point is a colligative property. For a dilute solution of a non-electrolyte, $\Delta T_f = K_f m$, where K_f is the molal freezing-point depression constant and m is the molality.
- Molality is moles of solute per kilogram of solvent: $m = (w/M)/W$, where w is the solute mass in grams, M its molar mass, and W the solvent mass in kilograms.

Step 1: Express the given data in compatible units The required depression is $\Delta T_f = 1.5 \text{ K}$, since a temperature difference of 1.5°C equals 1.5 K . The mass of acetic acid is the mass of solvent, not solution:

$$W = \frac{75}{1000} = 0.075 \text{ kg}.$$

For ascorbic acid, use $M = 176 \text{ g mol}^{-1}$ and $K_f = 3.9 \text{ K kg mol}^{-1}$. Treat the solute as molecular, so its van't Hoff factor is unity.

Step 2: Determine the molality and amount of solute Rearranging the freezing-point relation gives

$$m = \frac{\Delta T_f}{K_f} = \frac{1.5}{3.9} = 0.384615 \text{ mol kg}^{-1}.$$

Multiplying by the solvent mass in kilograms gives the required moles:

$$n = mW = 0.384615 \times 0.075 = 0.0288462 \text{ mol}.$$

Step 3: Convert the amount into mass Multiplying the number of moles by the molar mass,

$$w = nM = \frac{1.5 \times 0.075 \times 176}{3.9} = 5.0769 \text{ g}.$$

As a check, this amount gives a molality of about $0.385 \text{ mol kg}^{-1}$, which produces the requested depression on multiplication by K_f .

Step 4: Conclusion Dissolve approximately 5.08 g of ascorbic acid in 75 g of acetic acid (about 5.1 g to two significant figures).

Quick Tip to Solve: Use the 75 g as solvent mass and convert it to kilograms before applying $\Delta T_f = K_f m$; using grams directly introduces a factor-of-1000 error.

30. How will the rate of the reaction be affected when

- (a) Surface area of the reactant is reduced,
(b) Catalyst is added in a reversible reaction, and
(c) Temperature of the reaction is increased?

[3 marks]

Solution:

Concept:

- Reaction rate depends on effective collisions. At a reacting solid surface, a larger exposed area provides more sites for reactant particles to collide and react.
- A catalyst provides an alternative reaction pathway with lower activation energy. It accelerates both directions of a reversible reaction without changing the equilibrium constant at a fixed temperature.
- The Arrhenius equation is $k = Ae^{-E_a/(RT)}$, where k is the rate constant, A the frequency factor, E_a the activation energy, R the gas constant and T the absolute temperature.

Step 1: Examine the reduction in surface area (a) For a reaction involving a solid reactant, reducing its exposed surface area decreases the rate, with other conditions unchanged. Fewer surface sites are accessible to the other reactant per unit time, so there are fewer effective collisions. Thus a large lump reacts more slowly than the same mass of finely divided solid.

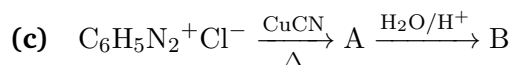
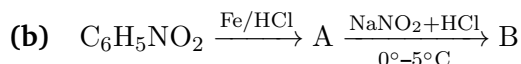
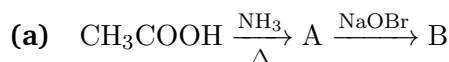
Step 2: Consider the catalyst in the reversible reaction (b) The catalyst increases both the forward and reverse reaction rates by providing a pathway with a lower energy barrier. The system therefore reaches equilibrium more quickly. It does not favour one equilibrium composition over another, and neither the equilibrium constant nor the equilibrium yield changes. If the system is already at equilibrium, the two opposing rates increase equally and remain equal, so there is no net change in composition.

Step 3: Apply the effect of higher temperature (c) Increasing the temperature generally increases the rate of reaction. A larger fraction of molecules has energy equal to or greater than the activation energy, so more collisions are effective. For the usual positive activation energy, increasing T makes $-E_a/(RT)$ less negative and increases k in the Arrhenius equation; at the same reactant concentrations, this increases the reaction rate.

Step 4: Conclusion (a) The rate decreases. (b) Both forward and reverse rates increase; equilibrium is reached faster without a change in equilibrium composition. (c) The rate generally increases.

Quick Tip to Solve: Separate reaction speed from equilibrium position: a catalyst speeds up both directions but does not change the equilibrium yield.

31. Give the structures of A and B in the following sequence of reactions:



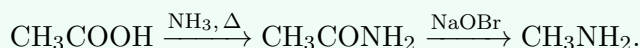
[3 marks]

Solution:

Concept:

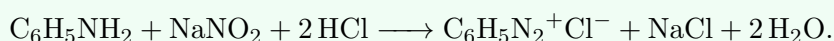
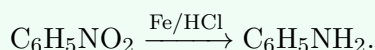
- Heating a carboxylic acid with ammonia forms an amide. Hofmann bromamide degradation converts a primary amide into an amine with one fewer carbon atom.
- Nitro-group reduction gives an amino group; diazotisation of a primary aromatic amine at $0-5^\circ\text{C}$ gives a diazonium salt.
- CuCN replaces a diazonium group by $-\text{CN}$; acidic nitrile hydrolysis converts $-\text{CN}$ into $-\text{COOH}$.

