

CBSE Class 12 Chemistry Compartment (Set 1 - 56/C/1) Question Paper with Solutions

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| Time Allowed :3 Hours | Maximum Marks :70 | Total Questions :35 |
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General Instructions

Read the following instructions very carefully and strictly follow them:

1. This question paper contains 35 questions. All questions are compulsory.
2. This question paper is divided into five Sections — A, B, C, D and E.
3. In Section A — Questions no. 1 to 18 are Multiple Choice (MCQ) type questions, carrying 1 mark each.
4. In Section B — Questions no. 19 to 25 are Very Short Answer (VSA) type questions, carrying 2 marks each.
5. In Section C — Questions no. 26 to 30 are Short Answer (SA) type questions, carrying 3 marks each.
6. There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 2 questions in Section C, 2 questions in Section D and 2 questions in Section E.

Section - A

Questions no. 1 to 18 are Multiple Choice (MCQ) type Questions, carrying 1 mark each. $18 \times 1 = 18$

1. Choose the compound which is more acidic than phenol:

- (A) *o*-nitrophenol
- (B) ethanol
- (C) *o*-methylphenol
- (D) *o*-methoxyphenol

Correct Answer: (A) *o*-nitrophenol

Solution:

Step 1: Phenol is weakly acidic because the phenoxide ion formed after deprotonation is stabilized by resonance.

Step 2: An electron-withdrawing group increases acidity by stabilizing the negative charge on the oxygen atom.

The nitro group ($-NO_2$) is a strong electron-withdrawing group due to its $-M$ (mesomeric) and $-I$ (inductive) effects.

Step 3: In *o*-nitrophenol, the nitro group is ortho to the hydroxyl group, so it withdraws electron density both through the ring and by induction. This additional stabilization makes the conjugate base (phenoxide ion) more stable, thereby increasing acidity compared to phenol.

Step 4: Ethanol is less acidic than phenol because it lacks resonance stabilization of the alkoxide ion.

Methyl and methoxy groups are electron-donating due to their $+I$ and $+M$ effects, which increase electron density and thus reduce acidity relative to phenol.

Quick Tip

Remember: Electron-withdrawing groups like $-NO_2$ increase acidity, while electron-donating groups like $-CH_3$ or $-OCH_3$ decrease it.

2. Which of the following reactions is a halogenated exchange reaction:

- (A) Alkene + $HX \rightarrow$ Alkane with halogen
(B) $R-X + NaI \xrightarrow{\text{Dry acetone}} R-I + NaX$
(C) $R-OH + HCl \xrightarrow{ZnCl_2} R-Cl + H_2O$
(D) Bromination of toluene with Br_2 and Fe in dark

Correct Answer: (B) $R-X + NaI \rightarrow R-I + NaX$

Solution:

Step 1: A halogen exchange reaction (also known as a halogen exchange or halogen replacement reaction) is a reaction where one halogen atom is replaced by another halogen atom.

Step 2: In option (B), an alkyl halide $R-X$ reacts with sodium iodide (NaI) in dry acetone. This results in the replacement of halogen X with iodine, forming $R-I$ and sodium halide (NaX).

This is a classic halogen exchange reaction, commonly known as the Finkelstein reaction.

Step 3:

- Option (A) is an addition reaction (hydrohalogenation of alkene).
- Option (C) is a conversion of an alcohol to an alkyl halide, not an exchange of halogens.
- Option (D) is an electrophilic aromatic substitution reaction, not an exchange of halogens.

Quick Tip

A Finkelstein reaction is a common lab method to prepare alkyl iodides by exchanging halogens using dry acetone as a solvent.

3. The most common oxidation state for all lanthanoids is:

- (A) +5
- (B) +2
- (C) +3
- (D) +4

Correct Answer: (C) +3

Solution:

Step 1: Lanthanoids belong to the f-block elements, specifically the 4f series. They are characterized by the filling of the 4f orbitals.

Step 2: The most stable and common oxidation state for almost all lanthanoids is +3. This is due to the stable removal of two 6s electrons and one 5d or 4f electron.

Step 3: Some lanthanoids can also show +2 and +4 oxidation states, but these are less common and occur only in certain cases (e.g., Eu^{2+} , Ce^{4+}). The +5 oxidation state is very rare and not typical for lanthanoids.

Quick Tip

Lanthanoids mostly form trivalent ions (+3), which is a key feature of their chemistry.

4. A reaction follows second order kinetics. How is the rate of reaction affected if the concentration of the reactant is reduced to half? Choose the correct value from the following:

- (A) four times
- (B) eight times
- (C) $\frac{1}{4}$ of the original value
- (D) three times

Correct Answer: (C) $\frac{1}{4}$ of the original value

Solution:

Step 1: For a second-order reaction, the rate law is:

$$\text{Rate} = k[A]^2$$

Step 2: If the concentration of the reactant $[A]$ is reduced to half:

$$\text{New Rate} = k \left(\frac{[A]}{2} \right)^2 = k[A]^2 \times \frac{1}{4}$$

Step 3: So, the new rate is one-fourth of the original rate.

Quick Tip

For second-order reactions, the rate depends on the square of the concentration. Reducing the concentration by half reduces the rate to $\frac{1}{4}$ of its original value.

5. Solutions of two electrolytes X and Y are diluted. Molar conductivity of X increases 25 times whereas that of Y increases 1.5 times. Which one is a stronger electrolyte?

- (A) X
- (B) Y
- (C) Both X and Y
- (D) None of the above

Correct Answer: (B) Y

Solution:

Step 1: When a solution is diluted, the molar conductivity (Λ_m) of an electrolyte increases because the degree of ionization increases.

Step 2: For a weak electrolyte, dilution greatly increases ionization, so the increase in molar conductivity is significant.

For a strong electrolyte, it is already almost completely ionized, so dilution only slightly increases molar conductivity.

Step 3: Since the molar conductivity of X increases 25 times, it must be a weak electrolyte. The molar conductivity of Y increases only 1.5 times, so Y must be a strong electrolyte.

Quick Tip

Strong electrolytes are almost fully ionized even at higher concentrations, so their molar conductivity changes little on dilution.

6. Unit of rate constant for the zero order reaction is:

- (A) s^{-1}
- (B) $mol^{-1}L s^{-1}$
- (C) $mol^{-2}L^2s^{-1}$
- (D) $mol L^{-1}s^{-1}$

Correct Answer: (4) $\text{mol L}^{-1}\text{s}^{-1}$

Solution:

Step 1: For a reaction of order n , the unit of the rate constant k is:

$$\text{Unit of } k = [\text{concentration}]^{1-n}[\text{time}]^{-1}$$

Step 2: For a zero order reaction ($n = 0$):

$$\text{Unit of } k = [\text{concentration}]^1[\text{time}]^{-1}$$

Step 3: In SI units, concentration is expressed as mol L^{-1} .

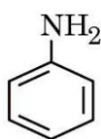
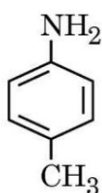
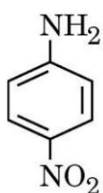
So,

$$\text{Unit of } k = \text{mol L}^{-1}\text{s}^{-1}$$

Quick Tip

Remember: For a zero order reaction, the rate constant has the same units as the rate of reaction.

7. Three compounds are given below:



The correct decreasing order of their basic strength is:

- (A) II > III > I
- (B) III > II > I
- (C) III > I > II
- (D) I > III > II

Correct Answer: (1) II > III > I

Solution:

Step 1: Basic strength of aniline depends on the availability of the lone pair on the nitrogen atom.

Step 2: Electron-donating groups (+I or +M) increase basic strength by increasing electron density on nitrogen.

Electron-withdrawing groups (−I or −M) decrease basic strength by pulling electron density

away.

Step 3: In compound I, the $-NO_2$ group is a strong electron-withdrawing group, so it decreases the basic strength significantly.

In compound II, the CH_3 group is an electron-donating group, increasing the basic strength relative to unsubstituted aniline (III).

Compound III is aniline with no substituents.

Step 4: Therefore, the correct decreasing order is:

II (methyl aniline) \succ III (aniline) \succ I (nitroaniline)

Quick Tip

Electron-donating groups increase basicity in aniline; electron-withdrawing groups decrease it.

