1 (a)   Lawsone is the dye that is extracted from the henna plant, *Lawsonia inermis.* Although its natural colour is yellow, lawsone reacts with the proteins in hair and skin to produce the characteristic brown henna colour. Compound A is a derivative of lawsone.
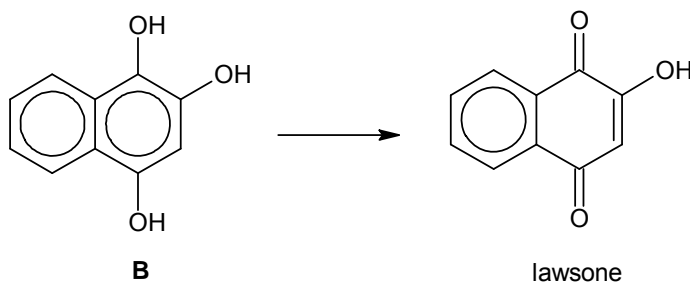

lawsone   A
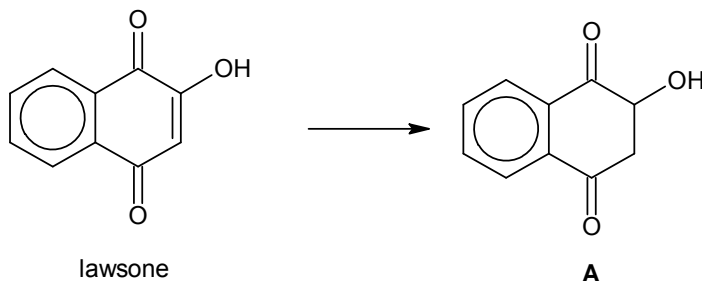
(i)   Name two functional groups in A, other than the phenyl group.

ketone, secondary alcohol

(ii)   Describe a reaction, with reagent and condition(s), to confirm one of the functional groups in A. Describe the observations you would make.

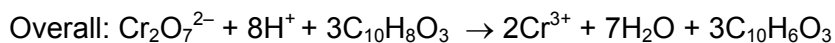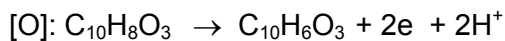| Reagent & conditions	A
Add 2,4–dintrophenylhydrazine.	Orange ppt seen.
Add PCl_5.	White fumes is seen.

(iii) Only one organic compound can be formed when lawsone is reacted with aqueous Br_2, through the loss of one water molecule. Suggest the structural formula of this compound.

or   *or*

[4]
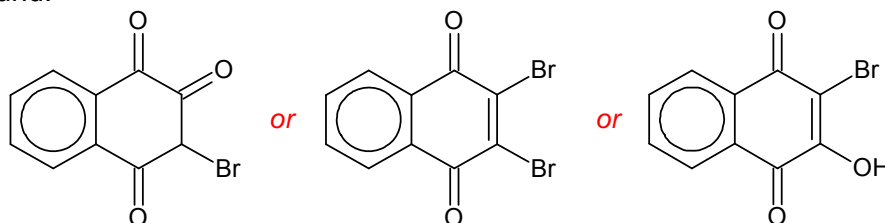
(b)   Compound B can be oxidised to lawsone by acidified $K_2Cr_2O_7$ involving two moles of electrons lost per mole of B.

B   lawsone

(i)   With the use of the *Data Booklet*, construct a balanced half–equation for the oxidation of B and a balanced equation for the overall reaction. You are to use the molecular formulae of lawsone ($C_{10}H_6O_3$), B ($C_{10}H_8O_3$) and $Cr_2O_7^{2-}$ in your equations.

[O]: $C_{10}H_8O_3 \rightarrow C_{10}H_6O_3 + 2e + 2H^+$

Overall: $Cr_2O_7^{2-} + 8H^+ + 3C_{10}H_8O_3 \rightarrow 2Cr^{3+} + 7H_2O + 3C_{10}H_6O_3$

(ii) Calculate the concentration of a solution of compound B given that 20.0 cm^3 of this solution required 12.50 cm^3 of 0.050 mol dm^{-3} $K_2Cr_2O_7$ solution to reach end–point.

[4]

No. of moles of B = $\dfrac{12.50}{1000}$ x 0.050 x 3 = 0.001875 mol
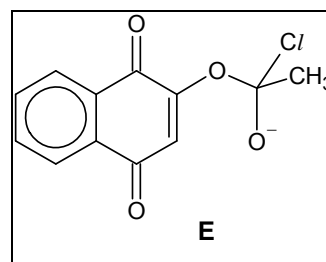
[B] = $\dfrac{0.001875}{20/1000}$ = 0.0938 mol dm^{-3}

(c) When lawsone is reacted under suitable condition, compound C is produced. Reacting C with ethanoyl chloride produces a neutral compound D, with molecular formula $C_{12}H_8O_4$.
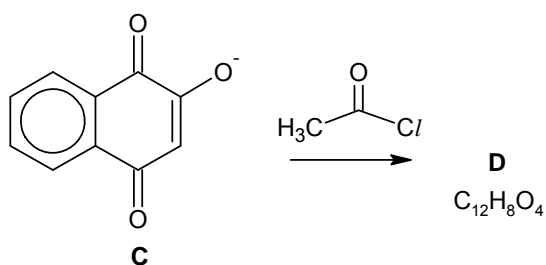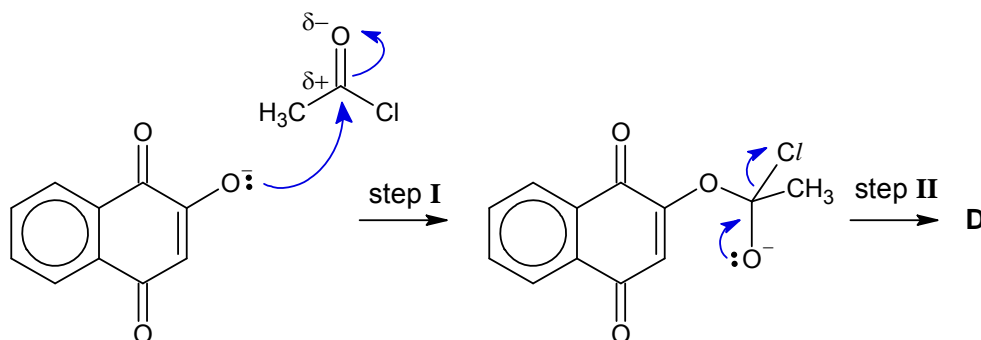

