1 Sulfuric acid is manufactured by the Contact Process.

1 (a) In this process, sulfur dioxide reacts with oxygen.
The equation for the equilibrium that is established is

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H = -98\ kJ\ mol^{-1}$$

1 (a) (i) State and explain the effect of a **decrease** in temperature on the equilibrium yield of SO_3

Effect of a decrease in temperature on yield .....

Explanation .....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

1 (a) (ii) Give **two** features of a reaction at equilibrium.

Feature 1 .....

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Feature 2 .....

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(2 marks)

1 (b) Write an equation for the reaction of concentrated sulfuric acid with potassium bromide to form potassium hydrogensulfate and hydrogen bromide.

.....

(1 mark)

1 (c) Bromine is one of the products formed when concentrated sulfuric acid reacts with hydrogen bromide.

Write an equation for this reaction.
State the role of sulfuric acid in this reaction.

Equation

.....

Role of sulfuric acid .....

(3 marks)

1 (d) Concentrated sulfuric acid is used in a two-stage process to convert 2-methylpropene into 2-methylpropan-2-ol.

Stage **1** $(CH_3)_2C=CH_2 + H_2SO_4 \longrightarrow (CH_3)_2C(OSO_2OH)CH_3$

Stage **2** $(CH_3)_2C(OSO_2OH)CH_3 + H_2O \longrightarrow (CH_3)_2C(OH)CH_3 + H_2SO_4$

1 (d) (i) Name and outline a mechanism for Stage **1** of this conversion.

Name of mechanism .....

Mechanism

(5 marks)

1 (d) (ii) Deduce the type of reaction in Stage **2** of this conversion.

.....

(1 mark)

1 (d) (iii) State the overall role of sulfuric acid in this conversion.

.....

(1 mark)

2 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair, give a suitable reagent that could be added separately to each compound to distinguish between them.
Describe what you would observe in each case.

2 (a) AgBr(s) and AgI(s)

Reagent .....

Observation with AgBr(s) .....

.....

Observation with AgI(s) .....

.....

(3 marks)

2 (b) HCl(aq) and HNO_3(aq)

Reagent .....

Observation with HCl(aq) .....

.....

Observation with HNO_3(aq) .....

.....

(3 marks)

2 (c) Cyclohexane and cyclohexene

Reagent .....

Observation with cyclohexane .....

.....

Observation with cyclohexene .....

.....

(3 marks)

Haloalkanes are used in the synthesis of other organic compounds.

3 (a) Hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane to form two alkenes that are structural isomers of each other. The major product is 2-methylbut-2-ene.

(a) (i) Name and outline a mechanism for the conversion of 2-bromo-3-methylbutane into 2-methylbut-2-ene according to the equation.

$$(CH_3)_2CHCHBrCH_3 + KOH \longrightarrow (CH_3)_2C{=}CHCH_3 + KBr + H_2O$$

Name of mechanism .....

Mechanism

(4 marks)

(a) (ii) Draw the **displayed formula** for the other isomer that is formed.

(1 mark)

(a) (iii) State the type of structural isomerism shown by these two alkenes.

.....

(1 mark)

(b) A small amount of another organic compound, **X**, can be detected in the reaction mixture formed when hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane.
Compound **X** has the molecular formula $C_5H_{12}O$ and is a secondary alcohol.

(b) (i) Draw the **displayed formula** for **X**.

(1 mark)

(b) (ii) Suggest **one** change to the reaction conditions that would increase the yield of **X**.

.....

.....

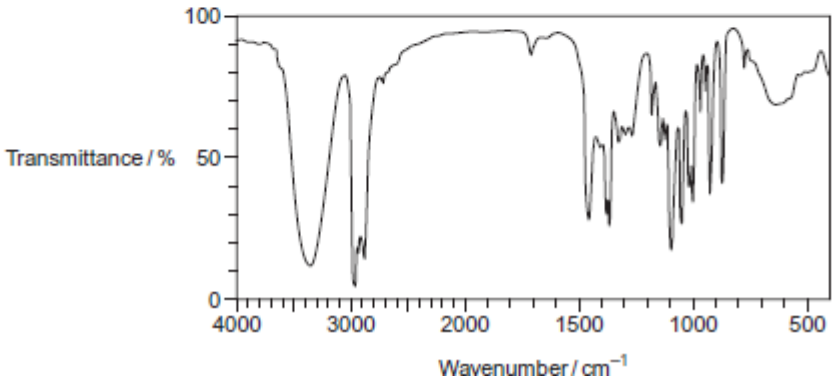
(1 mark)

(b) (iii) State the type of mechanism for the conversion of 2-bromo-3-methylbutane into **X**.