8. Which type of isomerism is shown by the complexes $[Co(NH_3)_5Br]SO_4$ and $[Co(NH_3)_5SO_4]Br$?

- (A) Linkage
- (B) Ionisation
- (C) Optical
- (D) Solvate

Correct Answer: (2) Ionisation

Solution:

Step 1: Ionisation isomerism occurs when two complexes differ in the counter ions present inside and outside the coordination sphere.

Step 2: In $[Co(NH_3)_5Br]SO_4$, the bromide ion is coordinated to cobalt, and sulfate is the counter ion.

In $[Co(NH_3)_5SO_4]Br$, the sulfate ion is coordinated to cobalt, and bromide is the counter ion.

Step 3: These two complexes produce different ions in solution:

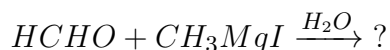
- The first gives Br^- inside the complex and SO_4^{2-} as free ion.
- The second gives SO_4^{2-} inside the complex and Br^- as free ion.

Step 4: Therefore, they are ionisation isomers.

Quick Tip

Ionisation isomers yield different ions in solution even though they have the same composition.

9. What would be the major product of the given reaction?



- (A) Ethanal
- (B) Propanol
- (C) Ethanol
- (D) Propanal

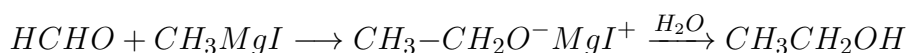
Correct Answer: (3) Ethanol

Solution:

Step 1: The given reaction involves formaldehyde ($HCHO$) reacting with methyl magnesium iodide (CH_3MgI), a Grignard reagent.

Step 2: Grignard reagents add to the carbonyl carbon of aldehydes and ketones to form alcohols after hydrolysis. Formaldehyde specifically gives a primary alcohol.

Step 3: The methyl group (CH_3) from the Grignard reagent adds to the carbon of formaldehyde:



Step 4: The product is ethanol (CH_3CH_2OH), which is a primary alcohol.

Quick Tip

Formaldehyde always gives primary alcohols on reaction with Grignard reagents.

10. Pentan-2-one and Pentan-3-one can be distinguished by:

- (A) Fehling's test
- (B) Sodium bicarbonate test
- (C) Tollens' test
- (D) Iodoform test

Correct Answer: (4) Iodoform test

Solution:

Step 1: The Iodoform test is used to detect the presence of a methyl ketone group (CH_3CO-) or a compound with the structure $CH_3CH(OH)-$.

Step 2: Pentan-2-one ($CH_3COCH_2CH_2CH_3$) has a methyl ketone group, so it gives a positive Iodoform test.

Step 3: Pentan-3-one ($CH_3CH_2COCH_2CH_3$) does not have a CH_3CO- group; it has a ketone flanked by ethyl groups, so it does not give the Iodoform test.

Step 4: Therefore, Pentan-2-one and Pentan-3-one can be distinguished by the Iodoform test.

Quick Tip

Remember: A positive Iodoform test indicates the presence of a methyl ketone or a secondary alcohol with a $CH_3CH(OH)-$ group.

11. Hoffmann Bromamide Degradation reaction is given by:

- (A) Nitrobenzene
- (B) Benzamide
- (C) Methyl cyanide
- (D) Propanamide

Correct Answer: (4) Propanamide

Solution:

Step 1: Hoffmann Bromamide Degradation reaction applies to **aliphatic or aromatic primary amides** to produce a primary amine with **one carbon atom less** than the parent amide.

Step 2: Among the given options, Propanamide ($CH_3-CH_2-CONH_2$) is an **aliphatic primary amide** which undergoes Hoffmann Bromamide Degradation to give ethylamine ($CH_3CH_2NH_2$).

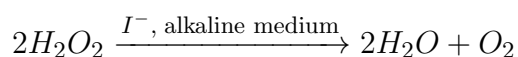
Step 3: While Benzamide (option B) also gives Hoffmann degradation, the question's image shows an aliphatic amide in option D (Propanamide) which exactly fits the typical example for the reaction.

Step 4: Therefore, Propanamide is the correct answer.

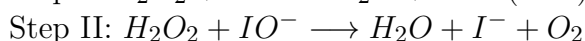
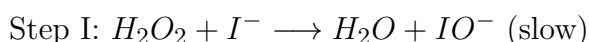
Quick Tip

Hoffmann Bromamide Degradation is commonly used to reduce an amide by one carbon atom and get a primary amine.

12. Given below is the decomposition of hydrogen peroxide in alkaline medium, which is catalysed by iodide ions:



The above reaction takes place in two steps:



Molecularity of Step I and Step II is:

- (A) Step I – 2, Step II – 2
- (B) Step I – 1, Step II – 2
- (C) Step I – 2, Step II – 1
- (D) Step I – 3, Step II – 1

Correct Answer: (1) Step I – 2, Step II – 2

Solution:

Step 1: Molecularity is the total number of reactant species involved in an elementary step.

Step 2: For Step I: $H_2O_2 + I^-$

$$\text{Number of species} = 2 \Rightarrow \text{Molecularity} = 2$$

Step 3: For Step II: $H_2O_2 + IO^-$

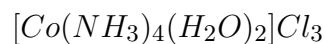
$$\text{Number of species} = 2 \Rightarrow \text{Molecularity} = 2$$

Step 4: So, both steps have a molecularity of 2.

Quick Tip

Molecularity counts the actual number of reacting species in a single step — it is always a whole number.

13. Oxidation state of central metal atom in the given complex is:



- (A) +2
- (B) +3
- (C) +1
- (D) +4

Correct Answer: (2) +3

Solution:

Step 1: Let the oxidation state of Co be x .

$$4(NH_3) + 2(H_2O) + Co + 3Cl^- = 0$$

Step 2: NH_3 and H_2O are neutral ligands, so they contribute zero charge. Chloride ion has a charge of -1 each. Total charge of three Cl^- is -3 .

$$x + 0 - 3 = 0 \implies x = +3$$

Quick Tip

For coordination complexes, neutral ligands don't affect the oxidation state calculation. Only the counter ions matter.

14. A galvanic cell can behave as an electrolytic cell when:

- (A) $E_{cell} = E_{ext}$
- (B) $E_{cell} > E_{ext}$
- (C) $E_{cell} = 0$
- (D) $E_{ext} > E_{cell}$

Correct Answer: (4) $E_{ext} > E_{cell}$

Solution:

Step 1: A galvanic cell generates electricity due to its cell potential (E_{cell}).

Step 2: To force the reaction to proceed in the opposite direction (as an electrolytic cell), an external voltage must be applied that is greater than the cell's potential.

$$E_{ext} > E_{cell}$$

Step 3: When this condition is met, the external source drives the non-spontaneous reaction by reversing the electron flow.

Quick Tip

To convert a galvanic cell into an electrolytic one, apply an external potential greater than its own cell potential.

15. Assertion (A): Phenol gives 2,4,6-trinitrophenol on treatment with concentrated HNO_3 and concentrated H_2SO_4 .

Reason (R): $-OH$ group in phenol is *m*-directing.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is *not* the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (3) Assertion (A) is true, but Reason (R) is false.

Solution:

Step 1: The Assertion is correct. Phenol reacts with concentrated nitric acid in the presence of sulfuric acid to form 2,4,6-trinitrophenol (picric acid).

Step 2: The Reason is incorrect. The $-OH$ group in phenol activates the benzene ring and is an *o,p*-directing group due to its +M effect, which increases electron density at the ortho and para positions.

Step 3: Therefore, while the Assertion is true, the Reason is false.

Quick Tip

Electron-donating groups like $-OH$ are always *o,p*-directing in electrophilic aromatic substitution.

16. Assertion (A): D (+)-Glucose is dextrorotatory.

Reason (R): Symbol 'D' represents its dextrorotatory nature.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is *not* the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (3) Assertion (A) is true, but Reason (R) is false.

Solution:

Step 1: D (+)-Glucose is indeed dextrorotatory — it rotates plane-polarized light to the right. So, Assertion (A) is true.

Step 2: However, the 'D' in D-glucose does not represent its optical activity. 'D' refers to its configuration relative to D-glyceraldehyde (it tells about the position of the –OH group on the chiral carbon farthest from the aldehyde group).