Step 1: Identify the amide and amine in (a) Acetic acid forms ammonium acetate with ammonia. Heating eliminates water to give ethanamide (acetamide), A. Sodium hypobromite causes Hofmann degradation, removing the carbonyl carbon and giving methylamine, B:



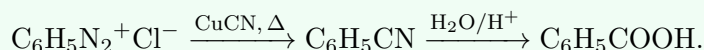
Thus A is $\text{CH}_3-\text{C}(=\text{O})-\text{NH}_2$ and B is CH_3-NH_2 ; the carbon count falls from two to one in the second reaction.

Step 2: Identify the amine and diazonium salt in (b) Iron and hydrochloric acid reduce the nitro group to give aniline, A (the free amine after work-up). Nitrous acid generated from NaNO_2/HCl then diazotises aniline at the stated low temperature:



Therefore A is $\text{C}_6\text{H}_5-\text{NH}_2$ and B is benzenediazonium chloride, with structure $\text{C}_6\text{H}_5-\text{N}^+ \equiv \text{N Cl}^-$.

Step 3: Identify the nitrile and acid in (c) The Sandmeyer reaction replaces the diazonium group by a cyano group, releasing nitrogen and giving benzonitrile, A. Acidic hydrolysis retains the nitrile carbon as the carboxyl carbon and gives benzoic acid, B:



The structures are A = $\text{C}_6\text{H}_5-\text{C}\equiv\text{N}$ and B = $\text{C}_6\text{H}_5-\text{C}(=\text{O})-\text{OH}$.

Step 4: Conclusion (a) A: CH_3CONH_2 ; B: CH_3NH_2 .

(b) A: $\text{C}_6\text{H}_5\text{NH}_2$; B: $\text{C}_6\text{H}_5\text{N}_2^+\text{Cl}^-$.

(c) A: $\text{C}_6\text{H}_5\text{CN}$; B: $\text{C}_6\text{H}_5\text{COOH}$.

Quick Tip to Solve: Track carbon atoms: Hofmann degradation removes the carbonyl carbon, while nitrile hydrolysis retains the nitrile carbon as the carboxyl carbon.

31(a). How will you distinguish between the following pairs of compounds:

(i) Aniline and Ethanamine

(ii) Aniline and N-methylaniline

[2 marks]

Solution:

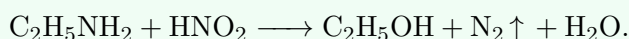
Concept:

- Primary aromatic amines form diazonium salts with nitrous acid at 273–278 K; primary aliphatic amines liberate nitrogen under the same conditions.
- The carbylamine test is given by primary amines only. Heating with chloroform and alcoholic potassium hydroxide produces an offensive-smelling isocyanide.

Step 1: Distinguish aniline from ethanamine Treat separate cold solutions with sodium nitrite and dilute hydrochloric acid at 273–278 K. Nitrous acid is generated in situ. Aniline forms a relatively stable benzenediazonium chloride solution:



Ethanamine forms an unstable aliphatic diazonium intermediate, which decomposes immediately, producing brisk effervescence of nitrogen and ethanol:



Thus nitrogen evolution in the cold identifies ethanamine; aniline undergoes diazotisation without this immediate gas evolution.

Step 2: Distinguish aniline from N-methylaniline Warm each compound separately with chloroform and alcoholic potassium hydroxide. Aniline, a primary amine, gives phenyl isocyanide with its characteristic offensive odour:



N-methylaniline, $\text{C}_6\text{H}_5\text{NHCH}_3$, is a secondary amine and does not give the carbylamine reaction. Hence it produces no isocyanide odour under this test.

Step 3: Conclusion (i) Cold nitrous acid gives nitrogen effervescence with ethanamine but diazotises aniline. (ii) The carbylamine test is positive for aniline and negative for N-methylaniline.

Quick Tip to Solve: Both aniline and ethanamine are primary amines, so carbylamine cannot distinguish that pair; use cold nitrous acid for them.

31(b). Arrange the following compounds in decreasing order of their boiling points:

Butanol, Butanamine, Butane

[1 mark]

Solution:

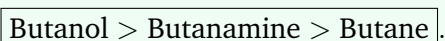
Concept:

- Boiling requires overcoming intermolecular attractions; stronger attractions generally give a higher boiling point for molecules of comparable size.
- Alcohols and primary amines form intermolecular hydrogen bonds, whereas alkanes have only London dispersion forces.

Step 1: Compare butanol with butanamine These compounds have comparable carbon-chain lengths. Butanol contains an O–H group, while butanamine contains an NH₂ group. Oxygen is more electronegative than nitrogen, so the hydrogen bonds between alcohol molecules are stronger than those between amine molecules. Butanol therefore requires more energy to boil.

Step 2: Compare the hydrogen-bonding compounds with butane Butane has no electronegative atom bonded to hydrogen and cannot form intermolecular hydrogen bonds. Its nonpolar molecules are held together only by relatively weak dispersion forces, so it has the lowest boiling point among these compounds.

Step 3: Conclusion The decreasing order of boiling points is



Quick Tip to Solve: For comparable carbon chains, compare the attractions: stronger alcohol hydrogen bonds, weaker amine hydrogen bonds, then alkane dispersion forces.

32. Give the plausible explanation for the following:

- (a) Glucose doesn't give 2,4-DNP test.
- (b) The two strands in DNA are not identical but are complementary.
- (c) Starch and cellulose both contain glucose unit as monomer, yet they are structurally different.

