

CBSE Class 12 Chemistry Question Paper 2020 with Solution PDF-Set 56-1-2

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 :

Read the given passage and answer the questions number 1 to 5 that follow: $1 \times 5 = 5$

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.

1. Predict the stereochemistry of the product formed if an optically active alkyl halide undergoes substitution reaction by S_N2 mechanism. [1 mark]

Solution:

Concept:

- An optically active alkyl halide has a chiral carbon with a definite spatial arrangement of substituents.
- In an S_N2 reaction, bond formation and bond breaking occur together through backside attack.

Step 1: Identify the direction of attack The nucleophile approaches the carbon bearing the halogen from the side opposite to the carbon-halogen bond. Front-side approach is unfavourable, so the entering group does not replace the leaving group from the same face.

Step 2: Determine the stereochemical change As the leaving halide departs, the three remaining groups turn over like an umbrella. This produces inversion of configuration at the reacting stereocentre, called Walden inversion. It does not produce the racemic mixture characteristic of an ideal S_N1 reaction.

Step 3: Conclusion The product shows inversion of configuration (Walden inversion).

Quick Tip to Solve: For S_N2 stereochemistry, place the incoming group opposite the departing halogen.

2. Write the structures of the products formed when anisole is treated with HI. [1 mark]

Solution:

Concept:

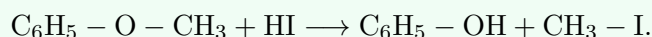
- Anisole is methyl phenyl ether, $C_6H_5 - O - CH_3$.
- HI cleaves the alkyl-oxygen bond of an aryl alkyl ether; the aryl-oxygen bond is retained.

Step 1: Protonate the ether oxygen The oxygen atom accepts a proton from HI. Protonation activates the ether towards cleavage and iodide acts as the nucleophile. The methyl group is accessible to backside attack.

Step 2: Identify the bond that breaks Iodide attacks the methyl carbon by the S_N2 mechanism,

Quick Tip to Solve: In anisole cleavage, break $O-CH_3$ and retain the phenyl-oxygen bond.

yielding methyl iodide and phenol:



The bond to the aromatic carbon does not undergo this substitution, so iodobenzene and methanol are not the products.

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

Quick Tip to Solve: In anisole cleavage, break $\text{O}-\text{CH}_3$ and retain the phenyl-oxygen bond.

3. Predict the major product formed when 2-Bromobutane undergoes a reaction with alcoholic KOH. [1 mark]

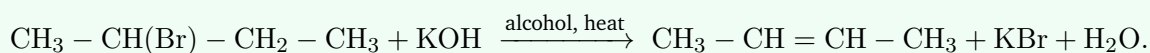
Solution:

Concept:

- Alcoholic KOH promotes elimination of HBr from a haloalkane (dehydrohalogenation).
- Saytzeff's rule favours the more substituted alkene as the major product.

Step 1: Locate the possible beta hydrogens In $\text{CH}_3 - \text{CH}(\text{Br}) - \text{CH}_2 - \text{CH}_3$, removal of a hydrogen from either neighbouring carbon can accompany loss of bromide. Removal from the terminal carbon gives but-1-ene, whereas removal from the internal carbon gives but-2-ene.

Step 2: Select the favoured alkene But-2-ene has a more substituted double bond and is more stable than but-1-ene. Thus elimination with alcoholic KOH gives it predominantly:



Aqueous KOH instead favours substitution to an alcohol.

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

Quick Tip to Solve: With alcoholic KOH, eliminate HBr and choose the more substituted double bond.

4. Name the instrument used for measuring the angle by which the plane polarised light is rotated. [1 mark]

Solution:

Concept:

- An optically active substance rotates the plane of plane-polarised light.
- The observed rotation is measured as an angle, α , by comparing the analyser setting with and without the sample.

Step 1: Recognise the property being measured The question asks about optical rotation, which is a change in the orientation of plane-polarised light as it passes through an optically active sample. It is not asking for the intensity or wavelength of the light.

Quick Tip to Solve: Associate measurement of optical rotation with a polarimeter and its rotating analyser.

Step 2: Identify the apparatus The appropriate apparatus contains a polariser, a tube holding the sample, and an analyser. The analyser is rotated to restore the reference condition, and its angular displacement gives the observed optical rotation. The apparatus used for this measurement has the specific name given below.

Step 3: Conclusion The instrument is a polarimeter.

Quick Tip to Solve: Associate measurement of optical rotation with a polarimeter and its rotating analyser.

5. Give one use of CHI_3 .

[1 mark]

Solution:

Concept:

- CHI_3 is iodoform, also called triiodomethane.
- Iodoform has been used as an antiseptic; its antiseptic action is associated with liberation of iodine.

Step 1: Identify the compound The formula CHI_3 contains one carbon atom bonded to one hydrogen and three iodine atoms. This compound is iodoform, the yellow solid encountered in the iodoform test for suitable alcohols and carbonyl compounds.

Step 2: State an accepted practical use Iodoform has been used as an antiseptic in wound dressings. The antiseptic effect is attributed to iodine released from the compound, rather than to a disinfecting action of unchanged iodoform itself. Since the question asks for one use, naming this application is sufficient.

Step 3: Conclusion CHI_3 (iodoform) is used as an antiseptic.

Quick Tip to Solve: Recognise CHI_3 as iodoform and recall its antiseptic use in wound dressings.

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

[1 mark]

Solution:

Concept:

- Biodegradation of a detergent involves breakdown of its hydrocarbon chain by microorganisms.
- Highly branched alkyl chains hinder this microbial breakdown compared with straight alkyl chains.

Step 1: Identify the relevant portion of the molecule A detergent molecule has a water-attracting ionic head and a hydrocarbon tail. The feature asked about concerns the structure of the hydrocarbon tail; the mere presence of a sulphate or sulphonate head does not determine non-biodegradability.

Step 2: Relate branching to persistence A highly branched alkyl group is difficult for microorganisms to degrade effectively, so detergents with such hydrocarbon chains persist in the environment. Straight-chain alkyl detergents are more readily biodegradable. Accordingly, it is branching in the alkyl chain that supplies the requested structural distinction.

Step 3: Conclusion A highly branched alkyl chain.

Quick Tip to Solve: Inspect the detergent tail: extensive alkyl branching indicates poor biodegradability.

7. Give the structure of the monomer of polypropene.

[1 mark]

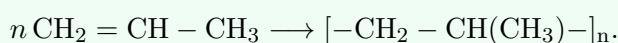
Solution:

Concept:

- Polypropene is an addition polymer formed from an unsaturated alkene monomer.
- Its repeating unit is $[-CH_2 - CH(CH_3)-]_n$; polymerisation opens the monomer's carbon-carbon double bond.

Step 1: Recover the unsaturated monomer The two carbon atoms in the polymer backbone correspond to the two atoms of the original double bond. The methyl substituent remains attached to one of these carbons throughout addition polymerisation.

Step 2: Write the monomer structure Restore a double bond between those two backbone carbons to obtain $CH_2 = CH - CH_3$, which is propene. This distinguishes the monomer from propane, which has only single bonds and cannot form polypropene by the same addition process. The polymerisation is



Step 3: Conclusion The monomer is propene: $CH_2 = CH - CH_3$.

Quick Tip to Solve: Restore the double bond in the two-carbon backbone and retain its methyl substituent.

8. Identify which liquid will have a higher 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:

- The normal boiling point is the temperature at which a liquid's vapour pressure equals atmospheric pressure.
- At a given temperature, the more volatile liquid has the higher vapour pressure and the lower normal boiling point.

Step 1: Compare the boiling points Liquid A boils at 140°C, whereas B boils at 180°C. Thus A reaches atmospheric vapour pressure at a lower temperature, indicating greater volatility and weaker intermolecular attractions in the usual comparison.

Step 2: Apply the comparison at the stated temperature At the same temperature, 90°C, both liquids are below their normal boiling points. The lower-boiling liquid has the greater tendency to escape into the vapour phase, so A has the higher vapour pressure.

Step 3: Conclusion Liquid **A** has the higher vapour pressure at 90°C.

Quick Tip to Solve: Compare boiling points at the same external pressure: the lower boiling point indicates higher vapour pressure.

9. 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 $k = Ae^{-E_a/(RT)}$, where k is the rate constant, A the frequency factor, E_a the activation energy, R the gas constant and T absolute temperature.
- In the standard Arrhenius treatment, A is taken as constant over the temperature range considered.

Step 1: Substitute zero activation energy Putting $E_a = 0$ in the Arrhenius equation gives

$$k = Ae^{-0/(RT)} = Ae^0 = A.$$

The exponential factor is unity for every positive absolute temperature.

Step 2: Interpret the result No temperature-dependent activation factor remains. Equivalently, $d(\ln k)/dT = E_a/(RT^2) = 0$. Thus, with the usual constant-frequency-factor assumption, changing T does not change k .

Step 3: Conclusion No. For $E_a = 0$, $k = A$, independent of T in the Arrhenius model.

Quick Tip to Solve: Substitute the activation energy into the exponential before judging the temperature dependence.

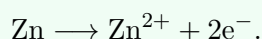
10. Out of zinc and tin, whose coating is better to protect iron objects? [1 mark]

Solution:

Concept:

- A metal more readily oxidised than iron acts as a sacrificial anode and protects iron from oxidation.
- Zinc is more reactive than iron, whereas tin is less reactive than iron.

Step 1: Consider a damaged zinc coating When the zinc coating is scratched, zinc is preferentially oxidised:



It supplies electrons and acts as the sacrificial anode, keeping the exposed iron cathodic and protecting it from rusting.

Step 2: Compare with a tin coating An intact tin coating provides a physical barrier. However, when it is scratched and moisture is present, iron is more readily oxidised than tin. The exposed iron becomes the anode of the iron-tin couple and corrodes; tin does not provide sacrificial protection.