Step 3: The sign (+) or (–) indicates optical rotation, while 'D' and 'L' indicate configuration only. So the Reason (R) is false.

Quick Tip

Remember: D/L is about configuration, +/- is about optical rotation direction.

17. Assertion (A): Zn, Cd and Hg are not regarded as transition elements.

Reason (R): Zn, Cd and Hg do not have partially filled d-orbitals in their ground state or in any one of their common oxidation states.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is *not* the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (1) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Solution:

Step 1: Zn, Cd, and Hg belong to the d-block but are not considered true transition elements because transition elements must have at least one ion with an incomplete d-subshell.

Step 2: In their ground state and common oxidation states (+2), Zn, Cd, and Hg have completely filled d-orbitals (d^{10} configuration).

Step 3: Therefore, both the Assertion and the Reason are true, and the Reason correctly explains the Assertion.

Quick Tip

Transition elements must have at least one partially filled d-orbital in their ground state or in any stable oxidation state.

18. Assertion (A): Benzene diazonium salt is stable and can be easily stored.

Reason (R): Benzene diazonium chloride decomposes easily.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is *not* the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (4) Assertion (A) is false, but Reason (R) is true.

Solution:

Step 1: Benzene diazonium chloride is not stable for long periods — it decomposes easily, especially at room temperature, releasing nitrogen gas. It must be used immediately or kept cold.

Step 2: Therefore, Assertion (A) is false.

Step 3: The Reason (R) is true because benzene diazonium chloride does indeed decompose readily, which is why it cannot be easily stored.

Quick Tip

Diazonium salts are generally unstable and are kept cold ($0-5^{\circ}\text{C}$) to prevent decomposition.

Section - B

19. The rate of a reaction quadruples when the temperature changes from 293 K to 313 K. Calculate the energy of activation of the reaction, assuming that it does not change with temperature.

$$(\log 2 = 0.30, \log 4 = 0.60) \quad [R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}]$$

Solution:

Step 1: Use the Arrhenius equation in the logarithmic form:

$$\log \left(\frac{k_2}{k_1} \right) = \frac{E_a}{2.303 R} \left(\frac{T_2 - T_1}{T_1 T_2} \right)$$

Step 2: Given: $\frac{k_2}{k_1} = 4$, $T_1 = 293 \text{ K}$, $T_2 = 313 \text{ K}$

$$\log 4 = 0.60 = \frac{E_a}{2.303 \times 8.314} \left(\frac{20}{293 \times 313} \right)$$

Step 3: Calculate denominator:

$$293 \times 313 = 91709$$

$$\Rightarrow 0.60 = \frac{E_a}{19.147} \times \frac{20}{91709}$$

Step 4: Rearranging,

$$0.60 = \frac{E_a \times 20}{19.147 \times 91709}$$

$$E_a = \frac{0.60 \times 19.147 \times 91709}{20}$$

$$E_a = \frac{0.60 \times 19.147 \times 91709}{20}$$

$$E_a = \frac{0.60 \times 19.147 \times 91709}{20} = \frac{0.60 \times 1757134.423}{20}$$

$$= \frac{1054280.65}{20} = 52714.03 \text{ J/mol}$$

Step 5: So, the activation energy is:

$$E_a \approx 52.7 \text{ kJ/mol}$$

Quick Tip

Always use the Arrhenius relation for comparing rates at two temperatures to find activation energy.

(20 a) (i) Name any two bases which are common to both DNA and RNA.

(ii) Which vitamin deficiency causes:

- (1) Bone deformities in children?
- (2) Pernicious anaemia?

Answer: Adenine and Guanine.

Explanation: Adenine (A) and Guanine (G) are purine bases found in both DNA and RNA. Thymine (T) is found only in DNA, Uracil (U) only in RNA, while Cytosine (C) is also common to both.

- (1) Deficiency of Vitamin D causes bone deformities (rickets) in children.
- (2) Deficiency of Vitamin B₁₂ causes pernicious anaemia.

Quick Tip

Vitamin D is essential for calcium absorption and bone development. Vitamin B₁₂ is vital for red blood cell formation and nerve function.

20. (b)i) Why do amino acids show amphoteric behaviour?

Correct Answer: They contain both acidic ($-\text{COOH}$) and basic ($-\text{NH}_2$) functional groups.

Solution:

Step 1: Amino acids have both a carboxylic acid group ($-\text{COOH}$) and an amino group ($-\text{NH}_2$).

Step 2: The $-\text{COOH}$ group can donate a proton (H^+) and act as an acid, while the $-\text{NH}_2$ group can accept a proton and act as a base.

Step 3: Due to the presence of both acidic and basic groups, amino acids can react with both acids and bases, hence they show amphoteric behaviour.

Quick Tip

Amino acids exist as zwitterions in aqueous solution, containing both positive and negative charges.

20. (b)(ii) What happens when D-Glucose is treated with hydroxylamine?

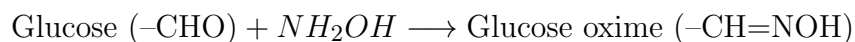
Correct Answer: D-Glucose forms an oxime.

Solution:

Step 1: D-Glucose contains an aldehyde group ($-\text{CHO}$) at its terminal carbon.

Step 2: Hydroxylamine (NH_2OH) reacts with aldehydes to form oximes.

Step 3: Therefore, when D-Glucose is treated with hydroxylamine, it forms a glucose oxime:



Quick Tip

Reaction with hydroxylamine confirms the presence of an aldehyde or ketone group in a molecule.

21(a). (i) Write the structure of 1-chloro-4-ethylcyclohexane.

Correct Answer: A cyclohexane ring with a chlorine atom at carbon-1 and an ethyl group at carbon-4.

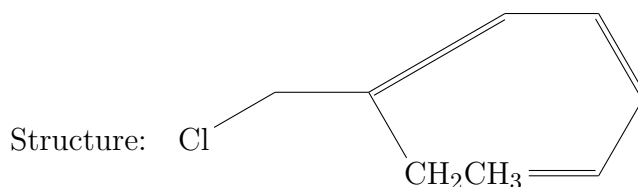
Solution:

Step 1: Draw a cyclohexane ring with six carbon atoms.

Step 2: Number the ring such that carbon-1 has a chlorine (Cl) atom.

Step 3: Place an ethyl group ($-\text{CH}_2\text{CH}_3$) on carbon-4 of the ring.

Step 4: This gives the correct structure of 1-chloro-4-ethylcyclohexane.



Quick Tip

Always begin substituent numbering to give the lowest possible number to the substituent with alphabetical priority.

21(a). (ii) Why is sulphuric acid not used during the reactions of alcohols with KI?

Correct Answer: Because sulphuric acid oxidizes iodide (I^-) to iodine (I_2).

Solution:

Step 1: In the reaction of alcohols with KI, HI is required as a nucleophile to replace the hydroxyl group.

Step 2: When sulphuric acid (H_2SO_4) is used, it oxidizes iodide ions (I^-) to iodine (I_2), reducing the amount of HI available for the reaction.

Step 3: Hence, sulphuric acid is avoided, and phosphoric acid (H_3PO_4) is preferred instead, as it does not oxidize iodide.

Quick Tip

Avoid oxidizing acids like H_2SO_4 when using iodide ions — they reduce reaction efficiency by forming iodine.

21(b). (i) Arrange the following in increasing order of their boiling points:

1-chloropropane, 2-chloropropane, 1-chlorobutane

(A) 2-chloropropane < 1-chloropropane < 1-chlorobutane

Correct Answer: (A) 2-chloropropane < 1-chloropropane < 1-chlorobutane

Solution:

Step 1: Boiling point depends on molecular weight, surface area, and branching.

Step 2: Among the three compounds:

- 2-chloropropane is more branched, hence has lower surface area and lower boiling point.
- 1-chloropropane is linear and less branched, so it has a higher boiling point than 2-chloropropane.
- 1-chlorobutane has a larger molecular size and greater surface area than both propyl compounds, hence the highest boiling point.

Order: 2-chloropropane < 1-chloropropane < 1-chlorobutane

Quick Tip

Boiling point increases with molecular mass and decreases with branching.