[3 marks]

Solution:

Concept:

- The 2,4-dinitrophenylhydrazine (2,4-DNP) test detects a free aldehyde or ketone carbonyl group through hydrazone formation.
- DNA base pairing is specific: adenine pairs with thymine and guanine pairs with cytosine through hydrogen bonds.
- Polysaccharide structure depends on the configuration of the glucose units and the positions and orientations of their glycosidic bonds.

Step 1: Explain the absence of the glucose 2,4-DNP test In solution glucose exists predominantly as cyclic hemiacetal forms. Its aldehyde group reacts intramolecularly with the hydroxyl group at carbon

Quick Tip to Solve: For these explanations, identify what is hidden in glucose, what pairs in DNA, and which glucose configuration and bond orientation differ in the polysaccharides.

5 to form a six-membered ring. Consequently, the carbonyl group is masked in the overwhelmingly predominant cyclic forms; the very small open-chain fraction does not give the characteristic 2,4-DNP precipitate under ordinary test conditions. Thus glucose does not show this usual free-carbonyl test, although its equilibrium with the open-chain form allows other reactions such as reduction of Tollens' reagent.

Step 2: Explain complementary DNA strands The nitrogenous bases point inward and pair specifically. Adenine (A) pairs with thymine (T) through two hydrogen bonds, and guanine (G) pairs with cytosine (C) through three hydrogen bonds. Therefore, each base in one strand determines the complementary base in the other; the second strand does not repeat the same sequence of bases. For example, a strand segment 5'-ATGC-3' pairs with 3'-TACG-5'. The strands are antiparallel and complementary.

Step 3: Compare starch and cellulose linkages Starch is made of α -D-glucose units. Its amylose component contains $\alpha(1 \rightarrow 4)$ glycosidic bonds; amylopectin also has $\alpha(1 \rightarrow 6)$ bonds at its branch points. Cellulose consists of β -D-glucose units linked by $\beta(1 \rightarrow 4)$ glycosidic bonds, producing straight, unbranched chains. These different linkage orientations give different chain shapes: starch has helical and branched components, while cellulose chains associate through hydrogen bonding to form fibres.

Step 4: Conclusion (a) Glucose's carbonyl is masked in its predominant cyclic hemiacetal forms. (b) Specific A-T and G-C pairing makes DNA strands complementary. (c) Starch has α -glucosidic linkages, whereas cellulose has $\beta(1 \rightarrow 4)$ linkages, giving different structures.

Quick Tip to Solve: For these explanations, identify what is hidden in glucose, what pairs in DNA, and which glucose configuration and bond orientation differ in the polysaccharides.

33. Explain the role of the following:

(a) NaCN in froth floatation process.

(b) I_2 in the metallurgy of Zr.

(c) Limestone in the metallurgy of Fe.

[3 marks]

Solution:

Concept:

- A depressant in froth floatation selectively prevents one sulphide ore from entering the froth, allowing separation from another sulphide.
- Vapour-phase refining converts an impure metal into a volatile compound, separates it from impurities and decomposes it to recover pure metal.
- A flux reacts with gangue to form a fusible slag that can be removed from the molten metal.

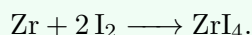
Step 1: Identify sodium cyanide as a depressant In the froth floatation of an ore mixture containing ZnS and PbS, sodium cyanide acts as a selective depressant for ZnS. It prevents zinc sulphide from being wetted by the collector and rising with the froth, while lead sulphide is carried into the froth. Cyanide complex formation at the zinc sulphide surface can be represented by



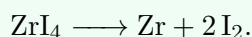
Quick Tip to Solve: Associate each reagent with its stage: cyanide separates ores, iodine purifies zirconium, and limestone removes silica gangue as slag.

Thus NaCN helps separate the two sulphide ores selectively.

Step 2: Explain iodine in zirconium refining Iodine is used in the van Arkel method. Impure zirconium is heated with iodine to form volatile zirconium tetraiodide, while nonvolatile impurities remain behind:

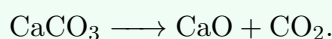


The iodide vapour passes over a hot tungsten filament and decomposes, depositing highly pure zirconium and regenerating iodine:

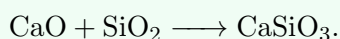


Thus iodine provides the volatile intermediate needed to transport and purify zirconium.

Step 3: Explain limestone as the source of basic flux In the blast furnace, limestone decomposes on heating to form calcium oxide:



The basic oxide CaO combines with acidic silica gangue to form calcium silicate slag:



The molten slag is less dense than molten iron, floats above it and is removed separately. Limestone therefore supplies the flux for removing silica impurity.

Step 4: Conclusion (a) NaCN depresses ZnS during selective froth flotation. (b) I₂ forms volatile ZrI₄ for van Arkel refining. (c) Limestone supplies CaO, which removes silica as CaSiO₃ slag.

Quick Tip to Solve: Associate each reagent with its stage: cyanide separates ores, iodine purifies zirconium, and limestone removes silica gangue as slag.

34. Distinguish between physisorption and chemisorption on the basis of

- (a) Force of attraction,
- (b) Temperature, and
- (c) Enthalpy of adsorption.

