

CBSE Class 12 — CHEMISTRY (043)

Sample Paper: Questions and Solutions · Academic Session 2026–27

Complete Questions, Answers, Solutions and Marking Scheme

Time: 3 hours

Max. Marks: 70

General Instructions

1. There are 33 questions in this question paper with internal choice.
2. SECTION A consists of 16 multiple-choice questions carrying 1 mark each.
3. SECTION B consists of 5 very short answer questions carrying 2 marks each.
4. SECTION C consists of 7 short answer questions carrying 3 marks each.
5. SECTION D consists of 2 case-based questions carrying 4 marks each.
6. SECTION E consists of 3 long answer questions carrying 5 marks each.
7. All questions are compulsory.
8. A separate question has been provided for visually impaired candidates in lieu of questions having visual inputs.
9. Use of log tables and calculators is not allowed.

SECTION A

16 marks

Questions 1 to 16 are multiple choice questions. Only one of the choices is correct. Select and write the correct choice as well as the answer to these questions.

Question 1

1 mark

The boiling points and K_b values of isomeric amines are given in Table 1. Which one of the following statements is correct?

Table 1

Amine	Boiling point / K	pK_b (approx.)
P	329.3	3.00
Q	310.5	9.83
R	350.8	3.22

- Amine P is more volatile than amine R, but less basic.
- Amine R will give a white precipitate with Hinsberg reagent, which is soluble in NaOH.
- Amine Q is more soluble in water as compared to R.
- Amine P and Q can be prepared by the Gabriel phthalimide process.

ANSWER

B. Amine R will give a white precipitate with Hinsberg reagent, which is soluble in NaOH.

SOLUTION

On the basis of the boiling points, **P is a secondary, Q a tertiary and R a primary amine**. A primary amine gives a white precipitate with Hinsberg reagent (benzenesulphonyl chloride); the N–H of that sulphonamide is acidic, so the product dissolves in NaOH.

Marking scheme: 1 mark for the correct option.

Question 2

1 mark

Which of the following complexes is tetrahedral in shape?

- $[\text{Ni}(\text{CN})_4]^{2-}$
- $[\text{Cu}(\text{NH}_3)_4]^{2+}$
- $[\text{NiCl}_4]^{2-}$
- $[\text{Co}(\text{en})_3]^{3+}$

ANSWER

| C. $[\text{NiCl}_4]^{2-}$

SOLUTION

$[\text{NiCl}_4]^{2-}$ is tetrahedral because Cl^- is a weak field ligand and does not cause pairing of electrons, so the metal uses sp^3 hybridisation. The other complexes are square planar or octahedral.

Marking scheme: 1 mark for the correct option.

Question 3

1 mark

The quantity of charge required to obtain one mole of metal "M" from M_2O_3 is:

- A. 1F
- B. 6F
- C. 3F
- D. 2F

ANSWER

| C. 3F

$\text{M}^{3+} + 3\text{e}^- \rightarrow \text{M} \quad \therefore \text{quantity of charge} = 3\text{F}$

Marking scheme: 1 mark for the correct option.

Question 4

1 mark

An organic compound "X" on reaction with chloroform and alcoholic KOH gives a foul-smelling product. In which of the following cases would compound X be produced?

- A. Chloromethane is treated with AgCN .
- B. Nitrobenzene is reduced.
- C. Benzene diazonium chloride is treated with Cu/KCN .
- D. Aniline reacts with acetyl chloride.

ANSWER

| B. Nitrobenzene is reduced.

SOLUTION

Reduction of nitrobenzene gives **aniline**. The foul smell is that of the **isocyanide** produced when an aliphatic or aromatic primary amine undergoes the carbylamine reaction. Only option B supplies a primary amine.

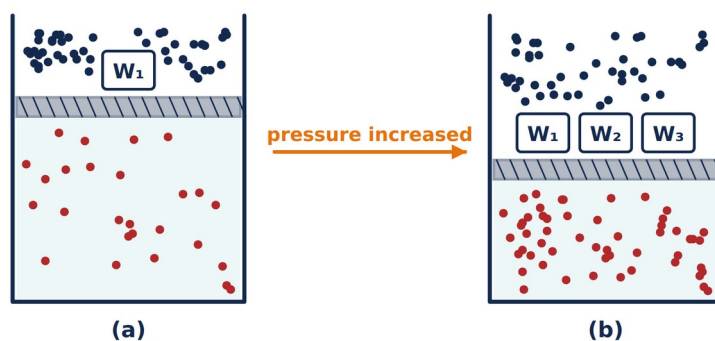
Marking scheme: 1 mark for the correct option.

Question 5

1 mark

Consider a system in a state of dynamic equilibrium, as shown in Fig. 1(a). The lower part is solution and the upper part is a gaseous system at pressure p and temperature T . The pressure is increased over the solution phase by compressing the gas to a smaller volume, as shown in Fig. 1(b). Which of the following statements is true about figure 1(b)?

Figure 1 — gas in equilibrium with a solution



More gas dissolves until a new dynamic equilibrium is reached.

● gas molecule ● dissolved gas molecule

Figure 1

- A. Solubility of the gas will increase until dynamic equilibrium is reached.
- B. Solubility of the gas will decrease until dynamic equilibrium is reached.
- C. Solubility of the gas will increase until static equilibrium is reached.
- D. Solubility of the gas will decrease until static equilibrium is reached.

For Visually Challenged Learners — According to Henry's law, the partial pressure P of a gas above the liquid at constant temperature is directly proportional to

- A. volume of the gas
- B. mole fraction of the gas in the solution
- C. atmospheric pressure
- D. vapour pressure of the solution

ANSWER

A. Solubility of the gas will increase until dynamic equilibrium is reached.

For Visually Challenged Learners: B. mole fraction of the gas in the solution

SOLUTION

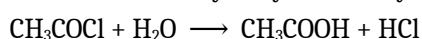
By **Henry's law**, $p = K_H x$: raising the partial pressure of the gas raises its mole fraction in solution, so more gas dissolves until the rates of dissolution and escape become equal once more — a new **dynamic** equilibrium.

Marking scheme: 1 mark for the correct option.

Question 6

1 mark

Aavya carries out the hydrolysis of acetyl chloride:



She carries out the reaction with (i) equimolar amounts of acetyl chloride and water and (ii) excess of water. The rate law obeyed in the two cases will be:

- A. (i) First order (ii) Second order
- B. (i) First order (ii) First order
- C. (i) Second order (ii) Second order
- D. (i) Second order (ii) First order

ANSWER

D. (i) Second order (ii) First order

SOLUTION

In case (i) the rate depends on both reactants. In case (ii), water is in large excess so its concentration is effectively constant and the rate becomes independent of it; such reactions are called **pseudo first order (pseudo unimolecular)** reactions.

Marking scheme: 1 mark for the correct option.

Question 7

1 mark

The amino acid $\text{HOOC}-\text{CH}_2-\text{CH}_2-\text{CH}(\text{NH}_2)\text{COOH}$ can be synthesised within our body. Which of the following is true about this amino acid?