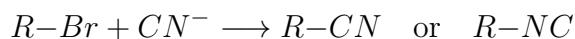
21(b). (ii) What is an ambident nucleophile? Give one example.

Correct Answer: An ambident nucleophile is one that can attack through two different atoms. Example: Cyanide ion (CN^-).

Solution:

Step 1: Ambident nucleophiles have two nucleophilic sites, and can attack through either site.

Step 2: For example, the cyanide ion (CN^-) can attack through carbon to form alkyl cyanides, or through nitrogen to form isocyanides.



Step 3: The actual product depends on the conditions of the reaction and the nature of the substrate.

Quick Tip

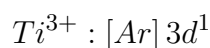
Other examples of ambident nucleophiles include NO_2^- and enolate ions.

22. (a) Why is $[Ti(H_2O)_6]^{3+}$ coloured?

Correct Answer: Due to $d-d$ transitions within the partially filled d-orbitals of Ti^{3+} .

Solution:

Step 1: In the complex $[Ti(H_2O)_6]^{3+}$, the titanium ion is in the +3 oxidation state with electronic configuration:



Step 2: The presence of one unpaired electron in the 3d orbital allows for electronic transitions between t_{2g} and e_g levels when light is absorbed.

Step 3: This $d-d$ transition is responsible for the colour observed in the complex.

Quick Tip

Transition metal complexes are coloured due to electronic transitions within split d-orbitals in the presence of ligands.

22. (b) Write IUPAC name of the given complex: $K_3[Cr(C_2O_4)_3]$

Correct Answer: Potassium tris(oxalato)chromate(III)

Solution:

Step 1: The complex anion consists of chromium metal surrounded by three bidentate oxalate ligands ($C_2O_4^{2-}$).

Step 2: The ligand “oxalate” is named as “oxalato”. Since there are three such ligands, we use the prefix “tris”.

Step 3: The oxidation state of chromium is +3.

Step 4: The metal is in a complex anion, so its name ends in “-ate”.

Final IUPAC name: Potassium tris(oxalato)chromate(III)

Quick Tip

Use prefixes like “bis”, “tris” for ligands already containing numerical prefixes, and add “-ate” for metals in anionic complexes.

23. (a) Why are iron pipes usually coated with zinc?

Correct Answer: To protect iron from rusting by sacrificial protection.

Solution:

Step 1: Zinc is more reactive than iron and undergoes oxidation preferentially.

Step 2: When coated on iron, zinc corrodes instead of iron, thus protecting the iron pipe from rusting — this is known as sacrificial protection or galvanization.

Quick Tip

Zinc acts as a sacrificial anode and prevents corrosion of iron.

23. (b) Why does mercury cell give a constant voltage throughout its life?

Correct Answer: Because the concentrations of reactants and products remain constant.

Solution:

Step 1: In a mercury cell, the overall cell reaction involves solid reactants and products, which maintain constant concentrations during use.

Step 2: Hence, the cell potential (EMF) remains nearly constant throughout the life of the cell.

Quick Tip

Mercury cells are used in watches and hearing aids for their steady voltage output.

24. (a) Write the mathematical relation between rate constant and half-life period of a zero order reaction.

Correct Answer: $t_{1/2} = \frac{[R_0]}{2k}$

Solution:

Step 1: For a zero order reaction, rate = k and the integrated rate law is:

$$[R] = [R_0] - kt$$

Step 2: At half-life, $[R] = \frac{[R_0]}{2}$

$$\Rightarrow \frac{[R_0]}{2} = [R_0] - kt_{1/2} \Rightarrow t_{1/2} = \frac{[R_0]}{2k}$$

Quick Tip

For zero-order reactions, half-life is directly proportional to the initial concentration.

24. (b) Define Pseudo first order reaction with an example.

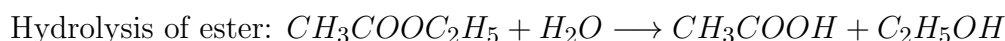
Correct Answer: A reaction involving two reactants but appears first order because one is in large excess.

Solution:

Step 1: In pseudo first order reactions, one reactant is present in large excess so its concentration remains nearly constant during the reaction.

Step 2: As a result, the rate depends effectively only on one reactant, giving an apparent first-order rate law.

Example:



Water is in excess, so the reaction appears to be first-order with respect to ester.

Quick Tip

Pseudo-first-order reactions simplify rate law analysis by holding one reactant constant.

25. (a) Why is pK_a of $ClCH_2COOH$ lower than the pK_a of CH_3COOH ?

Correct Answer: Due to the electron-withdrawing effect of Cl atom.

Solution:

Step 1: Chlorine is an electron-withdrawing group (–I effect).

Step 2: In $ClCH_2COOH$, the –Cl group stabilizes the conjugate base by dispersing the negative charge.

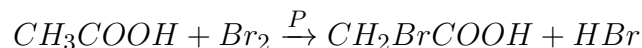
Step 3: Greater stability of the conjugate base increases acidity and hence lowers the pK_a value.

Quick Tip

Lower pK_a means stronger acid — more electron-withdrawing groups lead to stronger acids.

25. (b) Write the chemical equation for Hell-Volhard-Zelinsky reaction.

Correct Answer:

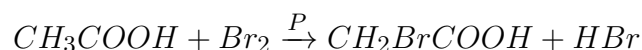


Solution:

Step 1: The Hell-Volhard-Zelinsky (HVZ) reaction is used for alpha-halogenation of carboxylic acids.

Step 2: In the presence of red phosphorus and halogen, the alpha hydrogen of a carboxylic acid is replaced by a halogen.

Step 3: Example:



Quick Tip

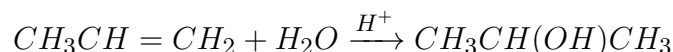
HVZ reaction works only on carboxylic acids having alpha-hydrogens.

26. Write the chemical equation for the following:

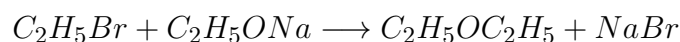
- (a) Hydration of propene in presence of an acid
- (b) Reaction between Ethyl bromide and C_2H_5ONa
- (c) Reaction between Dimethyl ether and Hydrogen iodide

Correct Answer:

(a)



(b)



(c)



Solution:

(a) The hydration of propene in acidic medium follows Markovnikov's rule. The -OH group attaches to the more substituted carbon to form 2-propanol.

(b) The reaction between ethyl bromide and sodium ethoxide is a classic Williamson ether synthesis, producing diethyl ether.

(c) Dimethyl ether reacts with hydrogen iodide (HI), cleaving the ether to form methyl iodide and methanol. This is an example of ether cleavage using hydrogen halides.

Quick Tip

Markovnikov's rule helps predict the major product in electrophilic additions. For ether cleavage, the least hindered group generally forms the alkyl halide.

27. Using valence bond theory, predict:

- (a) Hybridisation of central metal atom of the complex $[Co(NH_3)_6]^{3+}$
 - (b) Its shape and magnetic behaviour
 - (c) Whether it is a high spin or a low spin complex
- Atomic number: $CO = 27$

Correct Answer:

- (a) d^2sp^3 hybridisation
- (b) Octahedral shape; diamagnetic
- (c) Low spin complex

Solution:

Step 1: Determine the oxidation state of cobalt.

In $[Co(NH_3)_6]^{3+}$, NH_3 is a neutral ligand. Therefore, the oxidation state of Co is +3.

Step 2: Find the electronic configuration.

Atomic number of Co = 27

Electronic configuration of Co: $[Ar] 3d^7 4s^2$

Co^{3+} : $[Ar] 3d^6$

Step 3: Pairing of electrons and hybridisation

NH_3 is a strong field ligand (though borderline), so it causes pairing of electrons in the 3d orbitals:

3d orbital: $\uparrow\downarrow\uparrow\downarrow\uparrow\downarrow$ -- (all 6 electrons paired)

The hybridisation involves: - Two 3d orbitals - One 4s orbital - Three 4p orbitals

Hybridisation: d^2sp^3

Step 4: Shape and magnetic behaviour

- d^2sp^3 hybridisation gives an octahedral geometry.
- All electrons are paired, so the complex is diamagnetic.