[3 marks]

Solution:

Concept:

- Adsorption is the accumulation of an adsorbate on the surface of an adsorbent. The nature of the surface attraction distinguishes physisorption from chemisorption.
- Both processes are exothermic, so the enthalpy change of adsorption is negative. The magnitude of this change reflects the strength of the attraction formed.

Step 1: (a) Compare the force of attraction In physisorption, the adsorbate is held by weak van der Waals forces; no chemical bond is formed with the surface. In chemisorption, the adsorbate forms strong chemical bonds with the adsorbent. This makes chemisorption more specific to the chemical nature of the adsorbate and the surface.

Quick Tip to Solve: Link all three comparisons to bond strength: weak surface forces give low heat of adsorption, while chemical bonding gives a much larger heat release.

Step 2: (b) Compare the effect of temperature Physisorption is favoured at low temperature and generally decreases as temperature rises, because weakly held particles escape from the surface more readily. Chemisorption usually requires activation energy: it is favoured at higher temperatures than physisorption and initially increases with temperature as the activation barrier is overcome. At sufficiently high temperature, desorption becomes important, so chemisorption need not keep increasing indefinitely.

Step 3: (c) Compare the enthalpy of adsorption Physisorption has a small enthalpy magnitude, typically about $20\text{--}40\text{ kJ mol}^{-1}$, because the attractions are weak. Chemisorption has a much larger magnitude, typically about $80\text{--}240\text{ kJ mol}^{-1}$, owing to chemical bond formation. These ranges describe $|\Delta H_{\text{ads}}|$; the enthalpy change itself is negative in each case.

Step 4: Conclusion Physisorption involves weak van der Waals forces, low-temperature preference and low adsorption enthalpy magnitude. Chemisorption involves chemical bonds, an activation-energy requirement and a much higher adsorption enthalpy magnitude.

Quick Tip to Solve: Link all three comparisons to bond strength: weak surface forces give low heat of adsorption, while chemical bonding gives a much larger heat release.

Section D (15 marks)

35(a). Account for the following:

(i) Copper (I) compounds are white whereas Copper (II) compounds are coloured.

(ii) Chromates change their colour when kept in an acidic solution.

(iii) Zn, Cd, Hg are considered as d-block elements but not as transition elements.

[3 marks]

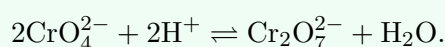
Solution:

Concept:

- In a ligand environment, the five d orbitals split into sets of different energies. Absorption of visible light for a $d\text{-}d$ transition can produce colour when the d subshell is partially filled.
- A transition element has an incompletely filled d subshell in its atom or in at least one of its usual oxidation states. Membership of the d block alone does not establish transition character.
- The chromate–dichromate equilibrium responds to acid concentration according to Le Chatelier's principle: added H^+ favours the side that consumes it.

Step 1: (i) Explain the colours of copper compounds Copper has configuration $[\text{Ar}] 3d^{10}4s^1$. Loss of its $4s$ electron gives $\text{Cu}^+ : [\text{Ar}] 3d^{10}$, whereas loss of one more electron gives $\text{Cu}^{2+} : [\text{Ar}] 3d^9$. The filled $3d$ subshell of copper(I) does not permit a $d\text{-}d$ transition; hence its compounds are generally white or colourless. Copper(II) has a partially filled d subshell. In its compounds, visible light can excite an electron between the split d levels, and the remaining light gives the observed colour.

Step 2: (ii) Explain the chromate colour change in acid Yellow chromate ions are converted into orange dichromate ions on acidification:



Quick Tip to Solve: For copper colours and transition character, write the ion's d -electron count first; for acidified chromate, show the balanced equilibrium and both colours.

Increasing H^+ concentration shifts this equilibrium to the right, changing the colour from yellow to orange. Chromium remains in oxidation state +6, so the colour change is due to a change in the ionic species, not a redox reaction.

Step 3: (iii) Explain why Zn, Cd and Hg are not transition elements Their atoms have the outer configurations $(n-1)d^{10}ns^2$: Zn has $3d^{10}4s^2$, Cd has $4d^{10}5s^2$, and Hg has $5d^{10}6s^2$. On forming their usual +2 ions, the two ns electrons are lost, leaving d^{10} . Thus their atoms and usual ions have completely filled d subshells. They belong to the d block by their position and electronic configuration but do not satisfy the definition of transition elements.

Step 4: Conclusion The d^{10} and d^9 configurations explain the contrasting copper colours; acid converts yellow chromate into orange dichromate; and the filled d subshells of Zn, Cd and Hg exclude them from transition elements.

Quick Tip to Solve: For copper colours and transition character, write the ion's d -electron count first; for acidified chromate, show the balanced equilibrium and both colours.

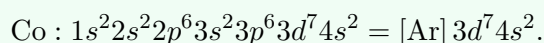
35(b). Calculate the spin-only moment of Co^{2+} ($Z = 27$) by writing the electronic configuration of Co and Co^{2+} . [2 marks]

Solution:

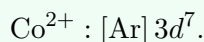
Concept:

- When a transition-metal atom forms a cation, the outer $4s$ electrons are removed before the $3d$ electrons. Hund's rule places electrons singly in degenerate orbitals before pairing.
- The spin-only magnetic moment is $\mu_{\text{so}} = \sqrt{n(n+2)} \mu_{\text{B}}$, where n is the number of unpaired electrons and μ_{B} is the Bohr magneton, commonly written as BM.