- A. an acidic and non-essential amino acid
- B. a neutral and non-essential amino acid
- C. an acidic and essential amino acid
- D. a neutral and essential amino acid

ANSWER

A. an acidic and non-essential amino acid

SOLUTION

The amino acid can be synthesised in our body, so it is **non-essential**. It has two $-\text{COOH}$ groups and only one $-\text{NH}_2$ group, so it is **acidic**.

Marking scheme: 1 mark for the correct option.

Question 8

1 mark

Identify the Grignard reagent and carbonyl compound which, on reaction followed by hydrolysis, will give 3-methylpentan-3-ol.

- (i) $\text{C}_2\text{H}_5\text{COC}_2\text{H}_5 + \text{CH}_3\text{MgCl}$
- (ii) $\text{C}_2\text{H}_5\text{COCH}_3 + \text{C}_2\text{H}_5\text{MgCl}$
- (iii) $\text{CH}_3\text{CHO} + \text{C}_2\text{H}_5-\text{CH}(\text{MgCl})-\text{C}_2\text{H}_5$
- (iv) $\text{C}_2\text{H}_5\text{CHO} + \text{CH}_3-\text{CH}(\text{MgCl})-\text{C}_2\text{H}_5$

- A. (i) and (iii)
- B. (ii) and (iv)
- C. (iii) and (iv)
- D. (i) and (ii)

ANSWER

D. (i) and (ii)

SOLUTION

3-Methylpentan-3-ol, $\text{CH}_3\text{CH}_2-\text{C}(\text{OH})(\text{CH}_3)-\text{CH}_2\text{CH}_3$, is a **tertiary** alcohol, so it must come from a **ketone** plus a Grignard reagent. Routes (i) and (ii) both supply the required CH_3 , C_2H_5 and C_2H_5 groups on the carbinol carbon. Routes (iii) and (iv) use **aldehydes**, which can give only secondary alcohols.

Marking scheme: 1 mark for the correct option.

Question 9

1 mark

Which one of the following elements will be a strong oxidising agent in its +3 oxidation state? (Atomic numbers: Cr = 24, Mn = 25, Ti = 22, Fe = 26)

- A. Cr
- B. Mn
- C. Ti
- D. Fe

ANSWER

B. Mn

SOLUTION

$\text{Mn}^{3+} (3d^4)$ is reduced to $\text{Mn}^{2+} (3d^5)$, gaining the extra-stable half-filled d^5 configuration; $E^\circ = +1.51 \text{ V}$. It therefore acts as a strong oxidising agent.

Marking scheme: 1 mark for the correct option.

Question 10

1 mark

When (–)-2-bromohexane reacts with sodium hydroxide, (+)-hexan-2-ol is formed. Which one of the following observations would be correct?

- A. The reaction follows the $\text{S}_{\text{N}}2$ mechanism and is accompanied by inversion of configuration.
- B. The reaction follows the $\text{S}_{\text{N}}1$ mechanism and is accompanied by inversion of configuration.
- C. The reaction follows the $\text{S}_{\text{N}}2$ mechanism and is accompanied by retention of configuration.
- D. The reaction follows the $\text{S}_{\text{N}}1$ mechanism and is accompanied by retention of configuration.

ANSWER

A. The reaction follows the $\text{S}_{\text{N}}2$ mechanism and is accompanied by inversion of configuration.

SOLUTION

A secondary halide with a strong nucleophile reacts by $\text{S}_{\text{N}}2$. Attack occurs from the side opposite the leaving group through a single transition state, giving **Walden inversion**. An $\text{S}_{\text{N}}1$ route would proceed through a planar carbocation and give racemisation.

Marking scheme: 1 mark for the correct option.

Question 11

1 mark

If the half-life of a first order reaction is 16 minutes, how much time does it take to complete 75% of the reaction?

- A. 16 min
- B. 32 min
- C. 48 min
- D. 64 min

ANSWER

B. 32 min

SOLUTION

50% of the reaction is complete in 16 min. For the remaining 50% to fall to half (i.e. 25% left) a further 16 min is needed. Hence $50\% + 25\% = 75\%$ is complete in **32 min**, that is two half-lives.

Marking scheme: 1 mark for the correct option.

Question 12

1 mark

Which solution has the highest conductivity?

- A. 0.1 M HCl
- B. 0.1 M CH_3COOH
- C. 0.1 M glucose
- D. 0.1 M NH_4OH

ANSWER

A. 0.1 M HCl

SOLUTION

HCl is a strong acid and dissociates almost completely into H^+ and Cl^- ; more ions mean higher conductivity, and H^+ has the highest ionic mobility. CH_3COOH and NH_4OH are weak electrolytes and only partially ionised; glucose is a non-electrolyte and furnishes no ions.

Marking scheme: 1 mark for the correct option.

Question 13

1 mark

A statement of Assertion (A) is followed by a statement of Reason (R). Select the most appropriate answer from the options given below.

Assertion (A): Nitration of aniline gives a significant amount of the meta derivative.

Reason (R): $-\text{NH}_2$ is an ortho and para directing and highly activating group.

- A. Both A and R are true, and R is the correct explanation of A.
- B. Both A and R are true, but R is not the correct explanation of A.
- C. A is true but R is false.
- D. A is false but R is true.

ANSWER

B. Both A and R are true, but R is not the correct explanation of A.

SOLUTION

In the strongly acidic nitrating mixture aniline is largely protonated to the **anilinium ion**, in which the positively charged $-\text{NH}_3^+$ group is deactivating and **meta directing**. The meta product therefore arises in spite of $-\text{NH}_2$ being o/p directing, not because of it.

Marking scheme: 1 mark for the correct option.

Question 14

1 mark

A statement of Assertion (A) is followed by a statement of Reason (R). Select the most appropriate answer from the options given below.

Assertion (A): Permanganate and manganate ions have a tetrahedral structure.

Reason (R): In permanganate and manganate ions, π bonding takes place which is due to overlap of p orbitals of oxygen with p orbitals of manganese.

- A. Both A and R are true, and R is the correct explanation of A.
- B. Both A and R are true, but R is not the correct explanation of A.
- C. A is true but R is false.
- D. A is false but R is true.

ANSWER

C. A is true but R is false.

SOLUTION

Both MnO_4^- and MnO_4^{2-} are tetrahedral, so A is true. The Reason is false: the π bonding is **$\pi\text{p}-\text{d}\pi$** , formed by overlap of the p orbitals of oxygen with the d orbitals of manganese.

Marking scheme: 1 mark for the correct option.

Question 15

1 mark

A statement of Assertion (A) is followed by a statement of Reason (R). Select the most appropriate answer from the options given below.

Assertion (A): Miscibility of ethers with water resembles those of alcohols of the same molecular mass.

Reason (R): The oxygen of ether can also form hydrogen bonds with water.

- A. Both A and R are true, and R is the correct explanation of A.
- B. Both A and R are true, but R is not the correct explanation of A.
- C. A is true but R is false.
- D. A is false but R is true.

ANSWER

A. Both A and R are true, and R is the correct explanation of A.

SOLUTION

The ether oxygen carries two lone pairs and can act as a hydrogen-bond **acceptor** towards the O-H of water. It is exactly this hydrogen bonding that makes an ether as miscible as the corresponding alcohol.