Step 5: High spin or low spin

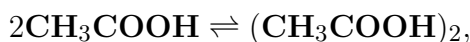
- As pairing occurs due to the strong ligand field of NH_3 , this is a low spin complex.

Quick Tip

Use the valence bond theory to determine geometry from hybridisation: - sp^3 : tetrahedral, - dsp^2 : square planar, - d^2sp^3/sp^3d^2 : octahedral.

For low/high spin, check whether the ligand is strong or weak field.

28. (a) Find the value of van't Hoff factor for acetic acid in benzene as per the given equation:

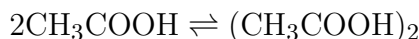


assuming its complete association.

Solution:

Step 1: Use the definition of van't Hoff factor $i = \frac{\text{number of particles after association}}{\text{number of particles before association}}$.

Step 2: The association reaction is:



Step 3: Assume 2 moles of CH_3COOH associate to form 1 mole of dimer. Then: - Initial moles = 2 - Final moles = 1

So,

$$i = \frac{\text{Final moles}}{\text{Initial moles}} = \frac{1}{2}$$

Quick Tip

For association in solutions, the van't Hoff factor $i < 1$. For complete dimerization of 2 units to 1, $i = \frac{1}{2}$.

(b) Osmotic pressure of a solution containing 3.5 g of dissolved protein in 0.05 L of a solution is 0.035 atm at 310 K. Calculate the molar mass of the protein. ($R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$)

Solution:

Step 1: Use the osmotic pressure formula:

$$\Pi = \frac{n}{V}RT = \frac{w}{M \cdot V}RT$$

Where: - $\Pi = 0.035 \text{ atm}$

- $w = 3.5 \text{ g}$

- $V = 0.05 \text{ L}$

- $T = 310 \text{ K}$

- $R = 0.0821$

$$0.035 = \frac{3.5}{M \cdot 0.05} \cdot 0.0821 \cdot 310$$

$$M = \frac{3.5 \cdot 0.0821 \cdot 310}{0.035 \cdot 0.05}$$

$$M = \frac{88.82785}{0.00175} \approx 50758 \Rightarrow M \approx 2930 \text{ g/mol}$$

Quick Tip

Osmotic pressure is especially useful for determining the molar mass of large molecules like proteins, where other colligative property methods are ineffective.

29. Give reasons for the following:

(a) Reduction with iron scrap and HCl is preferred for the preparation of amines from nitro compounds.

(b) Lower aliphatic amines are soluble in water.

(c) Pyridine is used in the acylation reaction of amines.

(d) Although amino group is *o*- and *p*-directing in aromatic electrophilic substitution reactions, aniline on nitration gives a substantial amount of *m*-nitroaniline.

Solution:

(a)

Step 1: Iron and HCl is a mild and selective reducing agent.

Step 2: It avoids strong reducing conditions that might affect other functional groups.

Step 3: Iron is cheap and environmentally friendly, forming less toxic waste.

(b)

Step 1: Lower aliphatic amines have nitrogen atoms with lone pairs.

Step 2: These lone pairs form hydrogen bonds with water molecules.

Step 3: Hydrogen bonding enhances solubility.

(c)

Step 1: During acylation, HCl is released.

Step 2: Pyridine, being a weak base, neutralizes this HCl.

Step 3: This prevents the protonation of the amine, allowing the reaction to proceed efficiently.

(d)

Step 1: In acidic nitration medium, the -NH_2 group gets protonated to form -NH_3^+ .

Step 2: The anilinium ion is deactivating and meta-directing.

Step 3: Hence, nitration gives a significant amount of meta product despite the original directing nature of -NH_2 .

Quick Tip

In reasoning questions, always consider electronic effects (inductive, resonance), medium conditions (acid/base), and steric effects for explanations.

30(a). (i) Why do tertiary alkyl halides undergo S_N1 reaction at a faster rate?

Solution:

Step 1: The S_N1 mechanism proceeds via formation of a carbocation intermediate.

Step 2: Tertiary alkyl halides have a carbon atom bonded to three alkyl groups. These groups stabilize the positive charge on the carbocation through:

- *Hyperconjugation* (delocalization of electrons from C–H bonds of adjacent alkyl groups), and
- *Inductive effect* (electron-donating nature of alkyl groups).

Step 3: This stability lowers the activation energy of the rate-determining step (carbocation formation), hence speeding up the reaction.

Quick Tip

Use the valence bond theory to determine geometry from hybridisation: - sp^3 : tetrahedral, - dsp^2 : square planar, - d^2sp^3/sp^3d^2 : octahedral.

For low/high spin, check whether the ligand is strong or weak field.

(ii) Define Enantiomers.

Solution: Step 1: Enantiomers are a type of stereoisomers that are:

- Non-superimposable mirror images of each other,
- Possess identical physical properties except optical activity, - Have opposite rotations of plane-polarized light.

Step 2: They arise due to chirality—typically involving a carbon atom bonded to four different groups (a chiral center).

Quick Tip

In reasoning questions, always consider electronic effects (inductive, resonance), medium conditions (acid/base), and steric effects for explanations.

(iii) Why is chloroform stored in dark coloured air tight bottles?

Solution: Step 1: Chloroform ($CHCl_3$) can oxidize in the presence of air and light to form phosgene ($COCl_2$), which is highly toxic.

Step 2: To avoid this photochemical reaction, chloroform is stored in:

- Dark coloured bottles to block light, - Air-tight containers to prevent oxygen exposure.

Conclusion: This prevents degradation and ensures safe handling and storage of chloroform.

Quick Tip

Use the valence bond theory to determine geometry from hybridisation: - sp^3 : tetrahedral, - dsp^2 : square planar, - d^2sp^3/sp^3d^2 : octahedral.

For low/high spin, check whether the ligand is strong or weak field.

(b)

(i) Write the major alkene that would be formed by dehydrohalogenation of 2-Bromopentane.

Correct Answer: 2-Pentene

Solution:

Step 1: Dehydrohalogenation is an elimination reaction in which a hydrogen atom and a halogen atom are removed from adjacent carbon atoms, leading to the formation of an alkene.

Step 2: The structure of 2-bromopentane is:



Step 3: In the presence of alcoholic KOH (a strong base), elimination follows Zaitsev's Rule, which favors the formation of the **more substituted alkene.

Step 4: Removal of a β -hydrogen from the third carbon (next to the carbon bearing bromine) leads to the formation of 2-pentene, which is more stable and thus the major product.

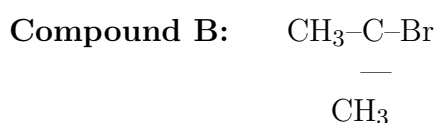
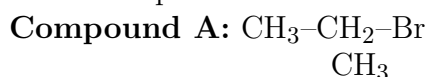
Conclusion: The major alkene obtained from dehydrohalogenation of 2-bromopentane is **2-pentene**.

Quick Tip

In reasoning questions, always consider electronic effects (inductive, resonance), medium conditions (acid/base), and steric effects for explanations.

(ii) Which would undergo S_N2 reaction at a faster rate and why?

Given compounds:



Correct Answer: Compound A ($\text{CH}_3\text{-CH}_2\text{-Br}$) undergoes S_N2 reaction faster.

Solution:

Step 1: The S_N2 mechanism is a one-step reaction where the nucleophile attacks the carbon atom bonded to the leaving group from the backside.

Step 2: The rate of S_N2 reaction is highly sensitive to **steric hindrance** around the carbon bearing the leaving group.

Step 3: - In **Compound A** ($\text{CH}_3\text{-CH}_2\text{-Br}$), the bromine is attached to a **primary carbon**, which is less hindered and easily accessible to the nucleophile.

- In **Compound B** ($\text{CH}_3\text{-C}(\text{CH}_3)_2\text{-Br}$), the bromine is attached to a **tertiary carbon**, which is highly hindered due to three bulky methyl groups, making backside attack very difficult.

Conclusion: Compound A undergoes S_N2 reaction at a much faster rate due to minimal steric hindrance.

Quick Tip

Use the valence bond theory to determine geometry from hybridisation: - sp^3 : tetrahedral, - dsp^2 : square planar, - d^2sp^3/sp^3d^2 : octahedral.