(i) The production of D occurs via a two–step mechanism.

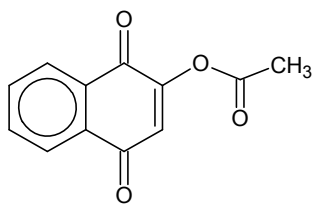Step I: B and ethanoyl chloride reacts to form an intermediate E as shown.

Step II: A chloride ion is eliminated to form D.

Outline the two mechanism steps by drawing relevant curly arrows, partial charges and lone pair of electrons in your answer. Label the steps clearly.
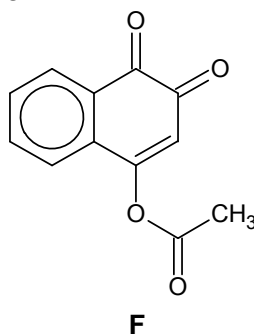
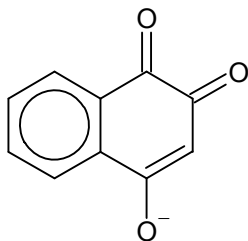(ii)   Hence or otherwise, draw the structural formula of D.

[3]

(d)   Another compound F, in addition to D, is also produced in the above reaction involving C and ethanoyl chloride.

F

(i)   Draw the structure of the nucleophile, G, involved in the formation of F.

(ii)   Hence, suggest with the use of curly arrows, to show how G is formed from C.

[2]
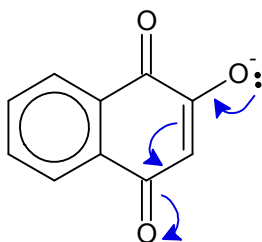
[2]

(e)   When added to silver nitrate solution, ethanoyl chloride forms a white precipitate, while ethanoyl bromide forms a cream precipitate.

(i)   Identify the precipitates.

AgCl and AgBr

(ii)   Write an equation for the formation of white precipitate from ethanoyl chloride.

$CH_3COCl + Ag^+ + H_2O \rightarrow CH_3COOH + AgCl + H^+$

(iii)   State and explain which of the two precipitate will be soluble in aqueous ammonia.

AgCl will be soluble in aqueous ammonia.

$AgCl(s) \rightleftharpoons Ag^+ (aq) + Cl^- (aq)$ ———— (1)

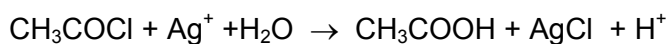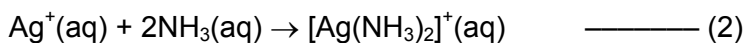$Ag^+(aq) + 2NH_3(aq) \rightarrow [Ag(NH_3)_2]^+(aq)$ ———— (2)

This enables aqueous NH_3 to react with free Ag^+ to form the soluble diammine complex $/[Ag(NH_3)_2]^+$. By Le Chateliers' Principle, equilibrium (1) shift right to increase $[Ag^+]$ hence AgCl dissolves.

The K_{sp} value of AgBr is lower than that of AgCl.

Thus there is a lower concentration of $Ag^+(aq)$ present in the solution which does not allow the formation of the soluble complex to bring about significant shift in equilibrium (1) to the right.

[7]
[Total: 20]

2   (a)   Over 80% of all lead produced ends up in lead–acid batteries, with lead metal and lead(IV) oxide used in them. In addition to starter batteries for road vehicles, lead and lead(IV) oxide are also used for zero emission and hybrid vehicles. The extraction of lead from its ore, galena (which is lead(II) sulfide, PbS), involves several processes.

Firstly, lead(II) sulfide is roasted in air to form lead(II) oxide (PbO) and sulfur dioxide. The lead(II) oxide is heated with coke (carbon) and air in a blast furnace. Some of the coke forms carbon monoxide, both carbon and carbon monoxide react with lead(II) oxide to form lead.

(i)   Write an equation for the reaction that occurs during roasting.

$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$
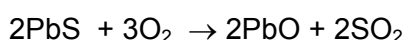
(ii)   What is the compound that can be formed when sulfur dioxide is added to water? Determine the colour of universal indicator in the solution obtained when this compound is added to water.

$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$
Red
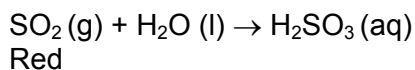
(iii) Identify the type of reaction that occurs to lead(II) oxide in the blast furnace.

Reduction

(iv)   Deduce two equations for the reactions in which lead is formed in the blast furnace.