Step 1: Write the atomic and ionic configurations Cobalt has atomic number 27, so its ground-state electronic configuration is



Removing both $4s$ electrons gives



Step 2: Count unpaired electrons and apply the spin-only formula For the free $3d^7$ ion, five electrons first occupy the five d orbitals singly. The next two pair in two of those orbitals. There are therefore two paired orbitals and three singly occupied orbitals, giving $n = 3$. Substitution yields

$$\mu_{\text{so}} = \sqrt{3(3+2)} \mu_{\text{B}} = \sqrt{15} \mu_{\text{B}} = 3.87 \mu_{\text{B}}.$$

This uses only the electron-spin contribution, as requested.

Step 3: Conclusion $\text{Co} : [\text{Ar}] 3d^7 4s^2$ and $\text{Co}^{2+} : [\text{Ar}] 3d^7$. With three unpaired electrons, the spin-only magnetic moment is 3.87 BM; the ion is paramagnetic.

Quick Tip to Solve: Remove the two $4s$ electrons before counting Co(II) 's unpaired electrons: a free d^7 ion has three, so its spin-only moment is the square root of 15 BM.

35(a). Give three points of difference between lanthanoids and actinoids.

[3 marks]

Solution:

Concept:

- Lanthanoids and actinoids are inner-transition elements: their differentiating electrons enter the $4f$ and $5f$ subshells, respectively.
- Oxidation states depend on the relative energies of the valence orbitals. Radioactivity is a nuclear property, distinct from chemical oxidation state.

Step 1: Compare the subshell being filled In the lanthanoid series, the $4f$ subshell is progressively filled, whereas in the actinoid series the $5f$ subshell is progressively filled. Thus these are the two different series of the f -block, involving different principal energy levels for the differentiating electron.

Step 2: Compare the range of oxidation states Lanthanoids show predominantly the +3 oxidation state; a few also show +2 or +4. Actinoids show a much wider range of oxidation states, commonly from +3 to +7, particularly among the earlier members. This is because the $5f$, $6d$ and $7s$ orbital energies are relatively close, so different numbers of electrons can participate in bonding.

Step 3: Compare radioactivity Most lanthanoids have stable isotopes and are not radioactive; promethium is the exception, with no stable isotope. All actinoids are radioactive, since none has a stable isotope. The distinction is therefore between a largely non-radioactive series and an entirely radioactive series, not between two series with identical nuclear behaviour.

Step 4: Conclusion The three differences are: $4f$ versus $5f$ filling; mainly +3 versus a wider range of oxidation states; and mostly non-radioactive lanthanoids (except Pm) versus entirely radioactive actinoids.

Quick Tip to Solve: Organise the comparison under three separate headings: subshell, oxidation states and radioactivity; remember the Pm exception.

35(b). Give reason and select one atom/ion which will exhibit asked property:

(i) Sc^{3+} or Cr^{3+} (Exhibit diamagnetic behaviour)

(ii) Cr or Cu (High melting and boiling point)

[2 marks]

Solution:

Concept:

- An atom or ion is diamagnetic when all its electrons are paired; an unpaired electron produces paramagnetism. When transition-metal cations form, $4s$ electrons are removed before $3d$ electrons.
- Melting and boiling require overcoming metallic bonding. Greater participation of unpaired valence electrons generally strengthens this bonding in transition metals.

Step 1: Compare the electron configurations of the ions Scandium has configuration $[\text{Ar}] 3d^1 4s^2$. Removing three electrons gives $\text{Sc}^{3+} = [\text{Ar}] 3d^0$, with every occupied orbital doubly filled. Chromium

Quick Tip to Solve: Remove the $4s$ electrons first for ionic configurations; use unpaired valence electrons to compare Cr and Cu metallic bonding.

has configuration $[\text{Ar}] 3d^5 4s^1$; hence $\text{Cr}^{3+} = [\text{Ar}] 3d^3$, with three unpaired d electrons. Apply the all-paired criterion to distinguish their magnetic behaviour.

Step 2: Compare metallic bonding in Cr and Cu Chromium has configuration $[\text{Ar}] 3d^5 4s^1$, whereas copper has $[\text{Ar}] 3d^{10} 4s^1$. Chromium has many more unpaired valence electrons available to contribute to metallic bonding. Its stronger metal-metal bonding requires more energy to overcome than in copper; consequently its melting and boiling points are higher.

Step 3: Conclusion (i) Sc^{3+} is diamagnetic because it has no unpaired electrons. (ii) Cr has the higher melting and boiling points because its metallic bonding is stronger than that of Cu.

Quick Tip to Solve: Remove the 4s electrons first for ionic configurations; use unpaired valence electrons to compare Cr and Cu metallic bonding.

36(a). Out of t-butyl alcohol and n-butanol, which one will undergo acid catalyzed dehydration faster and why? [2 marks]

Solution:

Concept:

- Acid-catalysed dehydration removes water from an alcohol to form an alkene. Protonation converts the poor leaving group $-\text{OH}$ into the good leaving group H_2O .
- For comparable conditions, ease of dehydration follows $3^\circ > 2^\circ > 1^\circ$. Alkyl groups stabilise a carbocation through the positive inductive effect and hyperconjugation.

Step 1: Identify the classes of the two alcohols In t-butyl alcohol, $(\text{CH}_3)_3\text{COH}$, the carbon bearing the hydroxyl group is bonded to three other carbon atoms, so it is a tertiary alcohol. In n-butanol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, that carbon is bonded to only one other carbon atom, so it is a primary alcohol.