Marking scheme: 1 mark for the correct option.

Question 16

1 mark

A statement of Assertion (A) is followed by a statement of Reason (R). Select the most appropriate answer from the options given below.

Assertion (A): $[\text{Co}(\text{NH}_3)_6]^{3+}$ is diamagnetic.

Reason (R): NH_3 is a strong field ligand and causes pairing of electrons.

- A. Both A and R are true, and R is the correct explanation of A.
 B. Both A and R are true, but R is not the correct explanation of A.
 C. A is true but R is false.
 D. A is false but R is true.

ANSWER

A. Both A and R are true, and R is the correct explanation of A.

SOLUTION

Co^{3+} is $3d^6$. NH_3 is a strong field ligand, so $\Delta_o > P$ and the electrons pair up as $t_{2g}^6 e_g^0$. With no unpaired electrons the complex is diamagnetic, and the pairing caused by the strong field ligand is precisely the cause.

Marking scheme: 1 mark for the correct option.

SECTION B**10 marks**

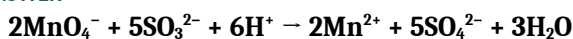
Questions 17 to 21 are very short answer questions carrying 2 marks each.

Question 17(A)**1 + 1 marks**

Attempt either A or B.

I Complete and balance the following reaction:

[1]

**ANSWER**

II Why does titanium melt at a lower temperature than chromium?

[1]

ANSWER

Chromium has a larger number of unpaired electrons than titanium, which leads to stronger interatomic attractions holding its atoms together. More energy is therefore needed to break them, so chromium melts at a higher temperature than titanium.

Marking scheme: I — 1 mark for the correctly balanced equation. II — 1 mark.

OR**Question 17(B)****1 + 1 marks**

I Why do titanium and scandium form complex compounds, whereas potassium and calcium do not, although they belong to the same period?

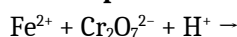
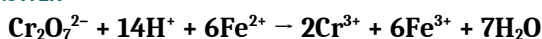
[1]

ANSWER

The transition metals form a large number of complex compounds because of the comparatively **smaller size** of their metal ions, their **high ionic charge** and the **availability of d orbitals** for bond formation. Titanium and scandium possess all three; potassium and calcium are large, of low charge, and have no d orbitals of suitable energy, so they do not form complexes.

II Complete and balance the following reaction:

[1]

**ANSWER**

Marking scheme: I — 1 mark. II — 1 mark for the correctly balanced equation.

Question 18**2 marks**

“The rate of reaction remains constant during the course of reaction.” Is this statement always true, or is it true under certain conditions? Reflect on the statement.

- The statement is true for a **zero order reaction**, as the rate is independent of the concentration of the reactants.
- For reactions of any other order — first, second and so on — the rate of reaction **decreases** as the concentration of the reactants decreases.

Marking scheme: 1 mark for each point.



Question 19

1 + 1 marks

I Complete the sequence of nitrogenous bases in the given DNA strand (Figure 2).

[1]

Figure 2 — a DNA strand and its complement

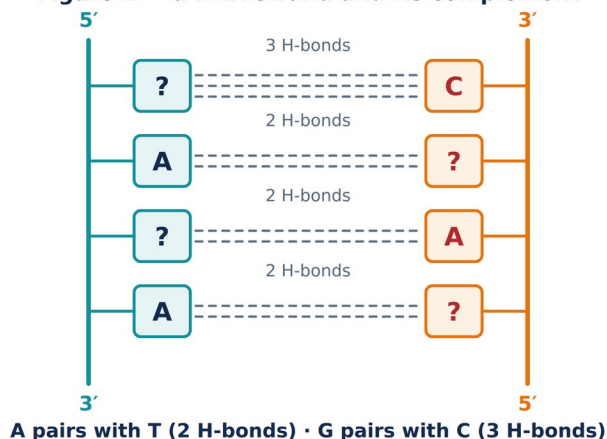


Figure 2

II Milk contains a protein called casein. How does the structure of casein change on addition of a few drops of lemon juice to milk?

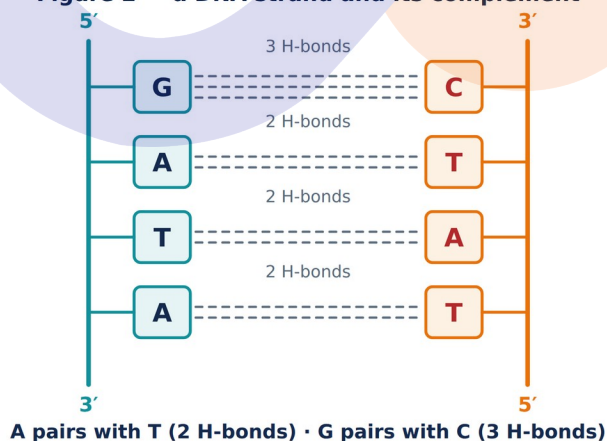
[1]

For Visually Challenged Learners — (I) Name the nitrogenous bases in DNA. (II) Milk contains a protein called casein. How does the structure of casein change on addition of a few drops of lemon juice to milk?

ANSWER

- I. The complementary bases follow Chargaff's rule — **G pairs with C** (three hydrogen bonds) and **A pairs with T** (two hydrogen bonds):
- II. Addition of lemon juice lowers the pH, which breaks the hydrogen bonds; the globules of casein unfold and the protein is **denatured**.
- For Visually Challenged Learners — I. Adenine, Guanine, Cytosine and Thymine. II. As above.

Figure 2 — a DNA strand and its complement



Completed strand

Marking scheme: I — 1 mark. II — 1 mark. (Same allocation for the Visually Challenged Learners' version.)

Question 20

2 marks

Chlorobenzene can be converted into phenol by heating in aqueous sodium hydroxide solution at 623 K and 300 atm; however, the presence of a substituent group affects its activity towards this nucleophilic substitution reaction. Which substituent, (i) nitro or (ii) methoxy, will increase the reactivity of chlorobenzene, and why?

ANSWER

The **nitro group** will increase the reactivity.

- The nitro group is a strong **electron-withdrawing group**, by both the inductive (–I) and the resonance (–M) effect, whereas the methoxy group is electron donating in nature.

- When the nitro group is present at the **ortho or para** position it withdraws electron density from the ring and stabilises the negative charge of the intermediate carbanion through resonance, which increases reactivity towards nucleophilic substitution.

Marking scheme: 1 mark for identifying the nitro group; $\frac{1}{2} + \frac{1}{2}$ marks for the reasoning.

Question 21

2 × 1 marks

Account for the following:

- I** Underground iron pipelines are often protected by connecting them to a more reactive metal like magnesium. [1]

ANSWER

Magnesium, being more reactive than iron, acts as a **sacrificial anode** and undergoes oxidation, $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$, supplying electrons to the iron pipe, which then behaves as the cathode. The iron is thus prevented from corroding.

- II** Write the reactions occurring at the cathode and the anode during the electrolysis of molten magnesium chloride. [1]

Cathode: $\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg(l)}$

Anode: $2\text{Cl}^- \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$

Marking scheme: I – 1 mark. II – $\frac{1}{2}$ mark for each electrode reaction.