$PbO + C \rightarrow Pb + CO_;$
$PbO + CO \rightarrow Pb + CO_{2;}$
$2PbO + C \rightarrow 2Pb + CO_2$
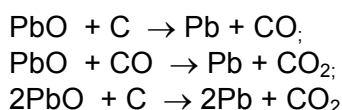
[6]

(b)   Silver is an impurity present in lead obtained from the blast furnace. It is removed

by a technique known as the Parkes process. In one of the steps, zinc is added to the lead and silver mixture. The mixture is then heated to a certain temperature, T, so that silver dissolves in zinc to form an alloy crust that floats. This separates silver from lead, allowing silver to be removed.

The Parkes process depends on the following:
- lead and zinc are almost immiscible just above their melting points
- silver is much more soluble in zinc than in lead
- silver/zinc alloys have higher melting points than pure zinc

Use the following data to answer the following questions:

metal	melting point /°C	boiling point /°C	density of metal at melting point /g cm^{-3}
lead	328	2023	10.7
silver	1233	2435	9.32
zinc	693	1180	6.57

(i) Give a reason why lead and zinc are almost immiscible above zinc's melting point.

They are of different densities/ lead is denser than zinc.

(ii) Suggest a suitable value for temperature T.

700 °C *or* any value from 693 – 1180 °C.

[Note: Temperature must be above melting point of zinc but below melting point of Ag so that it exists as liquid to dissolve solid silver.]

(iii) Suggest how silver can be recovered from the silver–zinc alloy crust.

Heat the alloy to above boiling point of zinc so that it distils off, leaving the solid silver.

(iv) At a constant temperature, silver distributes itself between two immiscible solvents in such a way that the ratio of its concentration in two solvents is a constant. At 800 °C, this constant is given as:

$$\frac{\text{concentration of Ag in molten zinc}}{\text{concentration of Ag in molten lead}} = 300$$

where concentration is measured in g cm^{-3}.

Determine the mass of silver that can be extracted with zinc when 2% zinc by mass is added to 1 kg of the lead mixture containing 0.2% silver by mass as impurity. Assume that densities of zinc and lead at 800 °C are the same as that given in the table.

Mass of zinc added = 2% x 1000 = 20 g
Mass of silver = 0.2% x 1000 = 2 g

Volume of 20 g zinc = mass/density = 20/6.57 = 3.044 cm^3
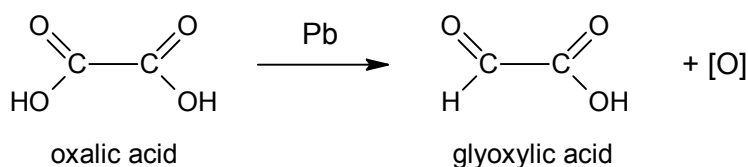Volume of 1 kg Pb = mass/density = (97.8% x 1000)/10.7 = 91.401 cm^3

Let mass of silver extracted with zinc be *y* g.

$$\text{concentration of Ag in molten zinc} \over \text{concentration of Ag in molten lead}} = \frac{y/3.044}{(2-y)/91.401} = 300$$

$y = 1.814 \cong 2.22$ g

[6]

(c)   Lead cathodes are used with an acidic electrolyte in the organic synthesis of glyoxylic acid from oxalic acid.

oxalic acid   glyoxylic acid

(i)   Give the IUPAC name of oxalic acid.

ethanedioic acid

(ii)   Glyoxylic acid has a pK_a value of 3.32.
Define pK_a and hence determine the acid dissociation constant of glyoxylic acid, giving its unit.

$pK_a = -\log_{10} K_a$

$K_a = 10^{-3.32} = 4.79 \times 10^{-4}$ mol dm^{-3}

(iii)   Which is a stronger acid, glyoxylic or ethanoic acid? Explain your answer.

Glyoxylic acid is a stronger acid as the adjacent electron withdrawing carbonyl group disperses the negative charge on its conjugate base and hence stabilising it.

Or
Ethanoic acid is a weaker acid as the adjacent electron donating alkyl/methyl group intensifies the negative charge on its conjugate base and hence destabilising it.

(iv)   Name the type of reaction involved when glyoxylic acid reacts with hydrocyanic acid, HCN in the presence of trace amount of sodium cyanide. Describe the mechanism of this reaction with relevant equations, partial charges and arrows showing movement of electrons.

Nucleophilic addition.

Mechanism:
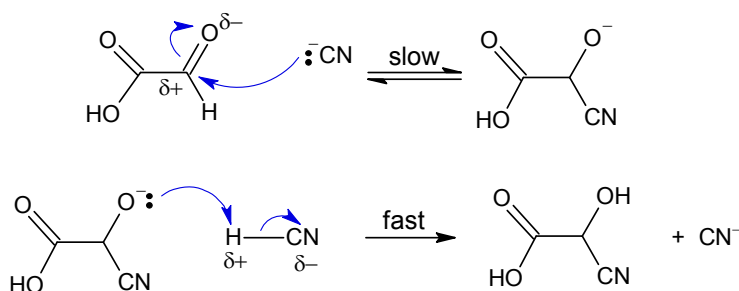
[8]
[Total: 20]

3 (a) The standard enthalpy change of formation of solid Al_2Cl_6 is found to be -1364.2 kJ mol^{-1} using the following data:

	ΔH^{θ} / kJ mol^{-1}
Al_2Cl_6 (s) $\rightarrow Al_2Cl_6$ (aq)	-650
H_2 (g) + Cl_2 (g) $\rightarrow$ 2HCl (g)	-184
HCl (g) $\rightarrow$ HCl (aq)	-72.7
2Al (s) + 6HCl (aq) $\rightarrow Al_2Cl_6$ (aq) + 3H$_2$ (g)	-1026

(i) State Hess' Law.

Hess' Law: The enthalpy change accompanying a chemical reaction is the same regardless of the route by which the chemical change occurs, provided the initial and final conditions are the same.