Step 2: Compare the ease of the elimination pathway Protonated t-butyl alcohol readily loses water to form the tertiary carbocation $(\text{CH}_3)_3\text{C}^+$. Its three methyl groups stabilise the positive charge by the $+I$ effect and hyperconjugation. Loss of a neighbouring hydrogen then forms 2-methylpropene and regenerates the acid. A corresponding primary carbocation from n-butanol would be very unstable; primary alcohol dehydration therefore requires harsher conditions and proceeds without a freely formed primary carbocation. The much more favourable ionisation step of the tertiary alcohol explains the rate comparison.

Step 3: Conclusion t-Butyl alcohol undergoes acid-catalysed dehydration faster than n-butanol because its tertiary carbocation intermediate is strongly stabilised by alkyl groups.

Quick Tip to Solve: Count the carbon groups attached to the OH-bearing carbon, then apply the dehydration order: tertiary, secondary, primary.

36(b). Carry out the following conversions:

(i) Phenol to Salicylaldehyde

(ii) t-butylchloride to t-butyl ethyl ether

(iii) Propene to Propanol

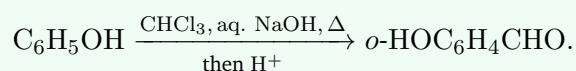
[3 marks]

Solution:

Concept:

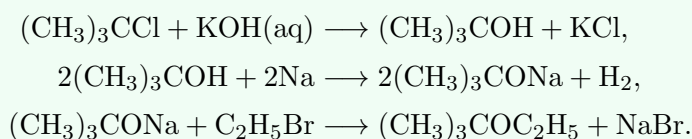
- The Reimer–Tiemann reaction introduces a –CHO group mainly ortho to the hydroxyl group of phenol using chloroform and aqueous alkali, followed by acidification.
- Williamson ether synthesis uses an alkoxide and a primary alkyl halide in an S_N2 reaction. Hydroboration–oxidation adds water across an alkene in the anti-Markovnikov orientation.

Step 1: (i) Convert phenol into salicylaldehyde Heat phenol with chloroform and aqueous NaOH, then acidify the mixture. The major aldehyde is salicylaldehyde, or 2-hydroxybenzaldehyde, with –OH and –CHO on adjacent ring carbons:



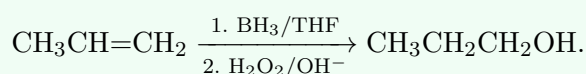
This is the Reimer–Tiemann formylation; the ortho product is the required conversion product.

Step 2: (ii) Use tert-butoxide as the nucleophile First hydrolyse t-butyl chloride with aqueous KOH to obtain t-butyl alcohol. Treat the alcohol with sodium metal to form sodium tert-butoxide, then react it with ethyl bromide:



The primary ethyl halide is the electrophile in the Williamson step. Directly treating the tertiary chloride with sodium ethoxide favours elimination, so it is unsuitable for preparing this ether.

Step 3: (iii) Convert propene into propan-1-ol Treat propene first with borane in tetrahydrofuran (THF), then oxidise with alkaline hydrogen peroxide:



Hydroboration places boron at the less substituted terminal carbon; oxidation replaces the carbon–boron bond by a carbon–oxygen bond, giving propan-1-ol. Ordinary acid-catalysed hydration instead gives propan-2-ol, so hydroboration–oxidation is used for the straight-chain primary alcohol.

Step 4: Conclusion (i) Use CHCl₃/NaOH, heat and acidification. (ii) Convert the chloride to t-butyl alcohol, then its sodium alkoxide, and react with ethyl bromide. (iii) Use BH₃/THF followed by H₂O₂/OH[–] to obtain propan-1-ol.

Quick Tip to Solve: For t-butyl ethyl ether, put the bulky t-butyl group on the alkoxide side and the primary ethyl group on the halide side.

36(a). Give the mechanism for the formation of ethanol from ethene.

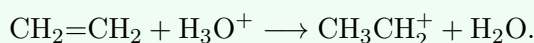
[2 marks]

Solution:

Concept:

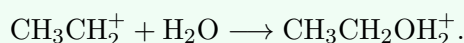
- Acid-catalysed hydration adds water across the carbon–carbon double bond of an alkene. Ethene gives ethanol in the presence of an acid catalyst.
- The electron-rich π bond accepts a proton; water then acts as a nucleophile. Deprotonation regenerates the acid catalyst.

Step 1: Protonate the double bond The π electrons of ethene attack a proton supplied by hydronium ion. The O–H bond electrons return to oxygen, producing the ethyl carbocation and water:



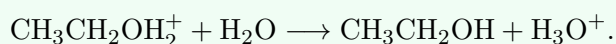
Both carbon atoms of ethene are equivalent, so protonation from either end gives the same intermediate.

Step 2: Attack by water A lone pair on the oxygen atom of water attacks the positively charged carbon of the ethyl carbocation, forming protonated ethanol:



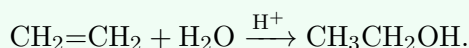
This creates the carbon–oxygen bond of the alcohol.

Step 3: Regenerate the catalyst Another water molecule removes a proton from the oxonium ion. The O–H bond electrons remain on the alcohol oxygen:



Hydronium ion is regenerated, so acid is a catalyst rather than a net reactant.