For low/high spin, check whether the ligand is strong or weak field.

(iii) Why is chlorobenzene less reactive towards nucleophilic substitution reaction?

Correct Answer: Due to resonance stabilization and partial double bond character in the C-Cl bond

Solution:

Step 1: In chlorobenzene, the chlorine atom is bonded to an sp^2 -hybridized carbon of the benzene ring.

Step 2: The lone pair of electrons on chlorine can delocalize into the aromatic ring through resonance, creating structures where the C-Cl bond exhibits **partial double bond character**. This strengthens the bond and makes it difficult to break.

Step 3: Additionally, the **benzene ring is electron-rich**, which repels nucleophiles (electron donors), making nucleophilic attack less favorable.

Conclusion: Due to resonance and the resulting partial double bond character, as well as electronic repulsion from the aromatic ring, chlorobenzene is much less reactive towards nucleophilic substitution than alkyl halides.

Quick Tip

In reasoning questions, always consider electronic effects (inductive, resonance), medium conditions (acid/base), and steric effects for explanations.

Section - D

31. Carbohydrates are the major components of all living organisms. Sugars are carbohydrates. The major types of sugars include monosaccharides and disaccharides. The main difference between monosaccharides, disaccharides and polysaccharides is that monosaccharides are monomer of sugars and disaccharides are composed of two monomers, whereas polysaccharides are composed of a large number of monomers. Monosaccharides are single sugar molecules which act as the building blocks of disaccharides and polysaccharides. Disaccharides are also simple sugars. Disaccharides are classified into two groups according to their reducing strength: Reducing and Non-reducing sugars. When a polymer is formed from a monomer, a condensation reaction occurs that forms a glycosidic bond and water molecule is lost. Starch, glycogen and cellulose are examples of polysaccharides. Starch is found in many parts of plant cell and consists of amylose and amylopectin. Glycogen is the major carbohydrate storage product found in humans. It is present in liver, muscles and brain.

Cellulose is the most abundant organic molecule on Earth. It makes up around 50% of all organic carbon.

(a) Name the linkage which connects monosaccharide units in polysaccharides.

Correct Answer: Glycosidic bond

Solution:

Step 1: Polysaccharides are polymers made up of repeating monosaccharide units.

Step 2: These monosaccharides are joined together by a covalent bond known as the **glycosidic bond**.

Step 3: This bond is formed during a **condensation reaction**, where a water molecule is eliminated.

Quick Tip

Remember: A glycosidic bond forms between the anomeric carbon of one sugar and a hydroxyl group of another sugar.

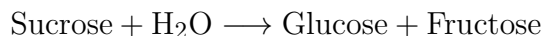
(b) Carbohydrates are classified on the basis of their behaviour on hydrolysis. Write the hydrolysis products of sucrose.

Correct Answer: Glucose and Fructose

Solution:

Step 1: Sucrose is a disaccharide composed of one glucose unit and one fructose unit.

Step 2: Upon hydrolysis (in the presence of dilute acid or the enzyme invertase), sucrose breaks down into:



Step 3: Both glucose and fructose are monosaccharides.

Quick Tip

Hydrolysis of disaccharides always gives the constituent monosaccharides. Use the enzyme-specific method (e.g., invertase for sucrose) in biology contexts.

(c) Write two differences between Amylose and Amylopectin.

Correct Answer:

1. **Structure:** Amylose is a linear polymer, whereas Amylopectin is a branched polymer.
2. **Solubility:** Amylose is slightly soluble in water, while Amylopectin is insoluble due to extensive branching.

Solution:

Amylose: - Consists of long unbranched chains of α -D-glucose units.

- Contains only $\alpha(1\rightarrow4)$ glycosidic bonds.

Amylopectin: - Is a highly branched molecule.

- Contains both $\alpha(1\rightarrow4)$ and $\alpha(1\rightarrow6)$ glycosidic linkages at branch points.

Quick Tip

Amylose: Linear and forms helical structures.

Amylopectin: Branched and more abundant in starch.

OR

(i) What are reducing sugars?

Correct Answer: Sugars that can reduce Tollens' or Fehling's reagent due to the presence of a free aldehyde or ketone group.

Solution:

Step 1: Reducing sugars are carbohydrates that possess a free anomeric carbon capable of acting as a reducing agent.

Step 2: They reduce mild oxidizing agents like: - Tollens' reagent (ammoniacal silver nitrate), and - Fehling's solution (alkaline Cu^{2+}).

Step 3: Examples: Glucose, fructose, maltose, and lactose.

Quick Tip

All monosaccharides are reducing sugars. Disaccharides are reducing only if one of the monosaccharide units has a free anomeric carbon.

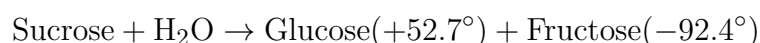
(ii) **Sucrose is dextrorotatory but the mixture obtained after hydrolysis is laevorotatory. Why?**

Correct Answer: Due to the higher specific rotation of laevorotatory fructose compared to dextrorotatory glucose.

Solution:

Step 1: Sucrose rotates plane-polarized light to the right (**dextrorotatory**).

Step 2: On hydrolysis, sucrose produces one molecule each of glucose and fructose:



Step 3: The overall rotation becomes negative because fructose has a greater negative specific rotation.

Conclusion: The resulting mixture becomes **laevorotatory**, a phenomenon known as **inversion of sugar**.

Quick Tip

Fructose dominates the optical rotation due to its higher magnitude of negative rotation. The phenomenon is called *inversion* and the product is called *invert sugar*.

(32) Raoult's law for volatile liquids states that the partial vapour pressure of each component in the solution is directly proportional to its mole fraction, whereas for a non-volatile solute, it states that the vapour pressure of a solution of a non-volatile solute is equal to the vapour pressure of the pure solvent at that temperature multiplied by its mole fraction.

Two liquids A and B are mixed with each other to form a solution, the vapour phase consists of both components of the solution. Once the components in the solution have reached equilibrium, the total vapour pressure of the solution can be determined by combining Raoult's law with Dalton's law of partial pressures.

If a non-volatile solute B is dissolved into a solvent A to form a solution, the vapour pressure of the solution will be lower than that of the pure solvent.

The solutions which obey Raoult's law over the entire range of concentration are ideal solutions, whereas the solutions for which vapour pressure is either higher or lower than that predicted by Raoult's law are called non-ideal solutions.

Non-ideal solutions are identified by determining the strength of the intermolecular forces between the different molecules in that particular solution. They can either show positive or negative deviation from Raoult's law depending on whether the A – B interactions in solution are stronger or weaker than A – A and B – B interactions.

(a) 20 mL of a liquid A was mixed with 20 mL of liquid B. The volume of resulting solution was found to be less than 40 mL. What do you conclude from the above data?

Correct Answer: The solution shows **negative deviation** from ideal behaviour.

Solution: Step 1: When two liquids A and B are mixed, if the resulting volume is **less than the sum of their individual volumes**, it indicates that the intermolecular forces between A and B are **stronger** than those between A–A and B–B.

Step 2: This causes the molecules to come closer, leading to volume contraction.

Conclusion: The solution exhibits **negative deviation from Raoult's Law**.

Quick Tip

Negative deviation implies stronger A–B interactions, causing decrease in volume and vapour pressure.

(b) Which of the following show positive deviation from Raoult's law?

Carbon disulphide and Acetone;

Phenol and Aniline;

Ethanol and Acetone

Correct Answer: Carbon disulphide and Acetone

Solution: Step 1: Positive deviation from Raoult's law occurs when A–B interactions are **weaker** than A–A and B–B interactions.

Step 2: This results in:

- Increased escaping tendency of molecules,
- Increased vapour pressure,
- Volume expansion.

Step 3: In the given options, **Carbon disulphide and Acetone** form a non-ideal solution with weak intermolecular forces, leading to positive deviation.

Quick Tip

Positive deviation = weaker intermolecular attractions, leading to higher vapour pressure and volume expansion.