(ii) Use the set of data and an appropriate energy cycle to verify the standard enthalpy change of formation value of solid Al_2Cl_6. Label the ΔH^{θ} values clearly in your cycle.
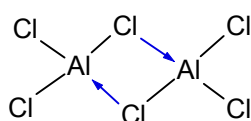
[4]
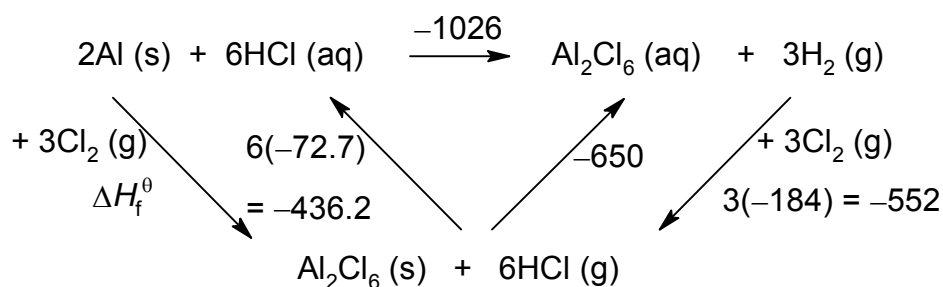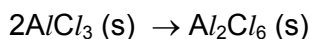

$-1026 = \Delta H_f^{\theta} - 6(-72.7) -650 -3(-184)$
$\Delta H_f^{\theta} = -1026 + 6(-72.7) + 650 +3(-184) = -1364.2$ kJ mol^{-1} (shown)

(b) Dimerisation of $AlCl_3$ in the gaseous state produces Al_2Cl_6.
(i) Draw the structure of Al_2Cl_6.

(ii) Given that the standard enthalpy change of formation of solid $AlCl_3$ is -705.6 kJ mol^{-1}, calculate the standard enthalpy change for the following reaction.

$$2AlCl_3 \text{ (s) } \rightarrow Al_2Cl_6 \text{ (s)}$$

$\Delta H^{\theta}_r = -1364.2 - 2(-705.6) = +47.0 \text{ kJ mol}^{-1}$

(iii)   Consider your answer in (i) and suggest with reasoning if the enthalpy value that you have determined in (ii) is as expected.

Unexpected as reaction is brought about by bond formation which should be an overall exothermic process with a negative enthalpy change.

(iv)   The standard entropy change of reaction for the dissociation of Al_2Cl_6 molecules into $AlCl_3$ molecules is $+88.0 \text{ J mol}^{-1} \text{ K}^{-1}$. Use your answer in (ii) to determine ΔG^{θ} of the dimerisation reaction. What is the significance of the sign of your answer?

$\Delta G^{\theta} = \Delta H^{\theta} - T\Delta S^{\theta}$
$= +47 - 298(-88 \times 10^{-3}) = +73.2 \text{ kJ mol}^{-1}$

Since $\Delta G_r > 0$ (positive), reaction is non–spontaneous.

[5]

(c)   Aluminium sulfate is the active ingredient in styptic pencils, which can be used to stop bleeding from small cuts. The Al^{3+} ions induce coagulation in the blood, which facilitates formation of a blood clot.

(i)   Suggest how Al^{3+} ions induce coagulation in blood.

- Al^{3+} ions can disrupt ionic linkages in blood protein. *or*
- Al^{3+} ions may also react with and disrupt disulfide bridges to form stable metal–sulfur salt bridges, resulting in precipitation of the protein. *or*
- Al^{3+} ions can also react with –SH groups of cysteine residues to form stable metal–sulfur salt bridges.

(ii)   It is also possible that the low pH of an aqueous solution of Al^{3+} brings about blood clotting. Write an equation to account for the low pH and explain how this happens.

$[Al(H_2O)_6]^{3+} \text{ (aq)} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} \text{ (aq)} + H^+ \text{ (aq)}$
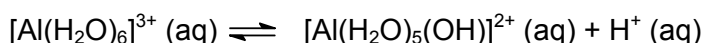
Reason:
High charge density of hydrated Al^{3+} ion enables it to attract electrons away from one of its surrounding water molecules, thereby polarising and weakening the O–H bond which results in the release of a proton.

(iii)   Hence determine the equilibrium constant for the reaction in (ii) for a 0.10 mol dm^{-3} aqueous solution of Al^{3+} with a pH of 2.95.

$$K_c = \frac{[[Al(H_2O)_5(OH)]^{2+}][H^+]}{[[Al(H_2O)_6]^{3+}]}$$

$$= \frac{(10^{-2.95})^2}{(0.10 - 10^{-2.95})} = 1.27 \times 10^{-5} \text{ mol dm}^{-3}$$

[5]

(d)   Alcohols can react with aluminium in the same way as it does with sodium metal.

(i)   Write the structural formula of the organic product obtained with propan–1–ol reacts with aluminium.

$CH_3CH_2CH_2O^-$ or $(CH_3CH_2CH_2O^-)_3Al^{3+}$
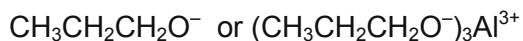
(ii) In the Meerwein–Ponndorf–Verley reaction shown below, ethoxide $(CH_3CH_2O^-)$ reduces 1–phenylethanone to an alcohol and itself oxidised to an aldehyde.