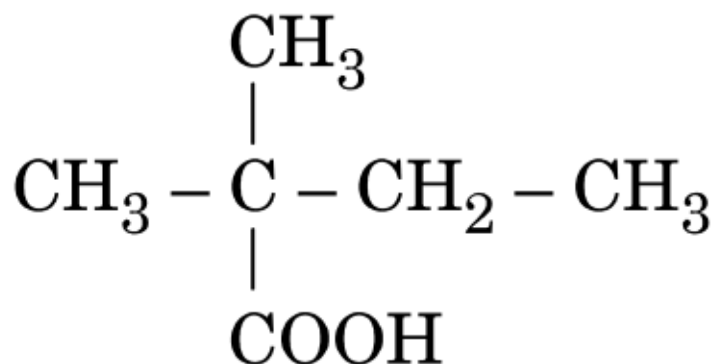
Step 3: Conclusion Zinc coating is better because it protects iron even when the coating is scratched.

Quick Tip to Solve: For a coating that remains protective after scratching, choose a metal more reactive than iron.

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

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

[1 mark]



Solution:

Concept:

- The parent chain of a carboxylic acid must contain the carboxyl carbon, which is numbered 1.
- Select the longest such chain and give the alkyl substituents their locants; the suffix is –oic acid.

Step 1: Select and number the parent chain The displayed structure is $\text{HOOC} - \text{C}(\text{CH}_3)_2 - \text{CH}_2 - \text{CH}_3$. The longest continuous chain containing the carboxyl carbon has four carbons, so the parent is butanoic acid. Numbering starts at COOH, placing the central carbon at position 2.

Step 2: Identify substituents and compare the options Two methyl groups are attached to carbon 2, giving the prefix 2,2-dimethyl. Option (B) treats the principal acid group as a carboxyl substituent; (C) selects a shorter parent chain; (D) gives incorrect connectivity and locants. Only (A) follows the longest-chain and principal-functional-group rules.

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

Quick Tip to Solve: Include the carboxyl carbon in the longest parent chain and always number it as carbon 1.

12. 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 both ns and $(n - 1)d$ electrons can participate in bonding.
- Manganese has configuration $[\text{Ar}] 3d^5 4s^2$, giving seven valence electrons available for bonding.

Step 1: Examine manganese Manganese exhibits a particularly wide range of oxidation states, including +2, +3, +4, +5, +6 and +7. Examples include Mn^{2+} , MnO_2 , MnO_4^{2-} and MnO_4^- . Its five d electrons and two s electrons allow this broad range.

Step 2: Compare the other listed elements Scandium predominantly shows +3; chromium commonly shows +2, +3 and +6; iron commonly shows +2 and +3. These elements do not show the extensive range characteristic of manganese in the first transition series. Thus (A), (B) and (D) are excluded.

Step 3: Conclusion $\text{Mn} (Z = 25)$, option (C), shows the maximum number of oxidation states.

Quick Tip to Solve: In the first transition series, remember manganese at the middle of the series for the widest oxidation-state range.

13. Hardening of leather in tanning industry is based on

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

[1 mark]

Solution:

Concept:

- Oppositely charged colloidal particles neutralise each other and precipitate; this is mutual coagulation.
- Animal hide and tanning agents form oppositely charged colloidal systems, enabling their interaction during tanning.

Step 1: Apply the colloid principle to tanning Animal hide contains positively charged colloidal protein particles. Tannin forms a negatively charged colloidal system. Their contact neutralises the colloidal charges and causes mutual coagulation, which hardens the hide to form leather.

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

Quick Tip to Solve: When two oppositely charged colloids meet and precipitate, identify the process as mutual coagulation.

between hide and tannin involved here.

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

Quick Tip to Solve: When two oppositely charged colloids meet and precipitate, identify the process as mutual coagulation.

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

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

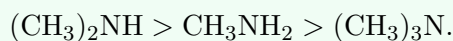
[1 mark]

Solution:

Concept:

- An amine accepts a proton through the lone pair on nitrogen; electron-donating alkyl groups increase its availability.
- In water, basic strength also depends on solvation of the protonated amine, so alkyl substitution alone is insufficient.

Step 1: Compare the methylamines in water Dimethylamine has two electron-donating methyl groups and its conjugate acid is effectively solvated by water. It offers a favourable balance of the inductive effect and hydration. The aqueous order for these methylamines is



The trimethylammonium ion is less effectively hydrated because of crowding and fewer N-H bonds.

Step 2: Compare with aniline and eliminate the alternatives In aniline, the nitrogen lone pair is delocalised into the benzene ring by resonance, making it less available for protonation. Aniline is therefore much weaker than these aliphatic amines. Methylamine has less electron donation than dimethylamine; trimethylamine has a solvation disadvantage. Thus (A), (C) and (D) are not the strongest.

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

Quick Tip to Solve: For aqueous methylamines, use secondary > primary > tertiary and account for hydration as well as induction.

15. Iodoform test is not given by

- (A) Hexan-2-one
- (B) Hexan-3-one
- (C) Ethanol
- (D) Ethanal

[1 mark]

Solution:

Concept:

- The iodoform test detects the methyl ketone unit CH_3CO , or a compound oxidised to that unit by iodine in alkali.
- A positive test produces a yellow precipitate of iodoform, CHI_3 . Ethanol is oxidised to ethanal, which also gives this test.

Step 1: Check the two ketones Hexan-2-one has structure $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, so it contains the required methyl ketone group and gives a positive test. Hexan-3-one is $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_2\text{CH}_3$. Its carbonyl group is attached to ethyl and propyl groups; neither side is a methyl group directly attached to the carbonyl carbon.

Step 2: Check ethanol and ethanal Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, is oxidised to ethanal, CH_3CHO , under the test conditions. Ethanal contains the CH_3CO arrangement with hydrogen as the remaining substituent, and gives the yellow precipitate. Thus options (A), (C) and (D) all give the test.

Step 3: Conclusion Hexan-3-one does not give the iodoform test. Hence, the correct option is (B).

Quick Tip to Solve: Write the groups immediately beside the carbonyl: a ketone needs a directly bonded CH_3 group for this test.

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 is the number of reacting species participating in an elementary reaction step.
- For the elementary reaction described in the question, count reactant molecules, not the molecules formed as products.

Step 1: Judge Assertion (A) The written equation is $\text{H}_2 + \text{Br}_2 \longrightarrow 2\text{HBr}$. It shows one molecule of hydrogen and one molecule of bromine on the reactant side. Taking the elementary-step description

Quick Tip to Solve: For the elementary step stated here, count H_2 and Br_2 ; do not count the two product molecules.

given in the question, the apparent molecularity is therefore $1 + 1 = 2$, so Assertion (A) is correct.

Step 2: Judge Reason (R) Reason (R) says that two reactant molecules are involved in the given elementary reaction. The two species are H_2 and Br_2 , each appearing once, so this statement is correct in the stated elementary-reaction interpretation.

Step 3: Check the explanatory link Counting the two participating reactant molecules is exactly how the molecularity of an elementary step is determined. Thus the reason directly explains the apparent molecularity in the assertion. Molecularity is assigned to an elementary step; it should not generally be inferred from an overall multistep reaction equation.

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

Quick Tip to Solve: For the elementary step stated here, count H_2 and Br_2 ; do not count the two product molecules.

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 alternative donor atoms but binds through one of them at a time.
- Linkage isomers have the same ligand and composition but differ in the atom through which that ligand coordinates to the metal.

Step 1: Judge Assertion (A) Linkage isomerism arises when an ambidentate ligand can attach to the central metal ion through either of its alternative donor atoms. The ligand itself remains the same while its attachment changes. Therefore Assertion (A) is correct.

Step 2: Judge Reason (R) The nitrite ion, NO_2^- , can donate through nitrogen or through oxygen. These are different donor atoms of the same ligand, so nitrite is ambidentate. It forms an N-bonded nitro linkage or an O-bonded nitrito linkage. Reason (R) is correct.

Step 3: Check the explanatory link The availability of two different donor atoms makes the two alternative metal-ligand attachments possible. This is precisely the origin of linkage isomerism, so the reason explains the assertion rather than merely giving an unrelated property.

Step 4: Conclusion Both Assertion (A) and Reason (R) are correct, and Reason (R) is the correct explanation. The correct code is (i).

Quick Tip to Solve: For linkage isomerism, keep the ligand unchanged and identify whether the metal binds through N or O of NO_2^- .

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:

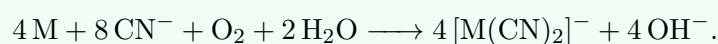
Concept:

- Leaching selectively dissolves the desired metal from its ore while leaving much of the gangue undissolved.
- Gold and silver form soluble dicyanide complexes, $[\text{Au}(\text{CN})_2]^-$ and $[\text{Ag}(\text{CN})_2]^-$, during cyanide leaching.

Step 1: Judge Assertion (A) Gold and silver can be extracted by leaching their ores with dilute sodium cyanide solution. The metal passes into solution as a soluble cyanide complex. Thus Assertion (A) is correct.

Step 2: Judge Reason (R) The purpose of this treatment is to dissolve the desired gold or silver selectively, rather than to dissolve the impurities. The insoluble impurities are separated from the complex-containing solution. Therefore the statement that the associated impurities dissolve in sodium cyanide is incorrect as the explanation of this extraction.

Step 3: Check the explanatory link The assertion rests on complex formation by the desired metal. For $M = \text{Au}$ or Ag , a representative balanced equation is



Since the reason identifies the wrong material as being selectively dissolved, it cannot explain the true assertion.

Step 4: Conclusion Assertion (A) is correct, but Reason (R) is incorrect. The correct code is (iii).

Quick Tip to Solve: In cyanide leaching, ask what enters the filtrate: the valuable metal as a soluble complex, while gangue is separated.

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:

- Each fluorine atom in F_2 has three lone pairs in addition to the bonding pair.
- In a very small atom, nonbonding electron pairs on adjacent atoms are close together, producing appreciable lone-pair repulsion.