(c) The vapour pressure of a solution of glucose in water is 750 mm Hg at 100°C. Calculate the mole fraction of solute.
(Vapour pressure of water at 373 K = 760 mm Hg)

Correct Answer: Mole fraction of glucose (solute) = 0.0132

Solution:

Step 1: According to Raoult's law:

$$P_{\text{solution}} = P_{\text{solvent}}^0 \times X_{\text{solvent}}$$

Step 2: Let $X_{\text{solute}} = x$, then:

$$X_{\text{solvent}} = 1 - x$$

Step 3: Given:

$$P_{\text{solution}} = 750 \text{ mm Hg}$$

$$P_{\text{solvent}}^0 = 760 \text{ mm Hg}$$

Step 4:

$$750 = 760(1 - x) \Rightarrow \frac{750}{760} = 1 - x$$
$$x = 1 - \frac{750}{760} = \frac{10}{760} = 0.0132$$

Conclusion: Mole fraction of glucose = 0.0132

Quick Tip

Use $P = P^0 \times X$ to calculate mole fraction. Always subtract to find solute's mole fraction:
 $X_B = 1 - X_A$.

OR

(c) The boiling point of solution increases when 1 mol of NaCl is added to 1 litre of water while addition of 1 mol of methanol to one litre of water decreases its boiling point. Explain the above observations.

Correct Answer: NaCl raises boiling point due to non-volatile nature; methanol lowers boiling point due to volatile nature and positive deviation.

Solution:

Observation 1: NaCl + Water (Boiling Point Increases)

- NaCl is a **non-volatile solute**.
- Its addition causes the **vapour pressure of water to decrease**.
- Hence, a higher temperature is required to reach atmospheric pressure, leading to **boiling point elevation**.

Observation 2: Methanol + Water (Boiling Point Decreases)

- Methanol is a **volatile liquid**.

- It increases the total vapour pressure of the solution.
- This results in the solution boiling at a lower temperature, i.e., **boiling point depression**.

Quick Tip

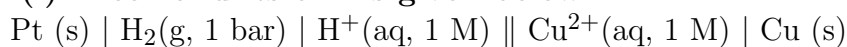
Boiling point elevation is a colligative property, influenced by vapor pressure.

- Non-volatile solutes → decrease vapor pressure → increase boiling point.
- Volatile solutes → increase vapor pressure → decrease boiling point.

Section - E

(33)(a)

(i) A cell and its emf is given below:



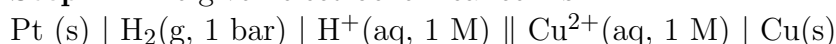
emf of the cell = +0.34 V

Write the reduction half-reaction at cathode.

Correct Answer: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu(s)}$

Solution:

Step 1: The given electrochemical cell is:

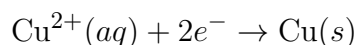


Step 2: According to standard notation:

- The left-hand side (LHS) represents the **anode** (oxidation).
- The right-hand side (RHS) represents the **cathode** (reduction).

Step 3: At the cathode, Cu^{2+} ions in solution accept electrons and get reduced to solid Cu.

Reduction half-reaction at cathode:



Quick Tip

Always remember:

- Oxidation occurs at the anode (left side of cell notation)
 - Reduction occurs at the cathode (right side of cell notation)
- Identify the species gaining electrons for the reduction half-reaction.

(ii) How is standard Gibbs energy for a reaction related to equilibrium constant?

Correct Answer: $\Delta G^\circ = -RT \ln K$

Solution:

Step 1: The standard Gibbs free energy change ΔG° is related to the equilibrium constant K by the formula:

$$\Delta G^\circ = -RT \ln K$$

Step 2: Where:

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

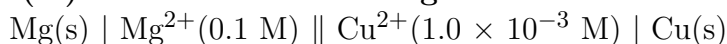
T = Temperature in Kelvin

K = Equilibrium constant of the reaction

Step 3: A negative ΔG° implies a spontaneous reaction and a large K .

Quick Tip

Use $\Delta G^\circ = -RT \ln K$ to link thermodynamics with equilibrium.
If $\Delta G^\circ < 0$, then $K > 1$, and the reaction favors products.

(iii) Calculate emf of the given cell:

Given:

$$E_{\text{Cu}^{2+}/\text{Cu}}^\circ = +0.34 \text{ V}, \quad E_{\text{Mg}^{2+}/\text{Mg}}^\circ = -2.37 \text{ V}$$

($\log 100 = 2$)

Correct Answer: $E_{\text{cell}} = 2.61 \text{ V}$

Solution:

Step 1: Identify anode and cathode.

- Mg has lower (more negative) standard reduction potential \rightarrow acts as **anode** (oxidation).
- Cu has higher (more positive) reduction potential \rightarrow acts as **cathode** (reduction).

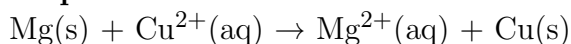
Step 2: Standard EMF of the cell:

$$E_{\text{cell}}^\circ = E_{\text{cathode}}^\circ - E_{\text{anode}}^\circ = 0.34 - (-2.37) = 2.71 \text{ V}$$

Step 3: Apply Nernst equation:

$$E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{n} \log \frac{[\text{products}]}{[\text{reactants}]}$$

Step 4: For the reaction:



Step 5: Substitute values:

$$E_{\text{cell}} = 2.71 - \frac{0.0591}{2} \log \left(\frac{0.1}{1.0 \times 10^{-3}} \right)$$

Step 6: Simplify:

$$\frac{0.1}{1.0 \times 10^{-3}} = 100, \text{ so } \log 100 = 2$$

$$E_{\text{cell}} = 2.71 - \frac{0.0591}{2} \times 2 = 2.71 - 0.0591 = 2.6509 \approx 2.61 \text{ V}$$

Quick Tip

Use:

- $E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ}$
- Nernst equation for non-standard conditions: $E = E^{\circ} - \frac{0.0591}{n} \log Q$

(b)

(i) **State Kohlrausch's law of independent migration of ions.**

Correct Answer:

Kohlrausch's law states that:

At infinite dilution, the molar conductivity of an electrolyte is equal to the sum of the individual contributions of the cation and anion.

Mathematically:

$$\Lambda_m^{\circ} = \lambda_+^{\circ} + \lambda_-^{\circ}$$

Solution:

Step 1: At infinite dilution, ions are far apart and do not interact with each other.

Step 2: Each ion migrates independently, contributing to the total molar conductivity.

Step 3: Hence, the total conductivity is additive, depending on the individual ion conductivities.

Quick Tip

Kohlrausch's law helps calculate:

- Limiting molar conductivity of weak electrolytes,
- Degree of dissociation,
- Ionic conductivities at infinite dilution.

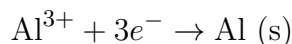
(ii) **How much electricity in terms of Faraday is required to produce 40 g of Al from molten Al_2O_3 ?**

(Given: Atomic mass of Al = 27 u)

Correct Answer: 4.44 Faraday

Solution:

Step 1: Reaction at cathode:



Step 2: Molar mass of Al = 27 g/mol

Moles of Al in 40 g = $\frac{40}{27} \approx 1.481$ mol

Step 3: Since 3 Faradays are needed to produce 1 mol of Al:

Total charge = $1.481 \times 3 = 4.44$ F

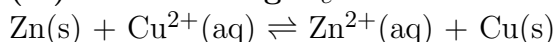
Conclusion: 4.44 Faraday of electricity is required.

Quick Tip

Use: Charge = mol \times n (electrons)

Always check the charge on the ion to find number of electrons transferred.

(iii) Calculate $\log K_c$ for the following reaction at 298 K:



Given:

$$E_{\text{Zn}^{2+}/\text{Zn}}^{\circ} = -0.76 \text{ V}, \quad E_{\text{Cu}^{2+}/\text{Cu}}^{\circ} = +0.34 \text{ V}$$

Correct Answer: $\log K_c = 37.29$

Solution:

Step 1: Calculate standard EMF:

$$E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ} = 0.34 - (-0.76) = 1.10 \text{ V}$$

Step 2: Use relation between EMF and equilibrium constant:

$$\Delta G^{\circ} = -nFE_{\text{cell}}^{\circ} = -RT \ln K_c$$

Or,

$$\log K_c = \frac{nE_{\text{cell}}^{\circ} \times 96500}{2.303 \times 8.314 \times 298}$$

Step 3: Substituting:

$$n = 2, \quad E^\circ = 1.10 \text{ V}$$

$$\log K_c = \frac{2 \times 1.10 \times 96500}{2.303 \times 8.314 \times 298} \approx 37.29$$

Quick Tip

Use this shortcut: $\log K_c = \frac{nE_{\text{cell}}^\circ \times 96500}{2.303RT}$

At 298 K, the denominator simplifies to approx. 5700.