1–phenylethanone
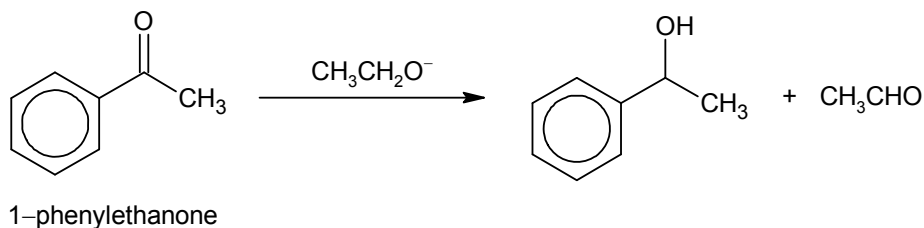
Use this reaction to devise a 2–step synthesis of 1–phenylpropene, starting from a suitable phenylketone and propan–1–ol. Include in your answers, suitable reagents and conditions and any organic compounds formed.
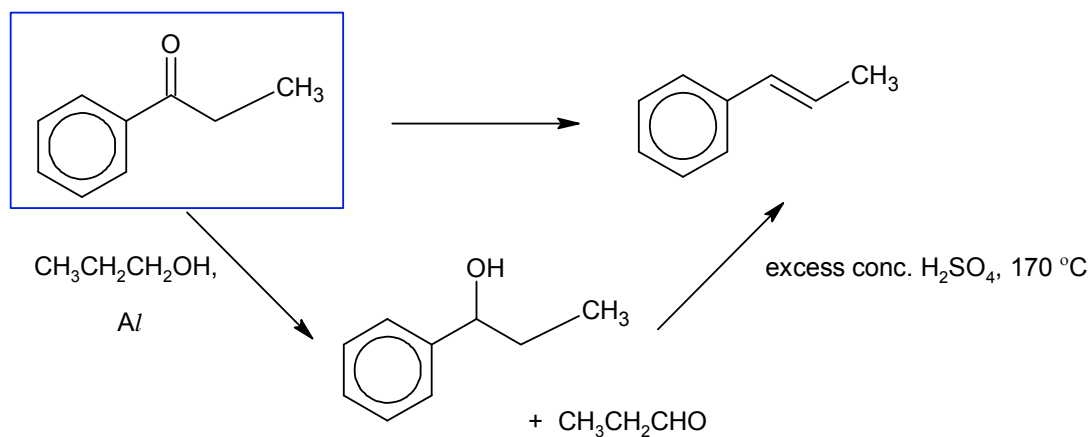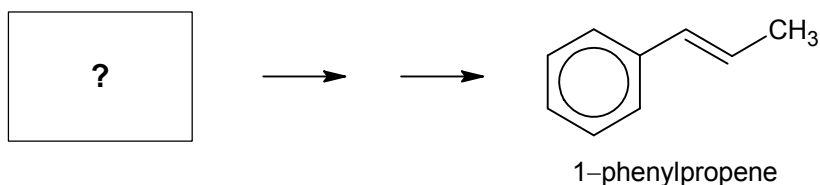
1–phenylpropene

(iii) 1–phenylpropene reacts with both HC*l* and HBr at different rates. Predict, with reasoning, which halide will react faster.

The slow step of this electrophilic addition reaction mechanism involves breaking of H–X bond and since
- Bond length: HBr > HC*l*
- Bond strength: HBr < HC*l*
HBr will react faster as less energy is needed to break the HBr bond.

[6]
[Total: 20]

4   Iron, the most common element on Earth, has an important role in biological systems and is found in a variety of chemical compounds.

(a) Iron can be found in seaweed as Fe(II) or Fe(III) cations. The total iron content of a

seaweed sample can be determined in the laboratory using volumetric analysis.

Dilute sulfuric acid is added to 100 g of seaweed and the mixture is filtered. The resulting filtrate is divided into two 25.0 cm^3 portions for analysis.

The first portion is titrated with 0.0005 mol dm^{-3} $KMnO_4$ and 1.70 x 10^{-5} mol of Fe^{2+} is found to be present. The second portion is treated with excess zinc, filtered, and titrated with the same 0.0005 mol dm^{-3} $KMnO_4$. A total of 10.25 cm^3 is required to reach the end–point.

(i)   With reference to the *Data Booklet*, explain the reaction between zinc and Fe^{3+}.

From Data Booklet,

$$E^{o}/V$$
$$Fe^{3+} + e \rightleftharpoons Fe^{2+} \qquad +0.77$$
$$Zn^{2+} + 2e \rightleftharpoons Zn \qquad -0.76$$
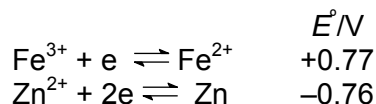
E^{o}_{cell} = +0.77 – (–0.76) = +1.53 V
Since E^{o}_{cell} is greater than 0, reaction is feasible. Redox reaction takes place. Zinc is oxidised to Zn^{2+} while Fe^{3+} is reduced to Fe^{2+}.

(ii)   Calculate the concentration of Fe^{3+} dissolved in dilute sulfuric acid in the second portion.

No. of moles of $KMnO_4$ used in second portion
= $\dfrac{10.25}{1000} \times 0.0005$ = 5.125 x 10^{-6} mol

Total amount of Fe^{2+} and Fe^{3+} present
= 5.125 x 10^{-6} x 5 = 2.562 x 10^{-5} mol

No. of moles of Fe^{3+} present
= 2.562 x 10^{-5} – 1.70 x 10^{-5} = 8.625 x 10^{-6} mol

Concentration of Fe^{3+} = $\dfrac{8.625 \times 10^{-6}}{0.025}$ = 3.45 x 10^{-4} mol dm^{-3}

(iii)   Given that the recommended total iron content for a three–year–old child is 0.007 g, determine the mass of seaweed required daily if the child does not eat any other source of iron.