SECTION C

21 marks

Questions 22 to 28 are short answer questions carrying 3 marks each.

Question 22

1 + 2 marks

- I** Which of the following has the highest magnetic moment? Justify your answer. Ti^{2+} , Co^{2+} , Fe^{2+} . [Atomic numbers: Ti = 22, Co = 27, Fe = 26] [1]

ANSWER

Fe^{2+} has the highest magnetic moment, because it contains the largest number of unpaired electrons of the three.

Ion	Configuration	Unpaired electrons (n)	$\mu = \sqrt{n(n+2)}$ / BM
Ti^{2+}	[Ar] 3d ²	2	2.83
Co^{2+}	[Ar] 3d ⁷	3	3.87
Fe^{2+}	[Ar] 3d ⁶	4	4.90

- II** Which characteristic of iron makes it suitable to (a) act as a catalyst in Haber's process, and (b) form an interstitial compound with oxygen? [2]

- (a) It provides a **large surface area** for adsorption and shows **variable oxidation states**, so it can form unstable intermediates and offer a path of lower activation energy.
- (b) Iron has a large crystal lattice containing **interstitial sites** big enough to accommodate small non-metal atoms such as oxygen, carbon and nitrogen.

Marking scheme: I – $\frac{1}{2}$ mark for the ion and $\frac{1}{2}$ mark for the justification. II – 1 mark for (a) and 1 mark for (b).

Question 23

3 marks

The values of $\log k$ and $1/T$ for a reaction are given below. The plot of $\log k$ versus $1/T$ obtained for this data is shown in Figure 3. Here k is the rate constant and T is the absolute temperature. Calculate E_a for the reaction. (Given $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$)

S. No.	$\log k$	$1/T \text{ (K}^{-1}\text{)}$
1.	-4.46	0.00333
2.	-3.91	0.00323
3.	-3.37	0.00313
4.	-2.82	0.00303
5.	-2.31	0.00294

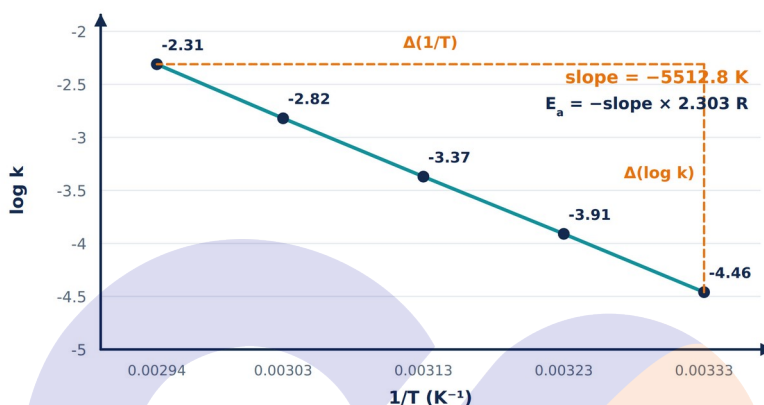
Figure 3 (redrawn) — $\log k$ versus $1/T$ 

Figure 3

For Visually Challenged Learners — The rate constant k of a reaction varies with temperature T according to $\log k = \log A - E_a/(2.303RT)$, where E_a is the activation energy. When a graph is plotted for $\log k$ versus $1/T$, a straight line with a slope of -4250 K is obtained. Calculate E_a for the reaction. (Given $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$)

ANSWER AND SOLUTION

$$\log k = \log A - E_a / (2.303 RT) \quad \therefore \text{slope} = - E_a / (2.303 R)$$

Taking two points from the plot:

$$\text{slope} = (y_2 - y_1) / (x_2 - x_1) = [-4.46 - (-3.91)] / (0.00333 - 0.00323) = -5500 \text{ K}$$

$$E_a = 5500 \times 2.303 \times 8.314 = 1.053 \times 10^5 \text{ J mol}^{-1}$$

$$E_a = 105.31 \text{ kJ mol}^{-1}$$

The value of the slope may vary slightly if different pairs of points are chosen; any slope between -5400 K and -5670 K , giving $E_a \approx 103\text{--}108 \text{ kJ mol}^{-1}$, is acceptable.

For Visually Challenged Learners

$$- E_a / (2.303 R) = -4250 \Rightarrow E_a = 4250 \times 2.303 \times 8.314$$

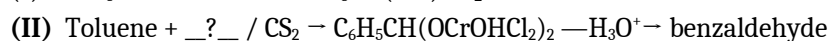
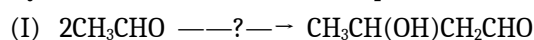
$$E_a = 81\,375 \text{ J mol}^{-1} = 81.37 \text{ kJ mol}^{-1}$$

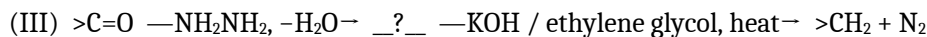
Marking scheme: $\frac{1}{2}$ mark for the formula, $\frac{1}{2}$ mark for the slope, 1 mark for the substitution and 1 mark for the correct answer with the correct unit.

Question 24

3 × 1 marks

Identify each name reaction and complete the missing reactant or product in the given reaction sequence.





Marking scheme: $\frac{1}{2} + \frac{1}{2}$ marks for each part — name of the reaction and the missing species.

1 + 1 + 1 marks

- Marking scheme: I – $\frac{1}{2} + \frac{1}{2}$ marks for (a) and $\frac{1}{2} + \frac{1}{2}$ marks for (b). II – $\frac{1}{2}$ mark for the formula and $\frac{1}{2}$ mark for the answer.

2 + 1 marks

- Marking scheme: I – 1 mark for each conversion. II – $\frac{1}{2} + \frac{1}{2}$ marks.

Question 27(A)

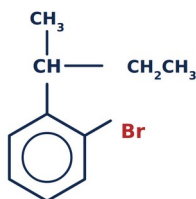
1 + 2 marks

Attempt either A or B.

I Write the IUPAC name of the following compound.

[1]

Q27 (A) (I) — structure to be named



ring carbon 1 carries the butan-2-yl group,
ring carbon 2 (ortho) carries —Br

IUPAC name
1-bromo-2-(butan-2-yl)benzene

ANSWER

1-Bromo-2-(1-methylpropyl)benzene — equivalently, **1-bromo-2-(butan-2-yl)benzene** in current IUPAC nomenclature.

II When $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ reacts with AgCN and with KCN , compounds “X” and “Y” respectively are formed. Identify “X” and “Y”. Support your answer with an appropriate reason. [2]

- With AgCN : X = $\text{CH}_3\text{CH}_2\text{CH}_2\text{NC}$ (propyl isocyanide).
- With KCN : Y = $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$ (propyl cyanide / butanenitrile).
- KCN is predominantly **ionic**; it dissociates in solution to give free CN^- , an **ambident nucleophile**, which attacks through the **carbon** atom, so the cyanide is formed.
- AgCN is predominantly **covalent**; only the lone pair on **nitrogen** is available, so bond formation occurs through nitrogen and the isocyanide is formed.

Marking scheme: I — 1 mark. II — $\frac{1}{2}$ mark for each product and $\frac{1}{2} + \frac{1}{2}$ marks for the reasons.