Step 4: Conclusion Thus ethene forms ethanol by protonation, nucleophilic attack of water and deprotonation:



Quick Tip to Solve: Write the three intermediates in order: ethyl carbocation, protonated ethanol, then ethanol; show regeneration of the acid.

36(b). Predict the reagent for carrying out the following conversions:

(i) Phenol to benzoquinone

(ii) Anisole to p-bromoanisole

(iii) Phenol to 2,4,6-tribromophenol

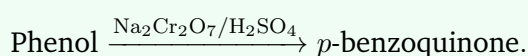
[3 marks]

Solution:

Concept:

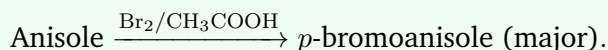
- Phenol can be oxidised to *p*-benzoquinone using a strong oxidising reagent such as acidified sodium dichromate.
- The $-\text{OCH}_3$ and $-\text{OH}$ groups activate benzene rings and direct electrophilic substitution to the ortho and para positions. The reagent medium determines the extent of bromination.

Step 1: (i) Oxidation of phenol Use sodium dichromate in sulphuric acid, $\text{Na}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$. Phenol undergoes oxidation to *p*-benzoquinone (benzene-1,4-dione):



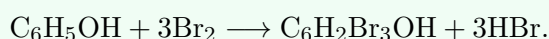
This is oxidation of the phenolic ring system, not replacement of the hydroxyl group by a halogen.

Step 2: (ii) Bromination of anisole Use bromine in ethanoic acid, $\text{Br}_2/\text{CH}_3\text{COOH}$. The methoxy group activates the aromatic ring, so a Lewis acid catalyst is not needed:



The para product predominates because substitution there is less sterically hindered than at an ortho position. Some ortho isomer is also formed; the reagent does not give exclusively the para product.

Step 3: (iii) Bromination of phenol Use excess bromine water, $\text{Br}_2(\text{aq})$, at room temperature. The strongly activating hydroxyl group facilitates substitution at both ortho positions and the para position:

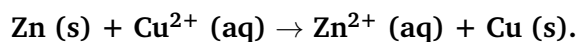


Bromine water is decolourised and a white precipitate of 2,4,6-tribromophenol is formed.

Step 4: Conclusion The required reagents are (i) $\text{Na}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$, (ii) Br_2 in CH_3COOH , and (iii) excess bromine water.

Quick Tip to Solve: Keep the bromination media distinct: anisole uses bromine in ethanoic acid; phenol with bromine water gives the tribromo product.

37(a). Calculate ΔG° for the reaction



Given: E° for $\text{Zn}^{2+}/\text{Zn} = -0.76 \text{ V}$ and E° for $\text{Cu}^{2+}/\text{Cu} = +0.34 \text{ V}$

$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$

$F = 96500 \text{ C mol}^{-1}$.

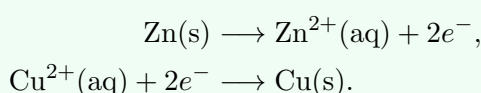
[3 marks]

Solution:

Concept:

- The standard cell potential is $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$, using reduction potentials for both electrodes.
- The standard Gibbs energy change is $\Delta G^\circ = -nFE^\circ_{\text{cell}}$, where n is the number of electrons transferred per reaction as written and F is the Faraday constant.

Step 1: Identify the half-reactions and electron transfer Zinc is oxidised at the anode and copper(II) ions are reduced at the cathode:



Adding the half-reactions gives the stated overall reaction. Two electrons cancel, hence $n = 2$, not four; the same electrons are released at one electrode and consumed at the other.

Step 2: Calculate the standard cell potential The supplied values are standard reduction potentials. Therefore, subtract the zinc reduction potential from the copper reduction potential:

$$\begin{aligned}E^\circ_{\text{cell}} &= E^\circ_{\text{Cu}^{2+}/\text{Cu}} - E^\circ_{\text{Zn}^{2+}/\text{Zn}} \\ &= 0.34 - (-0.76) \\ &= 1.10 \text{ V}.\end{aligned}$$

Electrode potentials are not multiplied by the electron coefficients when half-reactions are balanced.

Step 3: Convert cell potential to Gibbs energy Substitute $F = 96500 \text{ C mol}^{-1}$ and $n = 2$:

$$\begin{aligned}\Delta G^\circ &= -2 \times 96500 \times 1.10 \\ &= -212300 \text{ J mol}^{-1} \\ &= -212.3 \text{ kJ mol}^{-1}.\end{aligned}$$

Since $1 \text{ C V} = 1 \text{ J}$, the units are energy per mole of the reaction as written. The negative sign indicates that the forward reaction is thermodynamically favourable under standard conditions. The supplied gas constant R is not required because the standard cell potential is already known.

Step 4: Conclusion

$$\Delta G^\circ = -212.3 \text{ kJ mol}^{-1}$$

for the reaction $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$ under standard conditions.

Quick Tip to Solve: Subtract the anode reduction potential including its sign, then count the two transferred electrons before applying the minus sign in the Gibbs-energy formula.

37(b). Give two advantages of fuel cells.

[2 marks]

Solution:

Concept:

- A fuel cell converts the chemical energy of continuously supplied fuel and oxidant directly into electrical energy through electrode reactions.
- The hydrogen–oxygen fuel cell has the overall reaction $2\text{H}_2 + \text{O}_2 \longrightarrow 2\text{H}_2\text{O}$; water is its reaction product.