.....

(1 mark)

(b) (iv) Identify **one** feature of this infrared spectrum of a pure sample of **X** that may be used to confirm that **X** is an alcohol.
You may find it helpful to refer to **Table 1** on the Data Sheet.



4 (a) Chlorine displaces iodine from aqueous potassium iodide.

(a) (i) Write the **simplest ionic** equation for this reaction.

.....

(1 mark)

(a) (ii) Give **one** observation that you would make when this reaction occurs.

.....

.....

(1 mark)

(b) In bright sunlight, chlorine reacts with water to form oxygen as one of the products.
Write an equation for this reaction.

.....

(1 mark)

(c) Explain why chlorine has a lower boiling point than bromine.

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.....

.....

.....

(2 marks)

5 Chlorine can be used to make chlorinated alkanes such as dichloromethane.

(a) Write an equation for each of the following steps in the mechanism for the reaction of chloromethane (CH_3Cl) with chlorine to form dichloromethane (CH_2Cl_2).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

The termination step that forms a compound with empirical formula CH_2Cl

.....

(4 marks)

(b) When chlorinated alkanes enter the upper atmosphere, carbon–chlorine bonds are broken. This process produces a reactive intermediate that catalyses the decomposition of ozone. The overall equation for this decomposition is

$$2O_3 \rightleftharpoons 3O_2$$

(b) (i) Name the type of reactive intermediate that acts as a catalyst in this reaction.

.....

(1 mark)

(b) (ii) Write **two** equations to show how this intermediate is involved as a catalyst in the decomposition of ozone.

Equation 1 .....

Equation 2 .....

(2 marks)

6 In each of the following questions, you should draw the structure of the compound in the space provided.

(a) Draw the structure of the alkene that would form 1,2-dibromo-3-methylbutane when reacted with bromine.

(1 mark)

(b) Draw the structure of the alcohol with molecular formula $C_4H_{10}O$ that is resistant to oxidation by acidified potassium dichromate(VI).

(1 mark)

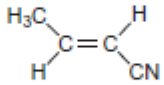
(c) Draw the structure of the alkene that has a peak, due to its molecular ion, at $m/z = 42$ in its mass spectrum.

(1 mark)

(d) Draw the structure of the organic product with $M_r = 73$, made from the reaction between 2-bromobutane and ammonia.

(1 mark)

7 The alkene (*E*)-but-2-enenitrile is used to make acrylic plastics.
The structure of (*E*)-but-2-enenitrile is



(a) (i) Draw the structure of (*Z*)-but-2-enenitrile.

(1 mark)

(a) (ii) Identify the feature of the double bond in the E and Z isomers that causes them to be stereoisomers.

.....

.....

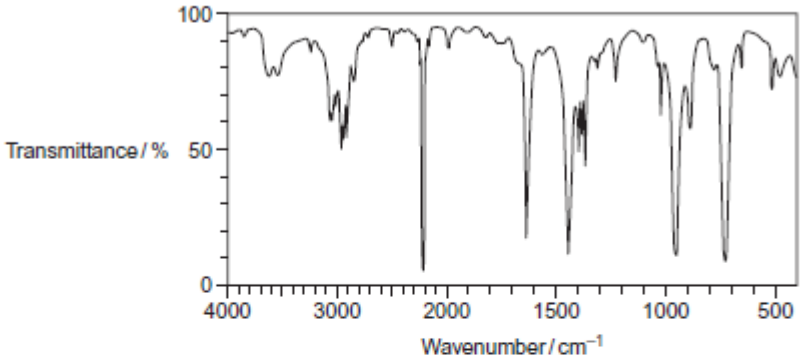
.....

(1 mark)

(b) Draw the repeating unit of the polyalkene formed by addition polymerisation of (*E*)-but-2-enenitrile.

v

(c) Consider the infrared spectrum of (*E*)-but-2-enenitrile.



Identify **two** features of the infrared spectrum that support the fact that this is the infrared spectrum for but-2-enenitrile.
You may find it helpful to refer to **Table 1** on the Data Sheet.

Feature 1 .....

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Feature 2 .....

.....

.....

(2 marks)

(1 mark)