Step 1: Judge Assertion (A) The F–F bond is unusually weak compared with what would be expected simply from its short length. Its bond dissociation enthalpy is lower than that of the Cl–Cl bond. Assertion (A) is therefore correct.

Step 2: Judge Reason (R) Fluorine is a small atom because its valence electrons lie in the compact second shell. Reason (R), which states that the fluorine atom is small, is correct.

Step 3: Check the explanatory link The small size brings the three lone pairs on each bonded fluorine atom close to the lone pairs on the other atom. Strong repulsions between these nonbonding electron pairs weaken the bond. The decisive cause of the weak bond is this lone-pair repulsion. The printed reason states only the small size and omits the repulsion; small size by itself generally favours effective orbital overlap and does not establish a weak bond. Therefore the printed reason is true but is not the correct explanation.

Step 4: Conclusion Both Assertion (A) and Reason (R) are correct, but Reason (R) is not the correct explanation of Assertion (A). The correct code is (ii).

Quick Tip to Solve: For the weak F–F bond, connect small size to repulsion between the three lone pairs on each fluorine atom.

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

Reason (R): Sucrose has glycosidic linkage.

(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 provide a reactive carbonyl group.
- A glycosidic linkage joins sugar units. Its mere presence does not establish that every anomeric centre is blocked.

Step 1: Judge Assertion (A) Sucrose is non-reducing because its glycosidic bond joins the anomeric carbon C_1 of glucose to the anomeric carbon C_2 of fructose. Both anomeric centres are involved, leaving no free hemiacetal or hemiketal group that can open to a reducing carbonyl form. Thus Assertion (A) is correct.

Step 2: Judge Reason (R) Sucrose does have a glycosidic linkage joining its glucose and fructose units, so Reason (R) is correct. However, the statement only mentions the presence of the linkage; it does not specify the participation of both anomeric carbons.

Step 3: Check the explanatory link The presence of a glycosidic bond alone is insufficient: reducing disaccharides such as maltose also have glycosidic linkages, but retain one free anomeric centre. The specific involvement of both anomeric centres explains sucrose being non-reducing. Hence the printed reason is true but is not the correct explanation.

Step 4: Conclusion Both Assertion (A) and Reason (R) are correct, but Reason (R) is not the correct explanation. The correct code is (ii).

Quick Tip to Solve: Do not decide reducing behaviour merely from a glycosidic bond: check whether any anomeric carbon remains free.

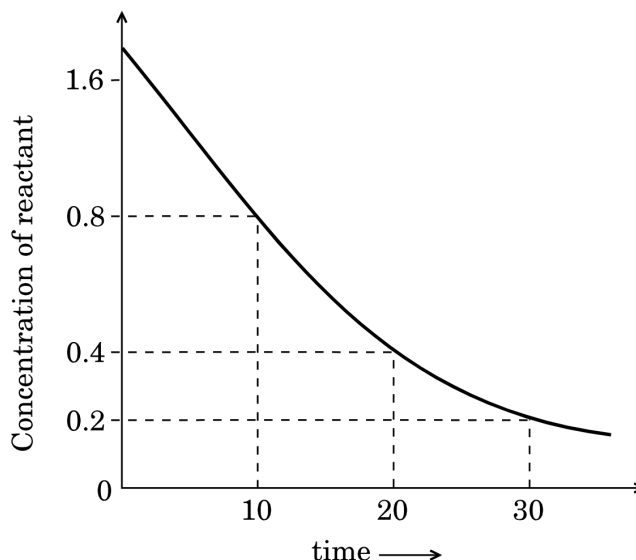
Section B (14 marks)

21. 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:

- For a first-order reaction, the rate law is $-d[A]/dt = k[A]$, where $[A]$ is reactant concentration and k is the rate constant.
- The integrated law is $[A]_t = [A]_0 e^{-kt}$. The half-life is $t_{1/2} = \ln 2/k$, independent of initial concentration.

Step 1: (a) Compare successive halving intervals The graph shows concentration decreasing from 1.6 to 0.8 during the first 10 time units, from 0.8 to 0.4 during the next 10, and from 0.4 to 0.2 during the next 10. Every halving therefore requires the same time. This constant half-life identifies first-order kinetics. Zero-order kinetics would instead give a straight concentration-time line.

Step 2: (b) Examine the infinite-time limit From $[A]_t = [A]_0 e^{-kt}$, the exponential remains positive for every finite time. Thus concentration cannot become exactly zero at a finite time. As $t \rightarrow \infty$, however, $e^{-kt} \rightarrow 0$, so $[A]_t \rightarrow 0$. The concentration approaches zero asymptotically: complete disappearance is attained only in the theoretical infinite-time limit.

Step 3: Conclusion (a) First-order reaction. (b) The concentration tends to zero as $t \rightarrow \infty$, but never becomes exactly zero at a finite time.

Quick Tip to Solve: Compare successive halving intervals: equal half-lives identify first-order decay even when no rate constant is supplied.

22. Draw the shape of the following molecules:

(a) XeF_4

(b) HClO_4

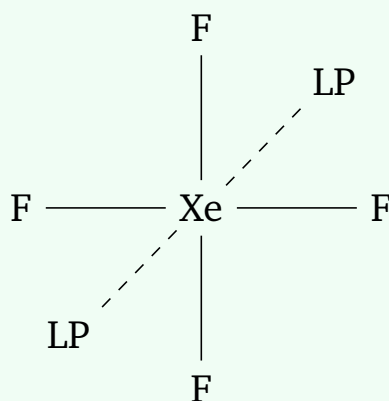
[2 marks]

Solution:

Concept:

- VSEPR theory places electron pairs around a central atom to minimise repulsion; molecular shape describes the positions of atoms, excluding lone pairs.
- In XeF_4 , four bond pairs and two lone pairs surround xenon. In HClO_4 , chlorine has four oxygen bonding domains; each multiple bond counts as one domain.

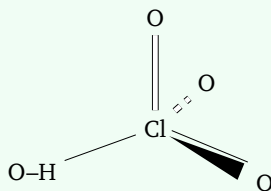
Step 1: (a) Shape of xenon tetrafluoride Xenon has six electron-pair domains: four Xe–F bonds and two lone pairs. Their electron-pair arrangement is octahedral. The two lone pairs occupy opposite positions, leaving the four fluorine atoms in one plane at the corners of a square. The molecular shape is square planar, with adjacent F–Xe–F angles of 90° and opposite angles of 180° .



Four F atoms in one plane

Square planar XeF_4 ; the two lone pairs lie above and below its plane.

Step 2: (b) Shape of perchloric acid Chlorine is bonded to four oxygen atoms, one belonging to an –OH group and three represented by $\text{Cl}=\text{O}$ bonds in the usual structural formula. Four bonding domains and no lone pair on central chlorine give a tetrahedral arrangement of oxygen atoms around chlorine, with approximately 109.5° O–Cl–O angles. The hydrogen is attached to oxygen, not directly to chlorine.



Solid: towards viewer; dashed: behind plane

Tetrahedral arrangement of the four oxygen atoms around chlorine in HClO_4 .

Step 3: Conclusion XeF_4 : square planar. HClO_4 : tetrahedral around chlorine.

Quick Tip to Solve: Count bonding domains and lone pairs on the central atom; a double bond occupies one direction in VSEPR.

23(a). Define the following terms:

(a) Tranquilizers

(b) Antiseptic

[2 marks]

Solution:

Concept:

- Tranquilizers act on the central nervous system and help control mental stress and anxiety.
- Antiseptics control microorganisms on living tissue; their suitable concentration permits application to wounds and skin.

Step 1: (a) Define tranquilizers Tranquilizers are drugs used to treat stress and mild or severe mental diseases. They relieve anxiety, tension, irritability or excitement and induce a sense of well-being. They act on the central nervous system. For example, diazepam is used as a tranquilizer; such medicines should be used under medical supervision.

Step 2: (b) Define antiseptics Antiseptics are substances that kill microorganisms or inhibit their growth and can be applied to living tissues, such as wounds, cuts, ulcers and diseased skin, to prevent infection. Examples include tincture of iodine and suitable dilute antiseptic preparations. Their use on living tissue distinguishes them from disinfectants, which are used on non-living surfaces.

Step 3: Conclusion Tranquilizers relieve mental stress and anxiety; antiseptics prevent microbial growth or kill microbes on living tissue.

Quick Tip to Solve: For antiseptics, include both the antimicrobial action and application to living tissue in the definition.

OR

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

[2 marks]

Solution:

Concept:

- A soap is a sodium or potassium salt of a long-chain fatty acid, represented as RCOO^-Na^+ .
- The ionic carboxylate head is hydrophilic (water-attracting), whereas the hydrocarbon tail R is hydrophobic and associates with grease.

Step 1: Attach soap molecules to the oily dirt Oily dirt does not dissolve readily in water. When soap solution is applied, the non-polar hydrocarbon tails enter the oil or grease, while the ionic carboxylate heads remain in the surrounding water. Many soap molecules arrange around the greasy particle with tails pointing inward and heads pointing outward, forming a micelle.

Step 2: Disperse and remove the grease Rubbing or agitation breaks the grease into small droplets enclosed by soap molecules. The outward-facing charged heads interact with water, and their mutual repulsion helps prevent the droplets from joining together again. Thus grease becomes dispersed as an emulsion in water. During rinsing, water carries away these suspended micelles, together with the trapped oily dirt, leaving the surface clean.

Quick Tip to Solve: Remember the micelle orientation: hydrocarbon tails enter grease; ionic heads face the water that removes it.

Step 3: Conclusion Soap cleans by surrounding grease with micelles, dispersing it in water and allowing it to be washed away.

Quick Tip to Solve: Remember the micelle orientation: hydrocarbon tails enter grease; ionic heads face the water that removes it.