34. (a) Compound A undergoes Rosenmund reduction to give compound B with molecular formula $\text{C}_7\text{H}_6\text{O}$. Compound B does not give Fehling's test but reacts with conc. NaOH to give C and D.

Identify A, B, C and D and write all the reactions involved.

Write one chemical test to distinguish between compound B and propanone.

Correct Answer:

A = Benzoyl chloride ($\text{C}_6\text{H}_5\text{COCl}$)

B = Benzaldehyde ($\text{C}_6\text{H}_5\text{CHO}$)

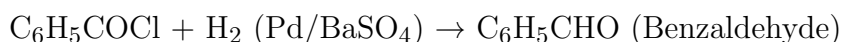
C = Benzoic acid ($\text{C}_6\text{H}_5\text{COOH}$)

D = Benzyl alcohol ($\text{C}_6\text{H}_5\text{CH}_2\text{OH}$)

Solution:

Step 1: Compound A undergoes Rosenmund reduction to give compound B.

Rosenmund reduction:

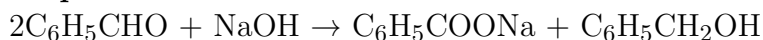


Step 2: Compound B ($\text{C}_6\text{H}_5\text{CHO}$):

- Does not give Fehling's test (indicates it's an aromatic aldehyde).

- Reacts with conc. NaOH \rightarrow undergoes **Cannizzaro reaction**.

Step 3: Cannizzaro Reaction:



(on acidification): C (Benzoic acid), D (Benzyl alcohol)

Final Identifications:

A = Benzoyl chloride ($\text{C}_6\text{H}_5\text{COCl}$)

B = Benzaldehyde ($\text{C}_6\text{H}_5\text{CHO}$)

C = Benzoic acid ($\text{C}_6\text{H}_5\text{COOH}$)

D = Benzyl alcohol ($\text{C}_6\text{H}_5\text{CH}_2\text{OH}$)

Distinguishing Test:

Use **Iodoform test**:

- Propanone gives a positive iodoform test (yellow precipitate of CHI_3)
- Benzaldehyde does **not** give the iodoform test.

Quick Tip

Rosenmund reduction converts acyl chlorides to aldehydes.
 Cannizzaro reaction occurs only in aldehydes without $\alpha\text{-H}$.
 Iodoform test detects methyl ketones and secondary alcohols with $-\text{CH}_3\text{CO}-$ group.

(b) Compound A with molecular formula ($\text{C}_2\text{H}_6\text{O}$) on oxidation by PCC gives compound B, which on treatment with dilute alkali forms compound C (a α -hydroxy aldehyde). B on oxidation by potassium permanganate forms D.

Identify A, B, C and D and write all the chemical equations involved.

Correct Answer:

A = Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$)
 B = Acetaldehyde (CH_3CHO)
 C = 3-Hydroxybutanal ($\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CHO}$)
 D = Acetic acid (CH_3COOH)

Solution:

Step 1: Compound A has formula $\text{C}_2\text{H}_6\text{O} \rightarrow$ Likely an alcohol.

A = Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$)

Step 2: Oxidation by PCC (mild oxidizing agent) converts ethanol to aldehyde.

$\text{CH}_3\text{CH}_2\text{OH} + [\text{O}] (\text{PCC}) \rightarrow \text{CH}_3\text{CHO}$ (Acetaldehyde)

So, B = Acetaldehyde

Step 3: B reacts with dilute alkali to give α -hydroxy aldehyde \rightarrow Aldol reaction:

$2 \text{CH}_3\text{CHO} + \text{dil. NaOH} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CHO}$

So, C = 3-Hydroxybutanal

Step 4: B on oxidation with KMnO_4 gives carboxylic acid:

$\text{CH}_3\text{CHO} + [\text{O}] \rightarrow \text{CH}_3\text{COOH}$

So, D = Acetic acid

Summary:

A = Ethanol
 B = Acetaldehyde
 C = 3-Hydroxybutanal
 D = Acetic acid

Quick Tip

- PCC is a mild oxidizing agent used for converting alcohols to aldehydes.
- Aldehydes without α -substitution undergo aldol condensation in basic medium.
- KMnO_4 strongly oxidizes aldehydes to carboxylic acids.

35. (a) The chemistry of the actinoids is more complex as compared to the lanthanoids. Why?

Correct Answer:

Actinoids exhibit more complex chemistry due to the greater number of oxidation states and greater tendency to form coordination compounds than lanthanoids.

Solution:

Step 1: In actinoids, 5f orbitals participate in bonding, while in lanthanoids, 4f orbitals are deeply buried and less involved.

Step 2: Actinoids show variable oxidation states ranging from +3 to +6 (sometimes +7), whereas lanthanoids predominantly show +3 oxidation state.

Step 3: The 5f electrons in actinoids are more shielded and more easily influenced by ligands.

Quick Tip

Actinoid contraction is more irregular; variable oxidation states and stronger 5f participation lead to complex behavior.

35. (b) Why is E° for $\text{Mn}^{3+}/\text{Mn}^{2+}$ redox couple more positive?

Correct Answer:

Because Mn^{3+} is unstable in aqueous solution and readily reduces to Mn^{2+} .

Solution:

Step 1: Mn^{3+} has a high charge density and causes strong hydration, making it less stable.

Step 2: Due to instability, Mn^{3+} has a high tendency to gain an electron (i.e., get reduced).

Step 3: Hence, the redox potential (E°) becomes more positive for the $\text{Mn}^{3+}/\text{Mn}^{2+}$ couple.

Quick Tip

A higher E° value indicates a greater tendency for reduction — Mn^{3+} is readily reduced due to instability in aqueous medium.

35. (c) Why do transition metals form large numbers of complex compounds?

Correct Answer:

Due to small size, high charge, and availability of vacant d-orbitals for bonding.

Solution:

Step 1: Transition metals have small atomic/ionic radii and high nuclear charge.

Step 2: Their partially filled (n-1)d orbitals are available to accept lone pairs from ligands.

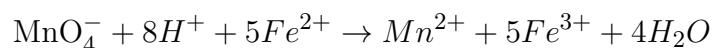
Step 3: Hence, they readily form coordinate bonds with ligands, resulting in stable complex compounds.

Quick Tip

Key factors: high charge density, small size, and availability of vacant d-orbitals enhance complex formation.

35. (d) How does acidified potassium permanganate solution react with Fe^{2+} ions? Write ionic equation.

Correct Answer:

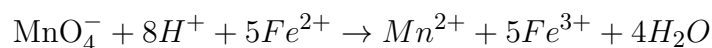


Solution:

Step 1: KMnO_4 in acidic medium acts as a strong oxidizing agent.

Step 2: Fe^{2+} is oxidized to Fe^{3+} , and MnO_4^- is reduced to Mn^{2+} .

Ionic equation:



Quick Tip

In acidic medium, KMnO_4 gets reduced to Mn^{2+} ; Fe^{2+} acts as the reducing agent.

35. (e) Calculate the ‘spin only’ magnetic moment of a divalent ion of a metal M in aqueous solution. The atomic number of the metal M is 25.

Correct Answer: $\mu = \sqrt{n(n+2)} = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92 \text{ BM}$

Solution:

Step 1: Atomic number of M = 25 \rightarrow Mn

Mn: $[\text{Ar}] 3d^5 4s^2$

Step 2: In divalent state (Mn^{2+}): loses two electrons $\rightarrow 3d^5$ configuration

Step 3: Number of unpaired electrons $n = 5$

Step 4: Magnetic moment (spin only):

$$\mu = \sqrt{n(n+2)} = \sqrt{5(5+2)} = \sqrt{35} \approx 5.92 \text{ BM}$$

Quick Tip

Spin-only magnetic moment depends on unpaired electrons:

$\mu = \sqrt{n(n+2)}$, where n = number of unpaired electrons.