Step 1: Advantage 1: high conversion efficiency Fuel cells produce electrical energy directly from a chemical reaction. They therefore avoid the sequence of burning a fuel to produce heat and then converting that heat into mechanical and electrical energy. Their conversion efficiency is consequently high compared with conventional thermal generation; hydrogen–oxygen fuel cells can achieve efficiencies of about 70%.

Step 2: Advantage 2: clean operation A hydrogen–oxygen fuel cell produces water as its product during operation. It does not release smoke or carbon dioxide from the cell reaction, so it causes much less local air pollution than combustion-based power generation. This advantage refers to the hydrogen–oxygen cell during operation; the water product follows directly from the combination of hydrogen and oxygen.

Step 3: Conclusion Two advantages are high efficiency in converting chemical energy into electrical energy and clean operation of the hydrogen–oxygen fuel cell, which forms water.

Quick Tip to Solve: For the pollution advantage, name the hydrogen–oxygen fuel cell and its water product; pair this with direct, efficient electricity generation.

OR

37(a). Out of the following pairs, predict with reason which pair will allow greater conduction of electricity:

- (i) Silver wire at 30°C or silver wire at 60°C.
- (ii) 0.1 M CH_3COOH solution or 1 M CH_3COOH solution.
- (iii) KCl solution at 20°C or KCl solution at 50°C.

[3 marks]

Solution:

Concept:

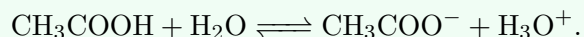
- Metals conduct through mobile electrons. Increasing temperature increases lattice vibrations and electron scattering, so metallic resistance rises and conductivity falls.
- Electrolytes conduct through mobile ions. Their conductivity depends on the number of ions per unit volume and the mobility of those ions; it must not be confused with molar conductivity.
- A weak acid ionises partially. For a weak monoprotic acid of concentration c , $K_a \approx c\alpha^2$, where α is its degree of ionisation, so the ion concentration $c\alpha \approx \sqrt{K_a c}$.

Step 1: Compare the silver wires in part (i) For silver wires of identical dimensions, the carrier is the

Quick Tip to Solve: First identify the carrier: heating hinders electrons in silver but helps ions in solution. For acetic acid, compare ions per unit volume, not the fraction ionised.

electron. At 60°C, the metal lattice vibrates more strongly than at 30°C, increasing the scattering of conducting electrons. Thus the wire has lower resistance and allows greater conduction at 30°C.

Step 2: Compare the acid solutions in part (ii) Acetic acid establishes the equilibrium



Diluting the acid increases the fraction ionised, but decreases the total number of ions per unit volume. Using the weak-acid approximation at a fixed temperature, each ionic concentration varies as $\sqrt{c}$. Hence the 1 M solution contains more charge-carrying ions per unit volume than the 0.1 M solution and gives greater conduction. The dilute solution has greater molar conductivity, which is a different quantity.

Step 3: Compare the potassium chloride solutions in part (iii) In aqueous KCl, K^+ and Cl^- carry the current. For solutions of the same concentration, raising the temperature reduces the solvent's viscosity and increases ionic mobility. The ions move more readily under an applied electric field, so conduction is greater at 50°C than at 20°C.

Step 4: Conclusion Greater conduction occurs in (i) silver wire at 30°C, (ii) 1 M CH_3COOH solution, and (iii) KCl solution at 50°C.

Quick Tip to Solve: First identify the carrier: heating hinders electrons in silver but helps ions in solution. For acetic acid, compare ions per unit volume, not the fraction ionised.

37(b). Give two points of differences between electrochemical and electrolytic cells.

[2 marks]

Solution:

Concept:

- In this comparison, an electrochemical cell means a galvanic cell, which produces electrical energy from a spontaneous chemical reaction.
- An electrolytic cell uses electrical energy supplied by an external source to drive a non-spontaneous chemical reaction. In both types, oxidation occurs at the anode and reduction at the cathode.

Step 1: Compare energy conversion and spontaneity In a galvanic cell, a spontaneous redox reaction converts chemical energy into electrical energy; the cell can supply current to an external circuit. For its working reaction, $\Delta G < 0$. In an electrolytic cell, an external power supply converts electrical energy into chemical energy by forcing a non-spontaneous reaction. This reaction has $\Delta G > 0$ and does not proceed in the required direction without the applied electrical input.

Step 2: Compare electrode polarities In a galvanic cell, the anode is negative and the cathode is positive. Oxidation at the anode supplies electrons to the external circuit. In an electrolytic cell, the anode is positive because it is connected to the positive terminal of the power source, while the cathode is negative because it is connected to the negative terminal. These polarity changes do not change the definitions of anode and cathode.

Step 3: Conclusion The two differences are: galvanic cells generate electricity from spontaneous reactions whereas electrolytic cells consume electricity to drive non-spontaneous reactions; and their

Quick Tip to Solve: Remember oxidation at the anode and reduction at the cathode in both cells; reverse only the electrode signs when moving from galvanic to electrolytic operation.

anode/cathode signs are respectively negative/positive and positive/negative.

Quick Tip to Solve: Remember oxidation at the anode and reduction at the cathode in both cells; reverse only the electrode signs when moving from galvanic to electrolytic operation.