Mass of Fe found in 100g of seaweed
= (2.562 x 10^{-5} x 2) x 55.8 = 0.002859 g

Mass of seaweed required by child
= $\dfrac{0.007}{0.002859} \times 100$ = 244.8 g = 245 g (3s.f.)

[5]

(b)   Iron is important in biological systems as it is found in haemoglobin, the oxygen transport protein. Explain qualitatively, the toxic nature of carbon monoxide by considering its ligand exchange with oxygen.

In haemoglobin molecule, the Fe^{2+} ion is coordinated to five nitrogen atoms. The sixth coordination site is occupied by a H_2O ligand. The H_2O ligand may be replaced by an O_2 ligand to form oxy–haemoglobin in a reversible ligand exchange

reaction.

The H_2O ligand may also be irreversibly replaced by a stronger CO ligand, preventing oxygen molecules from binding to the Fe^{2+} ion in haemoglobin to form oxy–haemoglobin.

[2]

(c)   Iron and its compounds have also been used in organic synthesis. An example involving a nitrile compound H is shown below.
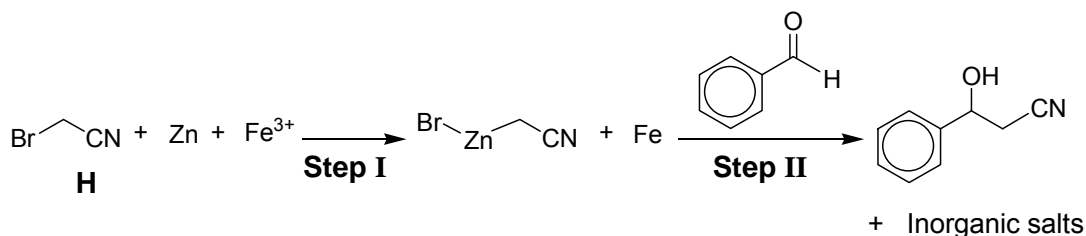

(i)   State the type of reaction in Step II.
Nucleophilic addition

(ii)   The final product can exist in two isomeric forms which rotates plane polarised light in opposite directions. Using an appropriate representation, draw the isomers.
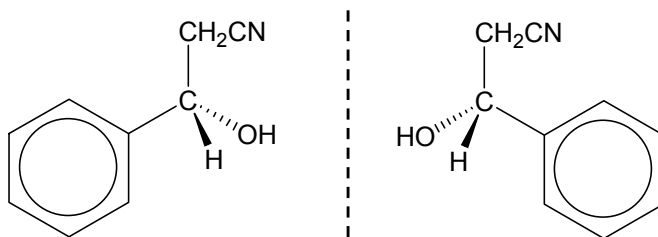
(iii)   In the presence of $FeBr_3$, H and benzaldehyde can react differently to produce a disubstituted aromatic ring. The reaction mechanism is similar to the $AlBr_3$ catalysed reaction of Br_2 and benzene.

Describe the mechanism of H and benzaldehyde catalysed by $FeBr_3$.

$BrCH_2CN + FeBr_3 \rightarrow FeBr_4^- + {}^+CH_2CN$
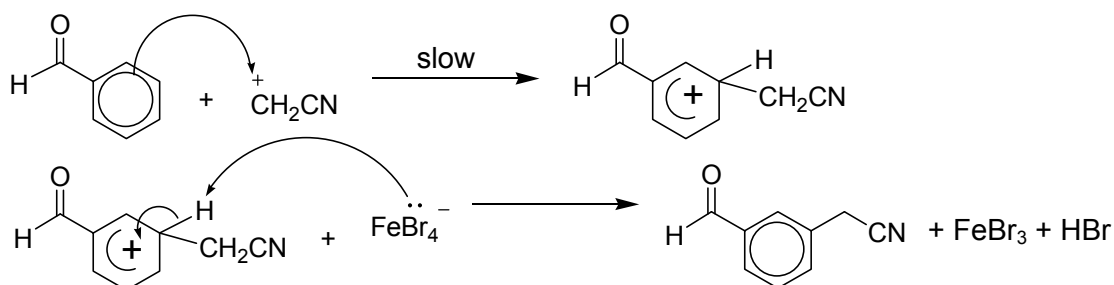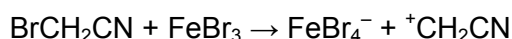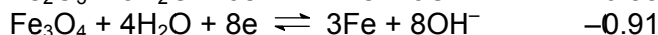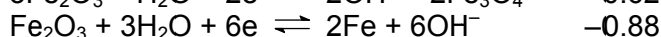

[4]

(d)   *Use of the Data Booklet is relevant to parts of this section.*

Iron is used to make many household items. In a humid environment, rusting occurs easily. There are two forms of rust, red rust, Fe_2O_3, and black rust, Fe_3O_4. Red rust is responsible for "rusty" household items. The following shows some standard electrode potentials involving both forms of rust.