24. Give the formulae of the following compounds:

(a) Potassium trioxalatoaluminate (III)

(b) Tetraammineaquachloridocobalt (III) chloride

[2 marks]

Solution:

Concept:

- The charge of a coordination entity equals the metal oxidation state plus the sum of ligand charges. Oxalato, $\text{C}_2\text{O}_4^{2-}$, has charge -2 ; ammine, NH_3 , and aqua, H_2O , are neutral.
- The ligands and central metal are enclosed in square brackets. Counter-ions are written outside the brackets in the number needed to make the complete compound electrically neutral.

Step 1: Determine the aluminate complex charge In potassium trioxalatoaluminate(III), aluminium is in the $+3$ oxidation state and three oxalato ligands contribute $3(-2) = -6$. Thus the complex charge is $+3 - 6 = -3$, giving $[\text{Al}(\text{C}_2\text{O}_4)_3]^{3-}$. Three potassium ions, each of charge $+1$, balance this anion.

Step 2: Determine the cobalt complex charge In tetraammineaquachloridocobalt(III), cobalt has oxidation state $+3$. The four ammine ligands and one aqua ligand contribute zero charge; the one chlorido ligand contributes -1 . Hence the complex has charge $+3 - 1 = +2$. Two chloride counter-ions are therefore required outside the coordination sphere. The coordinated chloride stays inside the brackets.

Step 3: Conclusion (a) $\boxed{\text{K}_3[\text{Al}(\text{C}_2\text{O}_4)_3]}$.

(b) $\boxed{[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}]\text{Cl}_2}$.

Quick Tip to Solve: Count chlorido inside the cobalt brackets first; use two additional chloride ions outside to neutralise the remaining $+2$ charge.

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

[R = 0.0821 L atm K⁻¹ mol⁻¹]

[2 marks]

Solution:

Concept:

- For a dilute solution, osmotic pressure obeys $\pi = CRT = nRT/V$, where C is molarity, n is the amount of solute, V is solution volume and T is absolute temperature.
- Urea is a molecular non-electrolyte, so its van't Hoff factor is $i = 1$. The percentage strength here is used as mass per volume: 5 g of urea in 100 mL of solution.

Step 1: Convert the percentage to molarity Take 100 mL = 0.100 L of solution. It contains 5 g of urea.

Quick Tip to Solve: Convert 5% to 50 g L⁻¹, divide by 60 for molarity, and then multiply by RT .

With molar mass $M = 60 \text{ g mol}^{-1}$,

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

Use the total solution volume in this calculation, since osmotic pressure depends on molarity, rather than on the mass of solvent.

Step 2: Substitute in the osmotic pressure equation Using $R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$ and $T = 300 \text{ K}$,

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

The litre, mole and kelvin units cancel, leaving atmospheres. No dissociation multiplier is needed because urea remains as molecules in the solution.

Step 3: Conclusion The osmotic pressure is $\pi \approx 20.5 \text{ atm}$.

Quick Tip to Solve: Convert 5% to 50 g L^{-1} , divide by 60 for molarity, and then multiply by RT .

OR

25(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:

- Freezing-point depression is $\Delta T_f = K_f m$ for a non-electrolyte, where K_f is the solvent cryoscopic constant and m is the number of moles of solute per kilogram of solvent.
- Both solutions use water and freeze at the same temperature, so they have equal freezing-point depressions. For molecular solutes, equal depressions in equal solvent masses imply equal amounts of solute in moles.

Step 1: Find the molality of the urea solution The amount of urea is

$$n_{\text{urea}} = \frac{7.5}{60} = 0.125 \text{ mol}.$$

The mass of water in each solution is $100 \text{ g} = 0.100 \text{ kg}$. Thus the molality of the urea solution is

$$m_{\text{urea}} = \frac{0.125}{0.100} = 1.25 \text{ mol kg}^{-1}.$$

Step 2: Equate freezing-point depressions Let the molar mass of Z be M_Z in g mol^{-1} . Using the same K_f for water in both solutions,

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

Quick Tip to Solve: When solvent masses and freezing points match, cancel K_f and the solvent mass before calculating: equate w/M for the two solutes.

Cancel the common solvent factor and rearrange:

$$\frac{7.5}{60} = \frac{42.75}{M_Z}, \quad M_Z = \frac{42.75 \times 60}{7.5} = 342 \text{ g mol}^{-1}.$$

This uses the usual molecular-solute relation, with no association or dissociation factor.

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

Quick Tip to Solve: When solvent masses and freezing points match, cancel K_f and the solvent mass before calculating: equate w/M for the two solutes.

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

(a) Nylon-6,6

(b) Buna-S

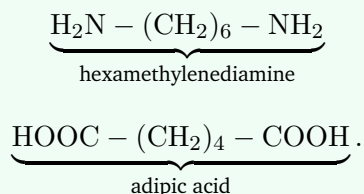
[2 marks]

Solution:

Concept:

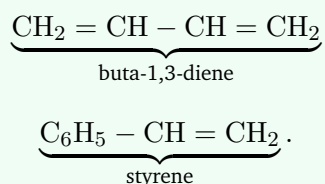
- A monomer is a small molecule whose units combine to form a polymer. Nylon-6,6 is a condensation polymer formed from a diamine and a dicarboxylic acid.
- Buna-S is an addition copolymer formed from a conjugated diene and styrene. Condensed structural formulae show the functional groups or double bonds that participate in polymerisation.

Step 1: Identify the two monomers of Nylon-6,6 The monomers are hexamethylenediamine (hexane-1,6-diamine) and adipic acid (hexanedioic acid). Their structures are



Each contains six carbon atoms, which explains the two 6s in the polymer name. The terminal amino and carboxyl groups react to form amide links with elimination of water.

Step 2: Identify the two monomers of Buna-S The monomers are buta-1,3-diene and styrene (phenylethene). Their structures are



In styrene, C_6H_5 denotes the phenyl group, a benzene ring attached to the vinyl group. The carbon-carbon double bonds permit addition copolymerisation; S in Buna-S identifies styrene as the comonomer.

Quick Tip to Solve: For Nylon-6,6 check that both monomers contain six carbon atoms; for Buna-S remember that S stands for styrene.

Step 3: Conclusion (a) Nylon-6,6: hexamethylenediamine, $\text{H}_2\text{N} - (\text{CH}_2)_6 - \text{NH}_2$, and adipic acid, $\text{HOOC} - (\text{CH}_2)_4 - \text{COOH}$.

(b) Buna-S: buta-1,3-diene, $\text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2$, and styrene, $\text{C}_6\text{H}_5 - \text{CH} = \text{CH}_2$.

Quick Tip to Solve: For Nylon-6,6 check that both monomers contain six carbon atoms; for Buna-S remember that S stands for styrene.

27. What happens when

(a) Butanone is treated with methylmagnesium bromide and then hydrolysed, and

(b) Sodium benzoate is heated with soda lime?

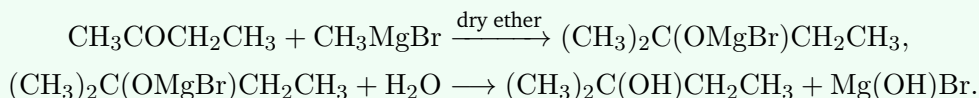
[2 marks]

Solution:

Concept:

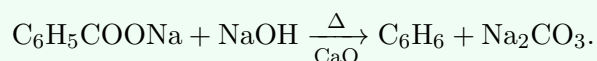
- A Grignard reagent adds its alkyl group to the carbonyl carbon of a ketone. Hydrolysis of the resulting magnesium alkoxide gives a tertiary alcohol.
- Heating a sodium carboxylate with soda lime, a mixture of NaOH and CaO, removes the carboxyl group as carbonate: this is decarboxylation.

Step 1: (a) Addition to butanone followed by hydrolysis Butanone is $\text{CH}_3\text{COCH}_2\text{CH}_3$. The methyl group from CH_3MgBr attacks its carbonyl carbon, and the carbonyl oxygen forms the magnesium alkoxide. On hydrolysis, the oxygen is protonated:



The carbon bearing the hydroxyl group is bonded to two methyl groups and one ethyl group, so the alcohol is tertiary.

Step 2: (b) Decarboxylation of sodium benzoate On heating sodium benzoate with soda lime, its carboxylate group is replaced by hydrogen. The carbon of the carboxylate group enters sodium carbonate:



Calcium oxide provides the soda-lime medium and is shown over the reaction arrow; it is not consumed in this balanced equation.

Step 3: Conclusion (a) Butanone gives the tertiary alcohol 2-methylbutan-2-ol. (b) Sodium benzoate gives benzene on heating with soda lime.

Quick Tip to Solve: Add the Grignard alkyl group to the carbonyl carbon, then replace O-MgBr by OH; soda lime removes the entire carboxylate carbon.

Section C (21 marks)

28. 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:

- For a dilute solution of a nonvolatile, non-electrolyte solute, the depression in freezing point is $\Delta T_f = K_f m$, where K_f is the solvent's molal depression constant and m is moles of solute per kilogram of solvent.
- If w is the solute mass and M its molar mass, then $n = w/M$. The solvent mass must be converted to kilograms before calculating molality.

Step 1: Identify the data and the required molality The required depression is $\Delta T_f = 1.5 \text{ K}$; a temperature difference of 1.5°C has the same numerical value in kelvin. For acetic acid, $K_f = 3.9 \text{ K kg mol}^{-1}$. Treating ascorbic acid as a non-electrolyte, as in the given colligative-property calculation, the molality needed is

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

Molality uses the mass of the solvent, not the total mass of the resulting solution.

Step 2: Calculate the moles of ascorbic acid The given solvent mass is $75 \text{ g} = 0.075 \text{ kg}$. Hence the amount of solute required is

$$n = m \times \text{mass of solvent in kg} = 0.384615 \times 0.075 = 0.0288462 \text{ mol}.$$

Keeping intermediate digits avoids introducing rounding error before the final mass is obtained.