OR

Question 27(B)

1 + 2 marks

I What is the IUPAC nomenclature of the compound $(\text{CH}_3)_3\text{C}-\text{C}(\text{CH}_3)\text{Br}-\text{CH}_2\text{CH}_3$?

[1]

ANSWER

3-Bromo-2,2,3-trimethylpentane

II Which of the following will be hydrolysed more readily? $\text{CH}_2=\text{CH}-\text{CH}_2\text{Cl}$ or $(\text{CH}_3)_2\text{CHCl}$. Support your answer with a reason. [2]

- $\text{CH}_2=\text{CH}-\text{CH}_2\text{Cl}$ (allyl chloride) will be hydrolysed more readily than $(\text{CH}_3)_2\text{CHCl}$.
- The allyl carbocation $\text{CH}_2=\text{CH}-\text{CH}_2^+$ is more stabilised than the secondary carbocation $(\text{CH}_3)_2\text{CH}^+$.
- This is due to **resonance** in the allyl carbocation, in which the positive charge is delocalised over two carbon atoms, making it more stable.

Marking scheme: I — 1 mark. II — 1 mark for the choice and 1 mark for the reason.

Question 28

2 + 1 marks

I On adding 100 g of non-volatile solute A to 1000 g of water, the vapour pressure is reduced by 50 per cent. Calculate the molar mass of solute A. [2]

$$(p^\circ - p_s) / p^\circ = \chi_B = n_B / (n_A + n_B) = 0.5$$

$$n_A = 1000 / 18 = 55.56 \text{ mol}$$

$$0.5 = n_B / (n_B + 55.56) \Rightarrow 0.5 n_B + 0.5 \times 55.56 = n_B \Rightarrow n_B = 55.56 \text{ mol}$$

$$M_B = w_B / n_B = 100 / 55.56$$

$$M_B = 1.8 \text{ g mol}^{-1}$$

II It has been observed that a nitric acid solution containing 32% of water by mass cannot be separated into its components through fractional distillation. Why? [1]

ANSWER

Such a solution forms an **azeotrope** (a constant boiling mixture). It has the same composition in both the liquid and the vapour phase, so the components cannot be separated by fractional distillation.

Marking scheme: I — $\frac{1}{2}$ mark for the relation, $\frac{1}{2}$ mark for n_A , $\frac{1}{2}$ mark for n_B and $\frac{1}{2}$ mark for the molar mass. II — 1 mark.

SECTION D

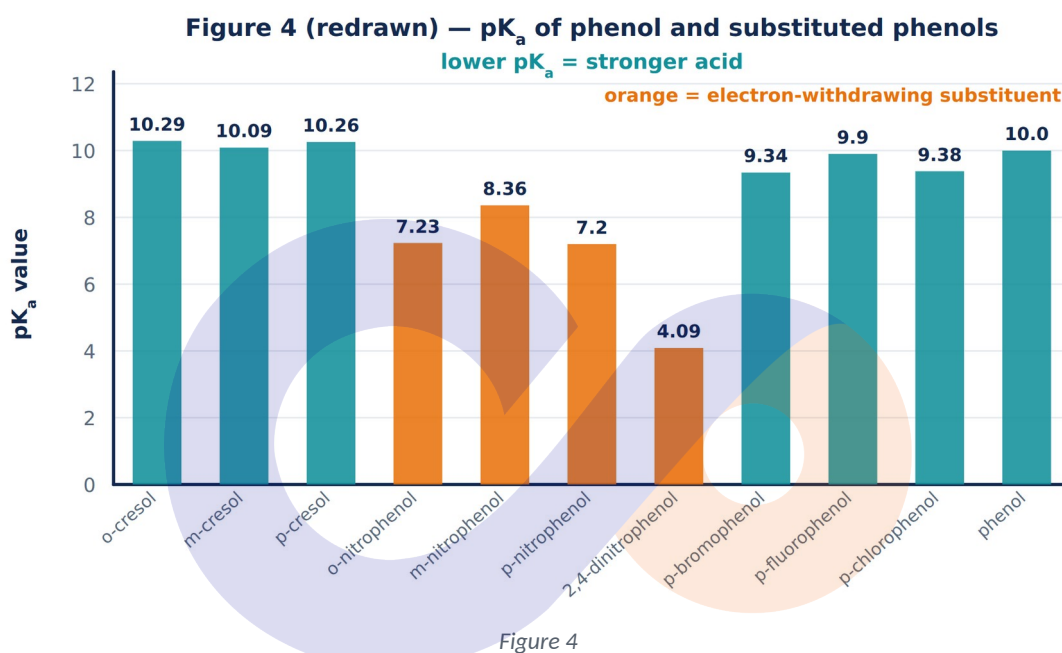
8 marks

Questions 29 and 30 are case-based / data-based questions carrying 4 marks each.

Question 29

1 + 1 + 2 marks

Acidity of substituted phenols. Phenol and substituted phenols are relatively more acidic than aliphatic alcohols. The pK_a value is a quantitative measure of the acidic strength. The effect of substituents on the acidity of phenols (pK_a values) is given in Figure 4. Study the graph and answer the following questions.



I The pK_a value of 2,4,6-trinitrophenol will be:

[1]

- A. more than 8.36
- B. between 7.2 and 8.3
- C. between 4.09 and 2.3
- D. less than 4.09

ANSWER

D. less than 4.09

SOLUTION

Each additional $-NO_2$ group withdraws electron density and delocalises the negative charge of the phenoxide ion further. With three nitro groups the phenoxide is more stable than that of 2,4-dinitrophenol ($pK_a = 4.09$), so the pK_a must be lower still.

II The order of acidity of the p-halophenols is:

[1]

- A. p-bromophenol > p-chlorophenol > p-fluorophenol > phenol
- B. phenol > p-fluorophenol > p-chlorophenol > p-bromophenol
- C. p-chlorophenol > p-bromophenol > p-fluorophenol > phenol
- D. phenol > p-fluorophenol > p-bromophenol > p-chlorophenol

ANSWER

A. p-bromophenol > p-chlorophenol > p-fluorophenol > phenol

SOLUTION

Reading the pK_a values from the graph — p-bromophenol 9.34, p-chlorophenol 9.38, p-fluorophenol 9.90, phenol 10.0 — and remembering that a **lower** pK_a means a **stronger** acid.

Attempt either (IIIA) or (IIIB).

IIIA Predict which one of the following two compounds will have the lower value of pK_a . Give a reason in support of your answer. [2]

Q29 (IIIA) — which has the lower pK_a ?



ANSWER

Phenol is a stronger acid than cyclohexanol, so it has the lower pK_a value.

- Phenol loses a hydrogen ion to form its conjugate base, the **phenoxide ion**, which is stabilised by **resonance**.
- In cyclohexanol the conjugate base formed is less stable, because the negative charge remains **localised on the oxygen atom**.

OR

IIIB Predict whether 4-chloro-2,6-dinitrophenol is more or less acidic than 2,4,6-trinitrophenol. Use the values in the graph to support your answer. [2]

ANSWER

4-Chloro-2,6-dinitrophenol is **less acidic** than 2,4,6-trinitrophenol.