E^{θ}/V

$$3Fe_2O_3 + H_2O + 2e \rightleftharpoons 2OH^- + 2Fe_3O_4 \quad -0.62$$
$$Fe_2O_3 + 3H_2O + 6e \rightleftharpoons 2Fe + 6OH^- \quad -0.88$$
$$Fe_3O_4 + 4H_2O + 8e \rightleftharpoons 3Fe + 8OH^- \quad -0.91$$

The following shows a "Do–It–Yourself" setup to remove rust from household tools. After the power has been turned on for a few hours, the iron sheet *will be sacrificed* and the rusty tool will be coated with a black layer.
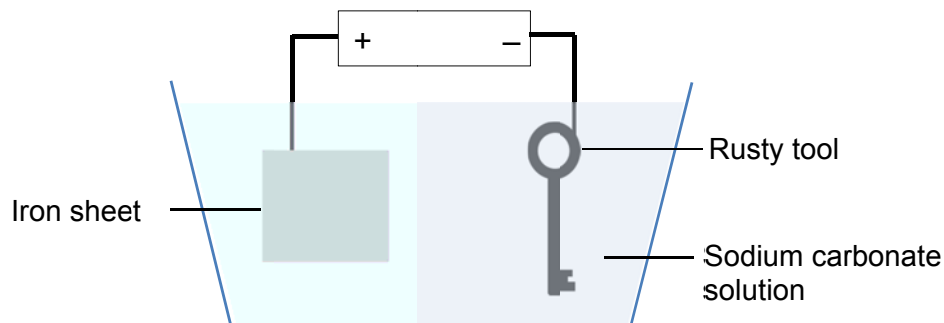
Note: Iron sheet contains trace amounts of zinc and chromium impurities.

(i) State if the iron sheet is the cathode or the anode, and explain why it *will be sacrificed* in this process.

$$E^{\circ}/V$$
$$O_2 + 2H_2O + 4e \rightleftharpoons OH^- \quad +0.40$$
$$Fe^{2+} + 2e \rightleftharpoons Fe \quad -0.44$$
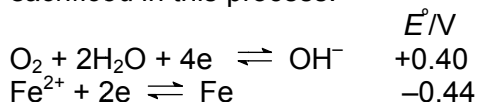
Since $E^{\circ}_{Fe2+/Fe}$ is more negative than $E^{\circ}_{O2/OH-}$, Fe is preferentially oxidised to Fe^{2+}. The iron sheet acts as the anode and will reduce in size as the time progresses. Carbonate anions present in the solution will not be oxidised as carbon is at the maximum oxidation state of +4.
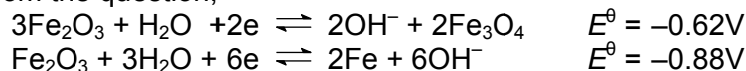
(ii) A handyman prepares the above setup with a 50 A power source, and turns it on for 15 hours. Determine the mass of the iron sheet *sacrificed*.

No. of moles of iron reduced = $\dfrac{50 \times 15 \times 60 \times 60}{2 \times 96500} = 13.98$ mol

Mass of iron sheet required = 13.98 x 55.8 = 781 g

(iii) With reference to the standard electrode potentials given above, state and explain the identity of the black layer formed after the process. Deduce if it is possible to regenerate pure iron on the household tool.
Using data from the question,

$$3Fe_2O_3 + H_2O + 2e \rightleftharpoons 2OH^- + 2Fe_3O_4 \quad E^{\theta} = -0.62V$$
$$Fe_2O_3 + 3H_2O + 6e \rightleftharpoons 2Fe + 6OH^- \quad E^{\theta} = -0.88V$$

The black layer is black rust, Fe_3O_4. Since $E^{\circ}_{Fe2O3/Fe3O4}$ is more positive/less negative than $E^{\circ}_{Fe2O3/Fe}$, Fe_2O_3 will be reduced to Fe_3O_4 and not to Fe.

$$Fe_3O_4 + 4H_2O + 8e \rightleftharpoons 3Fe + 8OH^- \quad E^{\theta} = -0.91V$$
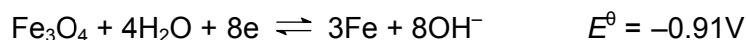
It is not possible to regenerate pure iron as the reduction potential $E^{\circ}_{Fe3O4/Fe}$ is the least positive/most negative, thus Fe_3O_4 will not be further reduced.

Note: Not necessary to copy data from question into answer.

(iv) Small amounts of chromium and zinc are also found to be coated on the tool after 15 hours. Briefly explain how the coating could have occurred.

Chromium and zinc were oxidised at the anode to form Cr^{3+} and Zn^{2+} respectively. These ions were reduced at the cathode and coated onto the tool.

[6]

(e) Iron(III) fluoride is a powerful dehydrating agent and is used in the production of ceramics. Its solubility product is 1.14×10^{-7} mol^4 dm^{-12}.

(i) Calculate the solubility of iron(III) fluoride in pure water.

$Ksp = [Fe^{3+}][F^-]^3$
Solubility of iron(III) fluoride in pure water

$= \sqrt[4]{\dfrac{1.14 \times 10^{-7}}{27}} = 0.00806$ mol dm^{-3}

(ii) Determine if a precipitate will be obtained when 10 cm^3 of 0.26 mol dm^{-3} iron(III) nitrate is added to 10 cm^3 of 0.182 mol dm^{-3} sodium fluoride.

Ionic product $= (\dfrac{0.26}{2})(\dfrac{0.182}{2})^3 = 9.80 \times 10^{-5}$ mol^4 dm^{-12}

Since ionic product > Ksp, precipitate will be obtained.

[3]
[Total: 20]

5 Acids and bases play a variety of roles in both organic and inorganic chemistry as exemplified by the following.

(a) Using the Bronsted–Lowry Theory, define a base, and state an example of a conjugate acid–base pair.

A base is a substance that can accept a proton from another substance in solution. For example OH^- (base) and H_2O (conjugate acid).