Step 3: Convert the amount to mass and check Using the molar mass $M = 176 \text{ g mol}^{-1}$,

$$w = nM = 0.0288462 \times 176 = 5.07692 \text{ g}.$$

Substitution checks the result: $3.9 \times [(5.07692/176)/0.075] = 1.5 \text{ K}$, the required decrease in freezing point.

Step 4: Conclusion Dissolve approximately 5.08 g of ascorbic acid in 75 g of acetic acid.

Quick Tip to Solve: Use $w = \Delta T_f MW / (1000 K_f)$ when the solvent mass W is in grams; the factor 1000 converts grams to kilograms.

29(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.

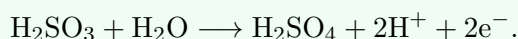
[3 marks]

Solution:

Concept:

- A reducing agent donates electrons and is itself oxidised. Oxidation-state changes identify the species that loses electrons.
- Fluorine is the most electronegative element and exhibits only the oxidation state -1 in its compounds. Its oxoacid chemistry therefore differs from that of the other halogens.
- Noble-gas atoms attract one another through London dispersion forces. These attractions become stronger as the electron cloud becomes larger and more easily polarised.

Step 1: (a) Reducing nature of sulphurous acid In H_2SO_3 , let the oxidation state of sulphur be x . Charge balance gives $2(+1) + x + 3(-2) = 0$, so $x = +4$. Sulphur can be oxidised to its more stable $+6$ state in sulphuric acid or sulphate, losing two electrons. The oxidation half-reaction is



By supplying these electrons to another substance, sulphurous acid reduces that substance and thus acts as a reducing agent.

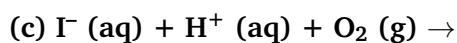
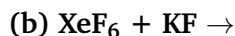
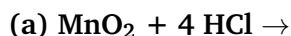
Step 2: (b) Only one oxoacid of fluorine Fluorine's very high electronegativity prevents it from exhibiting positive oxidation states. It therefore does not form the series of higher oxoacids that other halogens form in positive oxidation states. Its only oxoacid is hypofluorous acid, HOF , with the structure $\text{H}-\text{O}-\text{F}$. In this compound fluorine remains at -1 ; hydrogen is $+1$ and oxygen is 0 . Fluorine also lacks vacant d orbitals, as emphasised in the standard discussion of its anomalous chemistry.

Step 3: (c) Increase in noble-gas boiling points From He to Rn, atomic size and the number of electrons increase. The larger electron clouds are more readily distorted, so polarisability and London dispersion attractions increase. More thermal energy is consequently needed to separate the atoms into the gaseous state. Hence the boiling points rise down the group even though noble gases remain monatomic and have no permanent dipoles.

Step 4: Conclusion Sulphurous acid reduces other substances by oxidation of S from $+4$ to $+6$; fluorine forms only HOF because it cannot adopt positive oxidation states; noble-gas boiling points increase from He to Rn because dispersion forces strengthen with increasing polarisability.

Quick Tip to Solve: Link each explanation to its controlling feature: sulphur oxidation state, fluorine electronegativity, and noble-gas polarisability.

29(b). Complete the following chemical reactions:



[3 marks]

Solution:

Concept:

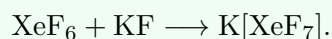
- Redox reactions conserve both atoms and charge. Oxidation increases oxidation number, whereas reduction decreases it.
- Xenon hexafluoride accepts a fluoride ion from KF to form the heptafluoroxenate(VI) ion, $[\text{XeF}_7]^-$.

Step 1: (a) Reaction of manganese dioxide with hydrochloric acid Manganese dioxide oxidises chloride ions to chlorine while manganese is reduced from +4 to +2. Two chloride ions enter manganese(II) chloride and two form chlorine. Hydrogen and oxygen balance as water:



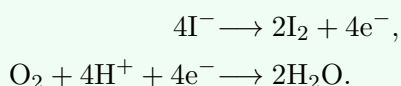
The equation contains one Mn, two O, four H and four Cl atoms on each side.

Step 2: (b) Reaction of xenon hexafluoride with potassium fluoride The fluoride ion supplied by KF acts as a Lewis base and is accepted by xenon hexafluoride. The resulting complex anion combines with potassium ion:



The product is potassium heptafluoroxenate(VI); xenon's oxidation state remains +6, so this is fluoride addition rather than a redox change.

Step 3: (c) Oxidation of iodide by oxygen in acidic solution Iodide loses electrons and oxygen gains them in the presence of acid:



Adding these half-reactions gives

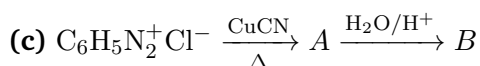
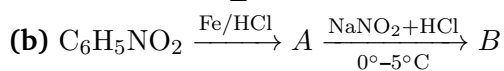
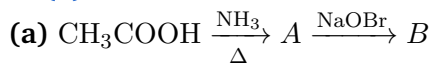


The net charge is zero on both sides, and oxygen is reduced from 0 to -2.

Step 4: Conclusion The products are $\text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$, $\text{K}[\text{XeF}_7]$, and $2\text{I}_2 + 2\text{H}_2\text{O}$, respectively, with coefficients as balanced above.

Quick Tip to Solve: For the iodide equation, balance the two half-reactions first; four iodide ions supply the four electrons required by one oxygen molecule.

30(a). Give the structures of A and B in the following sequence of reactions:



[3 marks]

Solution:

Concept:

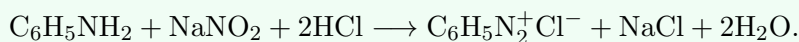
- Heating a carboxylic acid with ammonia produces the corresponding amide via an ammonium carboxylate.
- Hofmann bromamide degradation converts RCONH_2 into RNH_2 , removing the carbonyl carbon.
- A primary aromatic amine is diazotised with nitrous acid at $0^\circ-5^\circ\text{C}$. A nitrile hydrolyses to a carboxylic acid.

Step 1: (a) Form the amide and apply Hofmann degradation Ethanoic acid first forms ammonium ethanoate with ammonia. Heating eliminates water to give ethanamide (acetamide):



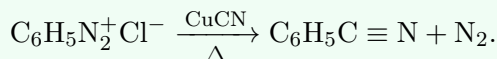
Thus A has the structure $\text{CH}_3 - \text{C}(=\text{O}) - \text{NH}_2$. Sodium hypobromite then causes Hofmann bromamide degradation. The carbonyl carbon is lost and the methyl group remains attached to nitrogen, so B is $\text{CH}_3 - \text{NH}_2$, methanamine (methylamine), not ethanamine.

Step 2: (b) Reduce nitrobenzene and diazotise aniline Iron and hydrochloric acid reduce the nitro group of nitrobenzene to an amino group without changing the benzene ring. A is therefore aniline, $\text{C}_6\text{H}_5 - \text{NH}_2$. Treatment with sodium nitrite and hydrochloric acid generates nitrous acid; at the specified low temperature it converts aniline into benzenediazonium chloride:



Thus B is $\text{C}_6\text{H}_5 - \text{N} \equiv \text{N}^+ \text{Cl}^-$. Cooling stabilises the diazonium salt and prevents its premature decomposition.

Step 3: (c) Replace the diazonium group and hydrolyse the nitrile CuCN replaces the diazonium group with a cyano group in the Sandmeyer reaction, releasing nitrogen:



A is benzonitrile, $\text{C}_6\text{H}_5 - \text{C} \equiv \text{N}$. Acidic hydrolysis converts its nitrile carbon into the carboxyl carbon, giving B as benzoic acid, $\text{C}_6\text{H}_5 - \text{C}(=\text{O}) - \text{OH}$. The aromatic ring remains intact in both conversions.

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: Count carbons in the Hofmann step: acetamide has two carbons, but methylamine has only one because the carbonyl carbon is removed.

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

(i) Aniline and Ethanamine

(ii) Aniline and N-methylaniline

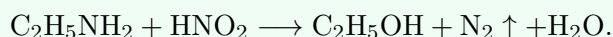
[2 marks]

Solution:

Concept:

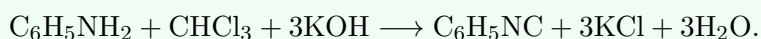
- Primary aromatic amines form stable diazonium salts at 0° – 5°C , whereas primary aliphatic diazonium salts immediately decompose with nitrogen evolution.
- The carbylamine test is positive only for primary amines: heating with chloroform and alcoholic KOH forms a foul-smelling isocyanide.

Step 1: (i) Distinguish aniline from ethanamine using nitrous acid Treat separate samples with sodium nitrite and dilute hydrochloric acid at 0° – 5°C . Aniline forms benzenediazonium chloride without brisk nitrogen evolution under these cold conditions. Ethanamine gives an unstable aliphatic diazonium species, which immediately decomposes with brisk evolution of nitrogen:



Thus immediate gas evolution identifies ethanamine. The cold aniline product can also be confirmed by coupling with alkaline beta-naphthol to form a coloured azo dye.

Step 2: (ii) Distinguish aniline from N-methylaniline by the carbylamine test Heat separate small samples with chloroform and alcoholic potassium hydroxide. Aniline is a primary amine and forms phenyl isocyanide, giving the characteristic offensive smell:



N-methylaniline, $\text{C}_6\text{H}_5\text{NHCH}_3$, is a secondary amine. It does not undergo the carbylamine reaction and gives no isocyanide smell. This difference identifies the two samples.

Step 3: Conclusion Aniline and ethanamine are distinguished by cold nitrous acid: ethanamine evolves N_2 briskly. Aniline and N-methylaniline are distinguished by the carbylamine test: only aniline is positive.

Quick Tip to Solve: Do not use carbylamine to separate aniline and ethanamine: both are primary amines and both give a positive result.