- From the graph, the pK_a of p-nitrophenol is 7.2 while that of p-chlorophenol is 9.38, so a para $-\text{NO}_2$ group lowers pK_a far more than a para $-\text{Cl}$ group does.
- Following this trend, the more the nitro groups, the lower the pK_a . Replacing the para nitro group by chlorine therefore **raises** the pK_a of 4-chloro-2,6-dinitrophenol above that of 2,4,6-trinitrophenol, and a higher pK_a means lower acidic strength.

For Visually Challenged Learners — Read the passage and answer the questions that follow.

The presence of electron withdrawing groups such as the nitro group enhances the acidic strength of phenol. It is due to the effective delocalisation of negative charge in the phenoxide ion. On the other hand, electron releasing groups, such as alkyl groups, in general do not favour the formation of the phenoxide ion, resulting in a decrease in acid strength. Cresols, for example, are less acidic than phenol. The pK_a value is a quantitative measure of the acidic strength; the higher the pK_a value, the lower is the acidic strength.

I Which of the following will form the least stable phenoxide ion? [1]

- phenol
- o-cresol
- o-nitrophenol
- o-chlorophenol

ANSWER

B. o-cresol

II Which group causes the maximum increase in the pK_a value of phenol? [1]

- $-\text{CH}_3$
- $-\text{OCH}_3$

- C. $-\text{NO}_2$
D. $-\text{Cl}$

ANSWER

B. $-\text{OCH}_3$

SOLUTION

An increase in pK_a means a decrease in acidity, which requires an **electron-releasing** group; this rules out $-\text{NO}_2$ and $-\text{Cl}$. Of the two remaining groups, $-\text{OCH}_3$ releases electron density into the ring most strongly through its **+R (resonance)** effect, destabilising the phenoxide ion to the greatest extent.

Attempt either (IIIA) or (IIIB).

IIIA Which of the following will be more acidic — nitrophenol or 2,4-dinitrophenol? Support your answer with an appropriate reason. [2]

ANSWER

2,4-Dinitrophenol is more acidic in nature.

- The nitro group is a strong electron-withdrawing group, exerting both the $-\text{I}$ and the $-\text{M}$ effect, and so withdraws electron density from the ring; the phenoxide ion formed is stabilised.
- The presence of **two** nitro groups makes the phenoxide ion more stable than the presence of only one.

OR

IIIB Predict whether the pK_a value of p-cresol or of p-nitrophenol will be higher or lower than that of phenol. Give a reason to support your answer. [2]

- The pK_a of **p-cresol** will be **higher** than that of phenol. The pK_a value increases due to the presence of an electron-donating group.
- The pK_a of **p-nitrophenol** will be **lower** than that of phenol. The pK_a value decreases due to the presence of an electron-withdrawing group.

Marking scheme: I — 1 mark. II — 1 mark. III — 1 + 1 marks. Total 4 marks. (Same allocation for the Visually Challenged Learners' version.)

Question 30

1 + 1 + 2 marks

Identification of carbohydrate. Students of class 12 are given a sample of carbohydrate obtained from a plant extract. They find that the carbohydrate is soluble in water. They take about 1–2 mL of an aqueous solution of the carbohydrate in a test tube and add 2 mL of Benedict's reagent. The test tube is heated in a water bath for 3–5 minutes and a brick red precipitate is obtained. The sample, on hydrolysis with dilute acid, gives only one type of monosaccharide.

I The sample gives a positive Benedict's test. We can conclude that the given carbohydrate is a [1]

- A. monosaccharide
B. reducing sugar
C. non-reducing sugar
D. polysaccharide

ANSWER

B. reducing sugar — reducing sugars give a brick red precipitate with Benedict's solution.

II Which of the following is a plant-based carbohydrate? (i) sucrose (ii) lactose (iii) starch (iv) glycogen [1]

- A. (i) and (ii)
B. (i) and (iii)
C. (iii) and (iv)
D. (i) and (iv)

ANSWER

B. (i) and (iii) — sucrose and starch are plant-based carbohydrates; lactose is milk sugar and glycogen is animal starch.

Attempt either (IIIA) or (IIIB).

IIIA Considering all the observations reported in the passage, the sample is most likely (i) glucose, (ii) fructose, (iii) sucrose, (iv) lactose or (v) maltose. Justify your answer. [2]

ANSWER

The sample is **maltose**.

- The sugar is **reducing** in nature, as it gives a positive Benedict's test — so it is not sucrose.
- The sugar **undergoes hydrolysis**, so it is not a monosaccharide — it is neither glucose nor fructose.
- The sugar gives only **one type of monosaccharide** on hydrolysis: lactose would give glucose and galactose, whereas maltose gives two molecules of glucose. Therefore it is maltose.

OR

IIIB Ravi reports that the given sample is starch. What could be his justification, based on the observations in the passage? Do you agree with Ravi? Why or why not? [2]

- **Ravi's justification:** the carbohydrate gives only one monosaccharide on hydrolysis, and starch on hydrolysis gives only glucose.
- **No, the carbohydrate is not starch.** The carbohydrate is soluble in water, while starch is insoluble; moreover, starch is **not a reducing sugar** and would not give a positive Benedict's test.

Marking scheme: I — 1 mark. II — 1 mark. III — 1 + 1 marks. Total 4 marks.

SECTION E

15 marks

Questions 31 to 33 are long answer type questions carrying 5 marks each.

Question 31(A)

3 + 2 marks

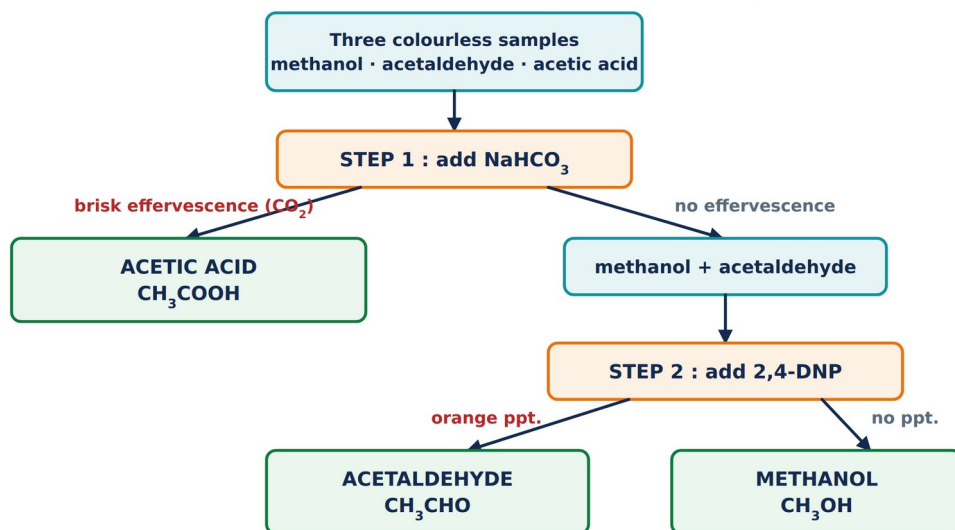
Attempt either A or B.