[2]

(b) Bases are common reagents in organic chemistry, and are often used in the formation of enolates. Enolates are the deprotonated anions of hydroxy alkenes. They are important intermediates in many carbon–carbon bond forming reactions, and are in equilibrium with the corresponding carbonyl compound as shown below.

enolate
R' = alkyl or alkoxyl group (e.g. $-OCH_3$)
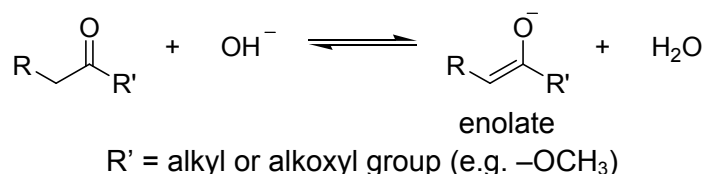
(i) In neutral conditions, the enolate concentration is very low. Suggest why reactions involving enolates are often carried out under basic conditions.

In basic conditions, $[OH^-]$ is high. By Le Chatelier's Principle, equilibrium shifts right to decrease $[OH^-]$. Concentration of enolate increases thus rate of reactions increases.

(ii) Methyl propanoate can be converted to its lithium enolate for further carbon–carbon bond forming reactions. Draw the structure of the lithium enolate formed.
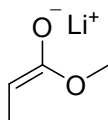
(iii) The lithium enolate of methyl propanoate was reacted to form compound J.

J is a neutral compound which does not react with 2,4–dinitrophenylhydrazine. When refluxed with acidified $K_2Cr_2O_7$, a colour change and effervescence is observed. The gas liberated produces a white precipitate with aqueous calcium hydroxide. More effervescence is observed when aqueous sodium carbonate is added to the remaining products.

J decolourises liquid bromine to give K, $C_6H_{10}Br_2O_2$. J also reacts with cold dilute alkaline $KMnO_4$ to give L, $C_6H_{12}O_4$. When heated with aqueous alkaline iodine, hydrolysis and oxidation occurs. L then gives a yellow precipitate and 2–hydroxy–2–methyl–propandioate as products.
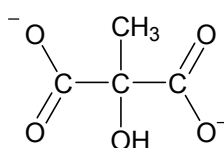
2–hydroxy–2–methyl–propandioate

Deduce with explanations, the structures of J, K and L.

- J does not undergo condensation with 2,4–dinitrophenylhydrazine.
  ⇒J is not ketone nor aldehyde.

- J undergoes hydrolysis with acidified $K_2Cr_2O_7$ to produce carboxylic acid and alcohol.
  ⇒ Jis an ester.

- J produced an alcohol which can be oxidised to carbon dioxide.
  ⇒ J is a methyl ester. The methanol produced from hydrolysis was oxidised to carbon dioxide.

- J undergoes electrophilic addition with liquid bromine to give K.
  ⇒ J is an alkene or K is a halogenoalkane.

- J undergoes oxidation with cold dilute $KMnO_4$ to give T.
  ⇒ J is an alkene or L is a diol.

- L undergoes hydrolysis and oxidation with aqueous alkaline iodine.
  ⇒ L contains the structure $CH_3CH(OH)$–R.

J   K   L
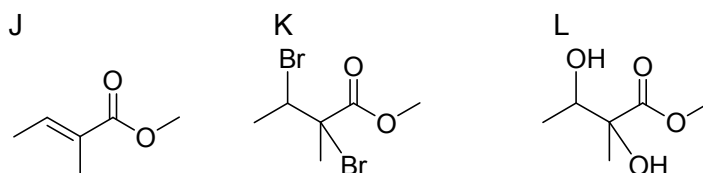
[10]

(c) Basic solutions can be formed from the reactions of Group II metals and water. Describe the reactivity and observations of Group II metals with water. Write the equation for the reaction of water with magnesium, including state symbols.

Berylium does not react with water. Magnesium reacts very slowly with cold water, but rapidly with steam to form magnesium oxide. Calcium, strontium and barium reacts vigourously with water to give aqueous hydroxides and hydrogen gas. Reactivity of Group(II) metals with cold water increases down the group.
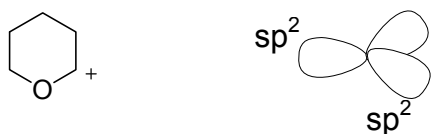
Mg (s) + H_2O (g) → MgO (s) + H_2 (g)
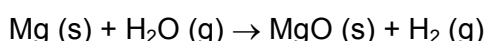
[3]

(d) Aqueous acids can react with alkenes.

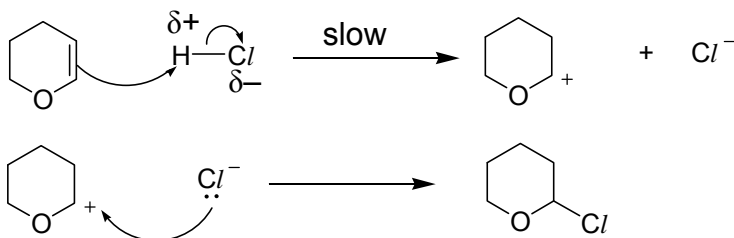The reaction between hydrochloric acid and cyclic alkene M is as shown below.
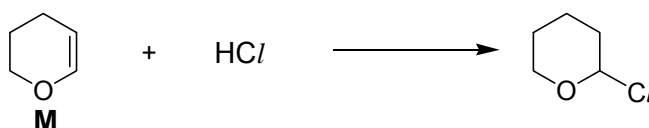
(i) Draw the structure of the reactive intermediate, and the hybrid orbitals of the reaction centre.

sp^2

(ii)   Hence, outline the mechanism of the above reaction.

(iii) Suggest why methanol is more soluble in water than cyclic alkene M.

Both methanol and M are simple molecules and can form hydrogen bond with water molecules. However, M has a larger alkyl group. The van der Waals' forces of attraction between molecules of M are more prominent, and interfere with the hydrogen bonding between M and water molecules.

[5]
[Total: 20]