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

Butanol, Butanamine, Butane

[1 mark]

Solution:

Concept:

- Boiling requires overcoming intermolecular attractions. For compounds of comparable size, stronger hydrogen bonding generally raises the boiling point.
- Oxygen is more electronegative than nitrogen, so alcohol hydrogen bonding is stronger than amine hydrogen bonding.

Step 1: Compare butanol and butanamine Butanol contains an O – H group and forms strong intermolecular hydrogen bonds. Butanamine contains N – H bonds and also forms hydrogen bonds, but these are weaker because nitrogen is less electronegative than oxygen. Hence butanol requires more energy to separate its molecules and boils above butanamine.

Step 2: Compare butanamine and butane Butane has no hydrogen-bond donor or acceptor and its nonpolar molecules attract mainly through London dispersion forces. Butanamine has hydrogen bonding as well as dipole attractions and dispersion forces. For these similarly sized carbon skeletons, its stronger overall attractions place its boiling point above that of butane.

Step 3: Conclusion The decreasing order is Butanol > Butanamine > Butane.

Quick Tip to Solve: For these similar carbon skeletons, compare the functional groups: strong O-H hydrogen bonding, weaker N-H hydrogen bonding, then dispersion alone.

31. 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 chemical behaviour of glucose depends on its predominant cyclic hemiacetal structure, in which a free aldehyde group is unavailable.
- DNA strands obey complementary base pairing: adenine pairs with thymine, and guanine pairs with cytosine.
- Polysaccharide structure depends on the configuration of glucose and the positions and geometry of the glycosidic linkages.

Step 1: (a) Explain the negative 2,4-DNP test 2,4-Dinitrophenylhydrazine gives a precipitate with compounds having a free aldehyde or ketone carbonyl group. Glucose exists predominantly in cyclic hemiacetal forms: its aldehyde group reacts intramolecularly with a hydroxyl group to form a ring. Hence it does not present a free aldehyde group in its predominant structure and does not give the 2,4-DNP test. This behaviour supports the cyclic structure of glucose.

Quick Tip to Solve: For polysaccharides, identify both the alpha/beta configuration and the linkage positions; naming the glucose monomer alone cannot distinguish the structures.

Step 2: (b) Explain complementary DNA strands The nitrogenous bases on opposite strands form specific hydrogen-bonded pairs. Adenine (A) pairs only with thymine (T) through two hydrogen bonds, while guanine (G) pairs with cytosine (C) through three hydrogen bonds. Thus an A on one strand requires T on the other, and G requires C. The sequence on one strand therefore determines a complementary sequence, rather than an identical sequence, on the other strand. The two strands run in opposite directions.

Step 3: (c) Compare the glucose units and linkages Starch is built from α -D-glucose units. Its amylose component has $\alpha(1 \rightarrow 4)$ linkages, while amylopectin also contains $\alpha(1 \rightarrow 6)$ branch linkages. Cellulose consists of β -D-glucose units joined by $\beta(1 \rightarrow 4)$ linkages and forms straight, unbranched chains. The different configurations and glycosidic bonds produce different chain arrangements even though both polymers contain glucose units.

Step 4: Conclusion Glucose has a cyclic hemiacetal structure; DNA strands are related by specific complementary base pairing; and starch and cellulose differ in glucose configuration and glycosidic linkages.

Quick Tip to Solve: For polysaccharides, identify both the alpha/beta configuration and the linkage positions; naming the glucose monomer alone cannot distinguish the structures.

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

(a) surface area of the reactant is increased,

(b) temperature of the reaction is decreased, and

(c) catalyst is added in a reversible reaction?

[3 marks]

Solution:

Concept:

- Reaction rate depends on the number of effective collisions per unit time; exposed surface matters when a solid reactant participates.
- The Arrhenius equation is $k = Ae^{-E_a/(RT)}$, where k is the rate constant, A the pre-exponential factor, E_a the activation energy, R the gas constant and T the absolute temperature.
- A catalyst provides an alternative reaction pathway with a lower activation energy and accelerates both directions of a reversible reaction.

Step 1: (a) Increase the exposed surface area The rate increases when the exposed surface area of a solid reactant is increased, keeping the other conditions unchanged. More reactant particles are then available at the interface for contact with the other reactant, so more effective collisions can occur per unit time. For example, a powdered solid generally reacts faster than the same mass in a large lump because powder exposes a larger total area.

Step 2: (b) Decrease the temperature The rate decreases when the reaction temperature is lowered. At lower temperature the particles have lower kinetic energy, and a smaller fraction of collisions has energy equal to or greater than the activation energy. From $k = Ae^{-E_a/(RT)}$, decreasing T for a positive E_a decreases k . At fixed reactant concentrations this produces a lower reaction rate; the important effect is the reduction in the fraction of sufficiently energetic collisions.

Quick Tip to Solve: Separate the speed of reaching equilibrium from its position: a catalyst changes the former, while leaving the equilibrium constant unchanged at fixed temperature.

Step 3: (c) Add a catalyst to a reversible reaction A catalyst increases the rates of both the forward and reverse reactions by providing a lower-activation-energy pathway. The system therefore reaches equilibrium more quickly. The catalyst does not change the equilibrium constant or the equilibrium composition at a fixed temperature, because it does not change the relative energies of reactants and products. If the system is already at equilibrium, both opposing rates increase equally and there is no net shift of equilibrium.

Step 4: Conclusion Increasing the surface area increases the rate; decreasing the temperature decreases the rate; and adding a catalyst accelerates both directions of a reversible reaction without shifting its equilibrium.

Quick Tip to Solve: Separate the speed of reaching equilibrium from its position: a catalyst changes the former, while leaving the equilibrium constant unchanged at fixed temperature.

33. (a) Compare physisorption and chemisorption on the basis of

(i) specificity, and

(ii) enthalpy of adsorption.

(b) Differentiate between adsorption and absorption.

[3 marks]

Solution:

Concept:

- Physisorption is caused by weak van der Waals forces; chemisorption involves the formation of chemical bonds between adsorbate and adsorbent.
- Adsorption is the accumulation of a substance at a surface, whereas absorption involves entry into the bulk of a material.

Step 1: (a)(i) Compare specificity Physisorption is not highly specific: van der Waals attractions can act between many kinds of adsorbate molecules and an adsorbent surface. Different gases can therefore be physically adsorbed on the same surface, although the amount adsorbed may differ. Chemisorption is highly specific because a chemical bond can form only when the adsorbate and the surface are chemically compatible. For example, nitrogen is chemisorbed on an iron surface under suitable conditions because it can interact chemically with that surface.

Step 2: (a)(ii) Compare enthalpy of adsorption Physisorption has a relatively low magnitude of enthalpy of adsorption, typically about $20\text{--}40\text{ kJ mol}^{-1}$, owing to its weak intermolecular attractions. Chemisorption has a much larger magnitude, typically about $80\text{--}240\text{ kJ mol}^{-1}$, owing to chemical-bond formation. Adsorption is generally exothermic, so these quoted positive values refer to the magnitudes of the heat released; the corresponding enthalpy change is negative.

Step 3: (b) Distinguish adsorption from absorption In adsorption, molecules accumulate mainly at the surface of a solid or liquid; their concentration is greater at the surface than in the interior. It is therefore a surface phenomenon, as when a gas collects on activated charcoal. In absorption, the substance penetrates into the bulk of the material and becomes distributed throughout it; it is a bulk phenomenon, as when water enters a sponge. The distinction is the location of the retained substance, rather than simply whether a material takes up another substance.

Quick Tip to Solve: Connect weak van der Waals attraction with low heat and low specificity, and chemical-bond formation with high heat and high specificity.

Step 4: Conclusion Physisorption is relatively non-specific and has low adsorption enthalpy, whereas chemisorption is specific and has high adsorption enthalpy. Adsorption occurs at the surface; absorption occurs throughout the bulk.

Quick Tip to Solve: Connect weak van der Waals attraction with low heat and low specificity, and chemical-bond formation with high heat and high specificity.

34. Explain the role of the following:

(a) CO in the refining of Ni.

(b) Limestone in the metallurgy of Fe.

(c) Depressant in the froth floatation method.

[3 marks]

Solution:

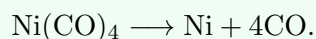
Concept:

- Mond refining separates nickel by forming its volatile carbonyl, $\text{Ni}(\text{CO})_4$, and then decomposing it to pure metal.
- A flux converts gangue into a fusible slag. In iron extraction, basic CaO removes acidic silica gangue.
- A depressant selectively prevents one sulphide from forming froth so that mixed sulphide ores can be separated.

Step 1: (a) Role of carbon monoxide In the Mond process, impure nickel is heated in a stream of carbon monoxide at about 330–350 K. Nickel forms a volatile complex, whereas the nonvolatile impurities remain behind:

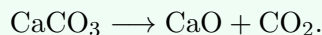


The nickel tetracarbonyl vapour is then heated to about 450–470 K:

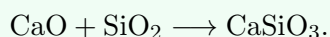


Thus CO acts as the complex-forming agent, enabling nickel to be transported away from impurities and deposited as pure nickel.

Step 2: (b) Role of limestone Limestone acts as a source of the basic flux in the blast furnace. It decomposes on heating:



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



The fusible slag can be removed separately from molten iron; limestone therefore helps remove acidic impurities.

Step 3: (c) Role of a depressant A depressant prevents a selected sulphide ore from being wetted by oil and hence from rising with the froth. For example, when an ore contains ZnS and PbS , sodium

Quick Tip to Solve: Link each reagent to its specific job: volatile complex, slag formation, or selective suppression of froth.

cyanide selectively depresses ZnS . Zinc sulphide remains in the aqueous mixture while PbS enters the froth, allowing their separation.

Step 4: Conclusion CO refines Ni through volatile nickel carbonyl; limestone supplies CaO to remove silica as slag; a depressant selectively suppresses flotation of one sulphide.

Quick Tip to Solve: Link each reagent to its specific job: volatile complex, slag formation, or selective suppression of froth.