I Account for the following: (a) The pH should be around 3.5 during the addition of ammonia derivative compounds to an aldehyde or ketone. (b) Alcohols are added to carbonyl compounds in the presence of dry HCl gas. (c) The reaction of aldehydes with sodium hydrogen sulphite is commonly used for the separation and purification of aldehydes. [3]

- (a) A highly acidic medium protonates the ammonia derivative, reducing its nucleophilicity. In a basic medium the carbonyl compound is not protonated, reducing its electrophilicity for nucleophilic attack. Hence a mildly acidic pH of about **3.5** gives the best rate for derivative formation.
- (b) Dry hydrogen chloride protonates the oxygen of the carbonyl compound and therefore increases the **electrophilicity of the carbonyl carbon**, facilitating nucleophilic attack by the alcohol.
- (c) The hydrogen sulphite addition compound is **water soluble** and can be converted back to the original carbonyl compound by treatment with dilute mineral acid or alkali. These adducts are therefore useful for the separation and purification of aldehydes.

- II** A student has three colourless samples: methanol, acetaldehyde and acetic acid. They have only NaHCO_3 and 2,4-DNP reagent. Devise a flowchart to identify each compound using only these two reagents. [2]

Identification flowchart — NaHCO_3 and 2,4-DNP only



Marking scheme: I — 1 mark for each of (a), (b) and (c). II — $\frac{1}{2} + \frac{1}{2}$ marks for the first test and $\frac{1}{2} + \frac{1}{2}$ marks for the second.

OR

Question 31(B)

3 + 2 marks

- I** Arrange the following according to the property indicated: (a) CH_3CHO , HCHO , $\text{C}_6\text{H}_5\text{CHO}$ — decreasing order of the ease of oxidation; (b) CH_3COCl , CH_3COOH , CH_3CONH_2 , $\text{CH}_3\text{COOCH}_3$ — increasing order of nucleophilic acyl substitution; (c) CH_3CHO , CH_3COCH_3 , CF_3CHO — increasing order of electrophilicity of the carbonyl carbon. [3]
- (a) $\text{HCHO} > \text{CH}_3\text{CHO} > \text{C}_6\text{H}_5\text{CHO}$
 - (b) $\text{CH}_3\text{CONH}_2 < \text{CH}_3\text{COOH} < \text{CH}_3\text{COOCH}_3 < \text{CH}_3\text{COCl}$
 - (c) $\text{CH}_3\text{COCH}_3 < \text{CH}_3\text{CHO} < \text{CF}_3\text{CHO}$
- II** Write any two possible isomers of the compound having molecular formula $\text{C}_3\text{H}_6\text{O}$. Identify which of these isomers will give a positive Tollens' test and explain the reason. [2]
- Propanal:** $\text{CH}_3\text{—CH}_2\text{—CHO}$ (an aldehyde)
 - Propanone:** $\text{CH}_3\text{—CO—CH}_3$ (a ketone)
 - Propanal gives a positive Tollens' test** (a silver mirror). Tollens' reagent oxidises aldehydes to carboxylates, reducing Ag^+ to metallic silver. Ketones have no hydrogen on the carbonyl carbon and are not oxidised under these mild conditions.

Marking scheme: I — 1 mark for each correct order. II — $\frac{1}{2} + \frac{1}{2}$ marks for the isomers and $\frac{1}{2} + \frac{1}{2}$ marks for the identification with the reason.

Question 32(A)

5 × 1 marks

Attempt either A or B. Answer the following questions.

- I** Two test tubes, X and Y, contain solutions of the complexes $[\text{Cr}(\text{H}_2\text{O})_3\text{Cl}_3]$ and $[\text{Cr}(\text{en})_3]^{3+}$ respectively. If plane-polarised light is passed through these solutions, which solution will rotate the plane of polarisation, and why? [1]

ANSWER

$[\text{Cr}(\text{en})_3]^{3+}$ (test tube Y) will rotate the plane of polarisation. It contains three bidentate ethylenediamine ligands arranged in a **chiral** octahedral geometry, so it is optically active. $[\text{Cr}(\text{H}_2\text{O})_3\text{Cl}_3]$ exists as **fac** and **mer** isomers, but neither is optically active because each possesses a plane of symmetry.

- II** $[\text{Ni}(\text{CO})_4]$ and $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ are two complexes of Ni. Which complex will have the higher crystal field splitting energy, and which factor determines this difference? [1]

ANSWER

$[\text{Ni}(\text{CO})_4]$ has the higher crystal field splitting, because CO is a **strong field ligand** whereas H_2O is a weak field ligand. The **nature of the ligand** — its position in the spectrochemical series — determines the difference.

- III** A solution of the coordination compound $\text{PdCl}_2 \cdot 4\text{NH}_3$ is treated with AgNO_3 , and 2 mol of AgCl precipitate. Determine the primary valency and the secondary valency of Pd in the compound. [1]

ANSWER

Two chloride ions are precipitated, so they lie outside the coordination sphere and the compound is $[\text{Pd}(\text{NH}_3)_4]\text{Cl}_2$. The **primary valency** is the oxidation number of the metal, which is **2**; the **secondary valency** is the coordination number, which is **4**, satisfied by the four NH_3 ligands.

- IV** The complex $[\text{Fe}(\text{CN})_6]^{4-}$ exhibits d^2sp^3 hybridisation. Based on this, comment on the strength of the ligand CN^- and its effect on the geometry of the complex. [1]

ANSWER

CN^- is a **strong field ligand**. It forces the 3d electrons of Fe^{2+} to pair, vacating two inner d orbitals for d^2sp^3 hybridisation and giving a **low-spin octahedral** complex that is diamagnetic.

- V** Why is anhydrous CuSO_4 white, but $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ blue in colour? [1]

ANSWER

In **anhydrous CuSO_4** there is no ligand around Cu^{2+} , so the d orbitals remain degenerate, crystal field splitting does not occur and no d–d transition is possible; the solid therefore appears **white**. In **$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$** the water molecules act as **ligands** and split the d orbitals, so the d^9 ion absorbs light in the visible region and the complementary **blue** colour is transmitted.

Marking scheme: 1 mark for each part — $\frac{1}{2}$ mark for the statement and $\frac{1}{2}$ mark for the reason where applicable.

OR

Question 32(B)

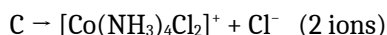
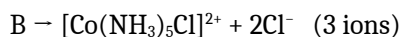
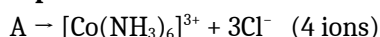
5 × 1 marks

Answer the following questions.

- I** Three coordination compounds of cobalt(III) are given — A: $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$; B: $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$; C: $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$. Which of the three compounds will show maximum electrolytic conductivity, and why? [1]

ANSWER

Compound A shows maximum conductivity.



The greater the number of ions furnished in solution, the higher is the conductivity.

- II** On the basis of crystal field theory, write the electronic configuration for a d^5 ion if $\Delta_o > P$. [1]

ANSWER

$t_{2g}^5 e_g^0$ — a strong field causes pairing within the t_{2g} set, so only one unpaired electron remains.