Section D (15 marks)

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

Solution:

Concept:

- Acid protonates the alcohol hydroxyl group, making water a good leaving group.
- Carbocation stability follows tertiary > secondary > primary, due to the electron-releasing effect of alkyl groups and hyperconjugation.

Step 1: Compare the structures t-Butyl alcohol, $(\text{CH}_3)_3\text{COH}$, is a tertiary alcohol, whereas n-butanol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, is primary. In acid-catalysed dehydration of the tertiary alcohol, the protonated alcohol loses water to form the tertiary carbocation $(\text{CH}_3)_3\text{C}^+$. The three methyl groups stabilise this positive charge.

Step 2: Relate stability to the reaction rate Formation of the carbocation is the slow step in tertiary-alcohol dehydration. Its relatively high stability lowers the barrier for loss of water; subsequent removal of a beta hydrogen gives $\text{CH}_2 = \text{C}(\text{CH}_3)_2$. n-Butanol cannot readily lose water to form an unstable primary carbocation and requires more vigorous dehydration conditions. Thus the usual acid-catalysed dehydration reactivity order is tertiary > secondary > primary.

Step 3: Conclusion t-Butyl alcohol undergoes acid-catalysed dehydration faster because its tertiary carbocation is much more stable than a primary carbocation.

Quick Tip to Solve: First classify the carbon bearing OH; a tertiary alcohol dehydrates more readily than a primary alcohol.

35(b). Carry out the following conversions:

(i) Phenol to Salicylaldehyde

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

(iii) Propene to Propanol

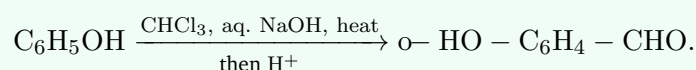
[3 marks]

Solution:

Concept:

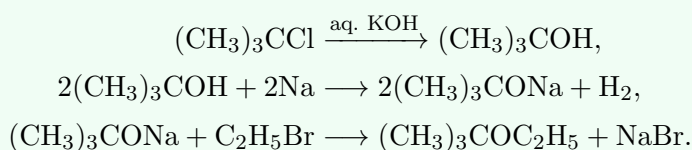
- Reimer–Tiemann formylation introduces $-\text{CHO}$ mainly ortho to the hydroxyl group of phenol.
- Williamson synthesis uses an alkoxide and a primary alkyl halide; a tertiary halide is unsuitable for the substitution step because elimination competes.
- Hydroboration–oxidation adds water across an alkene in the anti-Markovnikov direction, giving a primary alcohol from propene.

Step 1: (i) Phenol to salicylaldehyde Heat phenol with chloroform and aqueous sodium hydroxide, then acidify the reaction mixture. This is the Reimer–Tiemann reaction; the ortho product is salicylaldehyde (2-hydroxybenzaldehyde):



The phenolic hydroxyl group is retained and a formyl group is introduced at the adjacent ring carbon.

Step 2: (ii) t-Butyl chloride to t-butyl ethyl ether First hydrolyse t-butyl chloride with aqueous alkali to obtain t-butyl alcohol. Convert the alcohol into sodium tert-butoxide using sodium metal, then react this alkoxide with ethyl bromide:

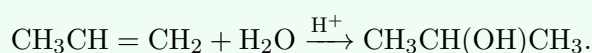


The primary ethyl halide is used in the Williamson substitution. Direct use of t-butyl chloride with sodium ethoxide favours elimination instead of the required ether.

Step 3: (iii) Propene to propanol To obtain propan-1-ol, use hydroboration followed by oxidation:



The hydroxyl group appears at the less substituted terminal carbon. If propan-2-ol is intended, acid-catalysed hydration gives that isomer:



The printed name propanol has no locant; the first route explicitly gives the primary isomer.

Step 4: Conclusion Use Reimer–Tiemann formylation for salicylaldehyde; hydrolysis, sodium and ethyl bromide for t-butyl ethyl ether; hydroboration–oxidation for propan-1-ol (acid hydration gives propan-2-ol).

Quick Tip to Solve: For the ether, put the bulky tertiary group in the alkoxide and the primary ethyl group in the halide.

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

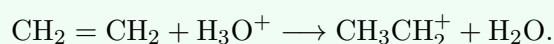
[2 marks]

Solution:

Concept:

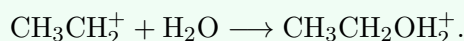
- An alkene undergoes electrophilic addition: its pi bond attacks a proton, after which water attacks the carbocation.
- The acid is a catalyst; it is consumed during protonation and regenerated during deprotonation.

Step 1: Protonation of ethene In aqueous acid, ethene accepts a proton at its electron-rich double bond, forming an ethyl carbocation. Because ethene is symmetrical, either carbon gives the same intermediate:



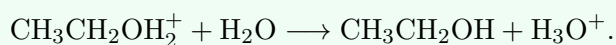
This converts the pi bond into a carbon–hydrogen bond and leaves the other carbon electron deficient.

Step 2: Nucleophilic attack by water A water molecule uses an oxygen lone pair to attack the positively charged carbon. This produces protonated ethanol, an oxonium ion:

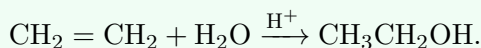


The new carbon–oxygen bond is formed in this step.

Step 3: Deprotonation and regeneration of acid Another water molecule removes a proton from the oxonium ion, yielding neutral ethanol and regenerating hydronium:



Overall, H and OH add across the double bond:



The catalyst therefore does not appear among the net products.

Step 4: Conclusion Ethene forms ethanol by protonation, water attack and deprotonation; the acid catalyst is regenerated.

Quick Tip to Solve: Write the mechanism in the order protonation, water attack, deprotonation, checking charge at each step.

35(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:

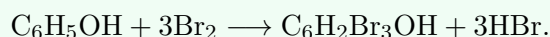
Concept:

- Phenol undergoes oxidation to a quinone with a suitable strong oxidising reagent.
- The methoxy group in anisole activates the benzene ring and directs electrophilic substitution mainly to the ortho and para positions.
- The hydroxyl group strongly activates phenol; bromine water therefore introduces bromine at all three activated positions, 2, 4 and 6.

Step 1: (i) Oxidise phenol to benzoquinone Use acidified sodium dichromate, $\text{Na}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$. This oxidising reagent converts phenol to *p*-benzoquinone (1,4-benzoquinone). The conversion involves oxidation of the aromatic phenol to the quinone having two carbonyl groups. Thus the required reagent is an acidified dichromate, rather than a reagent for substitution on the ring.

Step 2: (ii) Brominate anisole selectively Use bromine in ethanoic acid, $\text{Br}_2/\text{CH}_3\text{COOH}$. The electron-donating $-\text{OCH}_3$ group directs bromination to the ortho and para positions. The para product, *p*-bromoanisole, is the major product because attack at the para position is less sterically hindered than at the ortho position. A Lewis-acid catalyst is unnecessary for this activated aromatic ring.

Step 3: (iii) Brominate phenol with bromine water Use excess bromine water, $\text{Br}_2(\text{aq})$. Phenol reacts readily at room temperature to form a white precipitate of 2,4,6-tribromophenol:

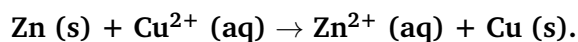


The aqueous reagent and sufficient bromine give substitution at both ortho positions and the para position.

Step 4: Conclusion The required reagents are (i) $\text{Na}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$, (ii) $\text{Br}_2/\text{CH}_3\text{COOH}$, and (iii) excess bromine water, $\text{Br}_2(\text{aq})$, respectively.

Quick Tip to Solve: Match the medium to the product: anisole uses bromine in ethanoic acid, whereas phenol gives the tribromo product with bromine water.

36(a). Calculate ΔG° for the reaction



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

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

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

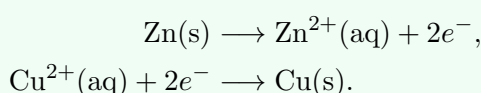
[3 marks]

Solution:

Concept:

- Using standard reduction potentials, the standard cell potential is $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$.
- Standard Gibbs energy and cell potential are related by $\Delta G^\circ = -nFE^\circ_{\text{cell}}$, where n is the number of electrons transferred per reaction as written and F is the Faraday constant.

Step 1: Identify the electrode reactions and electron transfer Zinc is oxidised, while copper(II) ions are reduced. The balanced half-reactions are



Adding them gives the stated reaction. Therefore $n = 2$; the electrons cancel and are not added to give four.

Step 2: Calculate the standard cell potential Copper is the cathode and zinc is the anode. Both given values are reduction potentials, so

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

The zinc value is subtracted as supplied; multiplying a half-reaction does not multiply its electrode potential.

Step 3: Substitute in the Gibbs energy relation With $F = 96500 \text{ C mol}^{-1}$,

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

Here $\text{C} \times \text{V} = \text{J}$, which gives the energy unit. The negative sign indicates that the reaction as written is thermodynamically spontaneous under standard conditions. The supplied gas constant R is not needed because no equilibrium constant or non-standard concentration is being calculated.

Step 4: Conclusion For the reaction as written, $\Delta G^\circ = -212.3 \text{ kJ mol}^{-1}$.

Quick Tip to Solve: First subtract the two reduction potentials, then use two electrons for the Zn-to-Zn(II) change in $-nFE^\circ$.

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

[2 marks]

Solution:

Concept:

- A fuel cell is a galvanic cell that converts the chemical energy of a continuously supplied fuel and oxidant directly into electrical energy.
- In a hydrogen-oxygen fuel cell, the overall reaction is $2\text{H}_2 + \text{O}_2 \longrightarrow 2\text{H}_2\text{O}$; electrons passing through the external circuit supply electrical energy.