- III** Using IUPAC norms, write the formula of diaquaquadiammine(oxalato)chromium(III) chloride. [1]

ANSWER



- IV** Compare the optical activity of $[\text{Co}(\text{NH}_3)_2\text{Cl}_2(\text{en})]\text{Cl}$ and $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$. Which one is optically active and why? [1]

ANSWER

$[\text{Co}(\text{NH}_3)_2\text{Cl}_2(\text{en})]\text{Cl}$ is **optically active**; $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ is not. The bidentate ligand **en** can produce a chiral, non-superimposable octahedral arrangement with no internal mirror plane, giving optical isomerism. Complexes with only monodentate ligands, of the type MA_4B_2 , are symmetric and achiral.



- V Explain why $[\text{Cu}(\text{NH}_3)_4]^{2+}$ shows a blue colour while $[\text{Cu}(\text{H}_2\text{O})_4]^{2+}$ shows a greenish colour. Which factor influences the colour difference? [1]

ANSWER

The different ligands (NH_3 and H_2O) produce different crystal field splitting Δ , so the two ions absorb light of different wavelengths and transmit different colours. The factor that controls the difference is the **nature, that is the field strength, of the ligand**, which fixes Δ and hence the energy of the d–d transition.

Marking scheme: 1 mark for each part.

Question 33(A)

3 + 1 + 1 marks

Attempt either A or B.

- I A student investigates the effect of concentration on the cell potential of a Zn–Cu galvanic cell at 298 K. The cell is $\text{Zn(s)} \mid \text{Zn}^{2+}(\text{aq}) \parallel \text{Cu}^{2+}(\text{aq}) \mid \text{Cu(s)}$, with $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76 \text{ V}$, $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34 \text{ V}$ and $E^\circ_{\text{cell}} = 1.10 \text{ V}$. The following experimental data were collected. [3]

Experiment	$[\text{Zn}^{2+}] / \text{M}$	$[\text{Cu}^{2+}] / \text{M}$	Measured EMF / V
1	1.00	1.00	1.10
2	0.1	1.00	1.16
3	1.00	0.10	1.04
4	0.01	1.00	1.22
5	1.00	0.01	0.98

- (a) Why does experiment 4 show the maximum EMF?
 (b) For experiment 3, calculate the theoretical EMF using the Nernst equation. Suggest one possible reason why the measured EMF differs slightly from the calculated value.

ANSWER AND SOLUTION

ANSWER

(a) The cell potential given by the Nernst equation increases as the reaction quotient $Q = [\text{Zn}^{2+}]/[\text{Cu}^{2+}]$ decreases. In experiment 4, $[\text{Zn}^{2+}] = 0.01 \text{ M}$ (very low) and $[\text{Cu}^{2+}] = 1.00 \text{ M}$ (high), so Q is very small, $\log Q$ is large and negative, the $-(0.059/2) \log Q$ term is positive and large, and E is therefore the highest.

(b)

$$E = E^\circ - (0.059/2) \log ([\text{Zn}^{2+}] / [\text{Cu}^{2+}])$$

$$= 1.10 - (0.059/2) \log (1.00 / 0.10) = 1.10 - 0.02955 \times 1$$

$$E = 1.07 \text{ V}$$

The measured EMF differs because, when current flows, the cell has an **internal resistance** — of the electrolyte, the electrodes and the salt bridge — which lowers the observed voltage.

- II If κ is expressed in S m^{-1} and the concentration c in mol m^{-3} , the units of molar conductivity are $\text{S m}^2 \text{ mol}^{-1}$. However, if S cm^{-1} is used for κ and mol cm^{-3} for c , the units of molar conductivity are $\text{S cm}^2 \text{ mol}^{-1}$. Show how $1 \text{ S m}^2 \text{ mol}^{-1}$ is related to $1 \text{ S cm}^2 \text{ mol}^{-1}$. [1]

$$1 \text{ m} = 100 \text{ cm} \Rightarrow 1 \text{ m}^2 = 10^4 \text{ cm}^2$$

$$1 \text{ S m}^2 \text{ mol}^{-1} = 10^4 \text{ S cm}^2 \text{ mol}^{-1} \quad \text{or} \quad 1 \text{ S cm}^2 \text{ mol}^{-1} = 10^{-4} \text{ S m}^2 \text{ mol}^{-1}$$

- III What happens to the specific gravity of the electrolyte in a lead storage battery during charging and discharging of the battery? [1]

ANSWER

During **charging** the specific gravity of the electrolyte **increases**, because H_2SO_4 is regenerated; while **discharging** it **decreases**, because H_2SO_4 is consumed and water is produced.

Marking scheme: I — 1 mark for (a); $\frac{1}{2} + \frac{1}{2}$ marks for the calculation in (b) and $\frac{1}{2}$ mark for the reason. II — 1 mark. III — $\frac{1}{2} + \frac{1}{2}$ marks.

OR



Question 33(B)

3 + 2 marks

- I** For aqueous NaCl at 25 °C the molar conductivities at two concentrations are measured as $\Lambda_m(0.010 \text{ M}) = 123.9 \text{ S cm}^2 \text{ mol}^{-1}$ and $\Lambda_m(0.040 \text{ M}) = 120.7 \text{ S cm}^2 \text{ mol}^{-1}$. Molar conductivity for strong electrolytes can be represented as $\Lambda_m = \Lambda_m^\circ - A\sqrt{c}$. Determine Λ_m° (molar conductivity at infinite dilution) and the constant A for NaCl solution. [3]

For $c_1 = 0.010 \text{ M}$: $123.9 = \Lambda_m^\circ - A(0.100)$... (1)

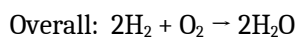
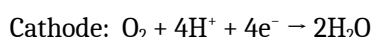
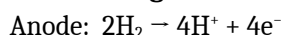
For $c_2 = 0.040 \text{ M}$: $120.7 = \Lambda_m^\circ - A(0.200)$... (2)

Subtracting (2) from (1): $3.2 = 0.100 A \Rightarrow A = 32.0$

Substituting in (1): $\Lambda_m^\circ = 123.9 + 32 \times 0.100 = 123.9 + 3.2$

$$\Lambda_m^\circ = 127.1 \text{ S cm}^2 \text{ mol}^{-1} \text{ and } A = 32.0 \text{ S cm}^2 \text{ mol}^{-1} \text{ M}^{-1/2}$$

- II** Write the electrode reactions that occur in a hydrogen–oxygen fuel cell. Also state two advantages of fuel cells compared to conventional batteries. [2]



In the alkaline cell described in NCERT, where the electrolyte is aqueous KOH or NaOH, the equivalent equations are anode: $2\text{H}_2 + 4\text{OH}^- \rightarrow 4\text{H}_2\text{O} + 4\text{e}^-$; cathode: $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$. Either form is acceptable.

Two advantages of fuel cells

- **Higher efficiency:** fuel cells convert chemical energy into electrical energy more efficiently than conventional batteries.
- **Continuous operation:** as long as fuel (hydrogen) and oxidant (oxygen) are supplied, a fuel cell can operate indefinitely, unlike a battery, which needs recharging.

Marking scheme: I – ½ mark for each equation, ½ mark for A and ½ mark for Λ_m° . II – ½ mark for each electrode reaction and ½ mark for each advantage.