Step 1: Advantage 1: efficient conversion into electrical energy Fuel cells have high energy-conversion efficiency because they convert chemical energy directly into electrical energy. They avoid the intermediate conversion into heat and mechanical work required in conventional thermal power generation, thereby reducing energy losses associated with those stages.

Step 2: Advantage 2: clean operation Hydrogen-oxygen fuel cells are environmentally friendly during operation because their reaction product is water. They do not release the carbon dioxide, smoke or ash associated with burning carbon-containing fuels to generate electricity. This makes the hydrogen-oxygen cell a clean source of electrical energy at the point of use.

Step 3: Conclusion Two advantages are high efficiency in producing electricity and clean operation, with water as the product of a hydrogen-oxygen fuel cell.

Quick Tip to Solve: Give two distinct benefits: direct energy conversion explains efficiency, and the hydrogen-oxygen reaction explains clean operation.

OR

36(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:

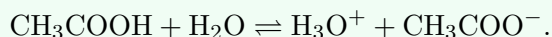
- Metallic conduction is due to mobile electrons; heating increases lattice vibrations and the scattering of electrons.
- Electrolytic conduction depends on the number of ions per unit volume and their mobility. Conductivity and molar conductivity are different quantities.

Step 1: Compare the silver wires For silver wires of the same dimensions, the wire at 30°C conducts better. At 60°C, stronger vibrations of the metal lattice scatter the conducting electrons more frequently. This raises resistance and lowers conductance; metallic conduction therefore decreases as temperature rises.

Step 2: Compare the ethanoic acid solutions The 1 M CH_3COOH solution allows greater conduction

Quick Tip to Solve: For acid concentration comparisons, count ions per unit volume; do not substitute the dilution trend of molar conductivity.

than the 0.1 M solution. Ethanoic acid is a weak electrolyte:



Dilution increases its degree of ionisation, but decreases the total concentration of electrolyte. For a weak acid, $[\text{H}_3\text{O}^+] \approx \sqrt{K_a c}$, so the more concentrated solution contains more charge-carrying ions per unit volume. The increased molar conductivity on dilution must not be confused with increased conductivity.

Step 3: Compare the KCl solutions The KCl solution at 50°C conducts better than that at 20°C, for otherwise identical solutions. Heating reduces the viscosity of the solvent and increases ionic mobility. The ions can carry charge through the solution more readily, so electrolytic conduction increases with temperature.

Step 4: Conclusion The better conductors are (i) silver at 30°C, (ii) 1 M ethanoic acid, and (iii) KCl at 50°C.

Quick Tip to Solve: For acid concentration comparisons, count ions per unit volume; do not substitute the dilution trend of molar conductivity.

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

[2 marks]

Solution:

Concept:

- A galvanic electrochemical cell obtains electrical energy from a spontaneous oxidation-reduction reaction.
- An electrolytic cell uses electrical energy supplied by an external source to drive a non-spontaneous reaction.

Step 1: Compare energy conversion and spontaneity In an electrochemical (galvanic) cell, a spontaneous chemical reaction converts chemical energy into electrical energy. It acts as a source of current for an external circuit. In an electrolytic cell, an external electrical source supplies energy to force a chemical reaction that would not proceed spontaneously in that direction. Thus electrical energy is converted into chemical energy.

Step 2: Compare electrode polarities In a galvanic cell, the anode is negative and the cathode is positive. In an electrolytic cell, the external source makes the anode positive and the cathode negative. These polarity differences do not change the definitions of the electrodes: oxidation occurs at the anode and reduction occurs at the cathode in both types of cell.

Step 3: Conclusion Two differences are: galvanic cells produce electricity through spontaneous reactions whereas electrolytic cells consume electricity to drive non-spontaneous reactions; their anode and cathode polarities are opposite.

Quick Tip to Solve: Remember anode = oxidation in both cells; it is the electrode sign that changes.

37(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]

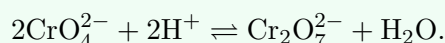
Solution:

Concept:

- Colour in many transition-metal compounds arises from electronic transitions between split d levels when the d subshell is partially occupied.
- Chromate and dichromate are connected by an acid-dependent equilibrium.
- A transition element has an incomplete d subshell in its atom or in at least one of its ordinary ions.

Step 1: Explain the copper colours Copper has configuration $[\text{Ar}] 3d^{10}4s^1$. The Cu^+ ion has configuration $[\text{Ar}] 3d^{10}$, with a completely filled d subshell. It cannot undergo the usual d-d transitions, so its compounds are white or colourless in the context of this question. The Cu^{2+} ion has configuration $[\text{Ar}] 3d^9$. Its partially filled d subshell permits transitions between split d levels by absorption of visible light, producing colour.

Step 2: Explain the acidic chromate solution Yellow chromate ions are converted into orange dichromate ions on acidification:



Increasing H^+ concentration shifts the equilibrium to the right, according to Le Chatelier's principle. Hence the solution changes from yellow to orange.

Step 3: Classify Zn, Cd and Hg Zn, Cd and Hg occupy positions in the d block, but their atoms have filled d subshells: $3d^{10}4s^2$, $4d^{10}5s^2$ and $5d^{10}6s^2$, respectively. Their usual +2 ions also retain the corresponding d^{10} configurations. They therefore lack an incomplete d subshell in their atoms or ordinary ions and do not meet the definition of transition elements.

Step 4: Conclusion Filled d^{10} explains white Cu(I) compounds and the exclusion of Zn, Cd and Hg from transition elements; acid converts yellow chromate into orange dichromate.

Quick Tip to Solve: Check the d-electron count of the ion, and write the balanced chromate equilibrium before predicting its colour.

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

[2 marks]

Solution:

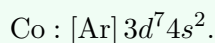
Concept:

- The spin-only magnetic moment is $\mu = \sqrt{n(n+2)} \text{ BM}$, where n is the number of unpaired electrons and BM denotes the Bohr magneton.
- When a transition-metal atom forms a cation, the outer ns electrons are removed before the (n-1)d

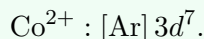
Quick Tip to Solve: Remove the 4s electrons first, then count three unpaired electrons in the free-ion d7 arrangement.

electrons.

Step 1: Write the electronic configurations For cobalt, $Z = 27$, the neutral atom has electronic configuration



Formation of Co^{2+} removes the two outer $4s$ electrons, giving



The seven d electrons occupy the five d orbitals according to Hund's rule: five first occupy separate orbitals, and the next two pair in two of those orbitals. Hence three d electrons remain unpaired.

Step 2: Substitute the unpaired-electron count With $n = 3$, the spin-only expression gives

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

This is the requested spin-only value, obtained from the unpaired-electron count without adding an orbital contribution.

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

Quick Tip to Solve: Remove the $4s$ electrons first, then count three unpaired electrons in the free-ion d^7 arrangement.

OR

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

[3 marks]

Solution:

Concept:

- Lanthanoids involve progressive filling of the $4f$ subshell, whereas actinoids involve progressive filling of the $5f$ subshell.
- Oxidation states depend on the availability of valence electrons for bonding. Radioactivity depends on nuclear stability, not on the electronic configuration.

Step 1: Compare the subshell being filled In the lanthanoid series, the differentiating electron enters the $4f$ subshell. In the actinoid series, it enters the $5f$ subshell. Thus the two series belong to different inner-transition series, even though both involve filling an f subshell and have many similar chemical properties.

Step 2: Compare oxidation states Lanthanoids predominantly show the $+3$ oxidation state; only a few also show $+2$ or $+4$, associated with particularly stable configurations. Actinoids show a much wider range of oxidation states, especially in the earlier members. This is because their $5f$, $6d$ and $7s$

Quick Tip to Solve: Use three separate comparisons: subshell filled, oxidation states and radioactivity; remember promethium as the lanthanoid exception.

levels have comparable energies, so different numbers of electrons can participate in bonding.

Step 3: Compare radioactivity Most lanthanoids are non-radioactive in their naturally occurring forms; promethium is the important exception, having no stable isotope. All actinoids are radioactive: none has a stable isotope. This difference concerns the stability of their nuclei and is independent of which oxidation state a particular compound has.

Step 4: Conclusion Three differences are: lanthanoids fill $4f$, whereas actinoids fill $5f$; lanthanoids mainly show $+3$, whereas actinoids show a wider range of oxidation states; and most lanthanoids are non-radioactive, whereas all actinoids are radioactive.

Quick Tip to Solve: Use three separate comparisons: subshell filled, oxidation states and radioactivity; remember promethium as the lanthanoid exception.

37(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:

- A species is diamagnetic when all its electrons are paired. An ion with unpaired electrons is paramagnetic.
- Stronger metallic bonding requires more energy to overcome, giving higher melting and boiling points. Participation of unpaired d electrons strengthens bonding in transition metals.

Step 1: Select the diamagnetic ion Scandium has configuration $[\text{Ar}] 3d^1 4s^2$. Loss of its two $4s$ electrons and one $3d$ electron gives



All electrons in the argon core are paired, so Sc^{3+} is diamagnetic. In contrast, Cr^{3+} has configuration $[\text{Ar}] 3d^3$, with three unpaired electrons, and is paramagnetic.

Step 2: Select the metal with higher melting and boiling points Chromium has configuration $[\text{Ar}] 3d^5 4s^1$, whereas copper has $[\text{Ar}] 3d^{10} 4s^1$. Chromium has more unpaired valence electrons available to participate in metallic bonding, producing stronger interatomic bonding and a greater enthalpy of atomisation than copper. More energy is therefore needed to separate chromium atoms on melting and vaporisation, so chromium has the higher melting and boiling points.

Step 3: Conclusion (i) $\boxed{\text{Sc}^{3+}}$ exhibits diamagnetic behaviour because it has no unpaired electrons. (ii) $\boxed{\text{Cr}}$ has higher melting and boiling points because of its stronger metallic bonding.

Quick Tip to Solve: Remove the $4s$ electrons before $3d$ electrons when forming ions; compare unpaired valence electrons when explaining metallic bonding.