2 Iodine reacts with concentrated nitric acid to produce nitrogen dioxide (NO_2).

(a) (i) Give the oxidation state of iodine in each of the following.

I_2 .....

HIO_3 .....

(2 marks)

(a) (ii) Complete the balancing of the following equation.

$$I_2 + 10HNO_3 \longrightarrow \text{.....}HIO_3 + \text{.....}NO_2 + \text{.....}H_2O$$

(1 mark)

(b) In industry, iodine is produced from the $NaIO_3$ that remains after sodium nitrate has been crystallised from the mineral Chile saltpetre.
The final stage involves the reaction between $NaIO_3$ and NaI in acidic solution.
Half-equations for the redox processes are given below.

$$IO_3^- + 5e^- + 6H^+ \longrightarrow 3H_2O + \tfrac{1}{2}I_2$$

$$I^- \longrightarrow \tfrac{1}{2}I_2 + e^-$$

Use these half-equations to deduce an overall ionic equation for the production of iodine by this process. Identify the oxidising agent.

Overall ionic equation

The oxidising agent .....

(2 marks)

1 (c) State and explain the general trend in the first ionisation energies of the Period 3 elements sodium to chlorine.

Trend .....

Explanation .....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

1 (d) State how the element sulfur deviates from the general trend in first ionisation energies across Period 3. Explain your answer.

How sulfur deviates from the trend .....

.....

Explanation .....

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(3 marks)

(Extra space) .....

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1 (e) A general trend exists in the first ionisation energies of the Period 2 elements lithium to fluorine. Identify **one** element which deviates from this general trend.

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(1 mark)

(c) When concentrated sulfuric acid is added to potassium iodide, solid sulfur and a black solid are formed.

(c) (i) Identify the black solid.

.....

(1 mark)

(c) (ii) Deduce the half-equation for the formation of sulfur from concentrated sulfuric acid.

.....

(1 mark)

(d) When iodide ions react with concentrated sulfuric acid in a different redox reaction, the oxidation state of sulfur changes from +6 to –2. The reduction product of this reaction is a poisonous gas that has an unpleasant smell.
Identify this gas.

.....

(1 mark)

(e) A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

(e) (i) Write the **simplest ionic** equation for the formation of the yellow precipitate.

.....

(1 mark)

(e) (ii) State what is observed when concentrated ammonia solution is added to this precipitate.

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(1 mark)

(e) (iii) State why the silver nitrate is acidified when testing for iodide ions.

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(1 mark)

(f) Consider the following reaction in which iodide ions behave as reducing agents.

$$Cl_2(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$$

(f) (i) In terms of electrons, state the meaning of the term *reducing agent*.

.....

.....

(1 mark)

(f) (ii) Write a half-equation for the conversion of chlorine into chloride ions.

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(1 mark)

(f) (iii) Suggest why iodide ions are stronger reducing agents than chloride ions.

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(2 marks)

(Extra space) .....

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3 The table shows the structures and names of three compounds with M_r = 72.0

Compound	Formula	Name
1	$CH_3CH_2CH_2CHO$	butanal
2	$CH_3CH_2CH_2CH_2CH_3$	pentane
3	$CH_3CH_2COCH_3$	butanone

(a) Explain why M_r values, measured to five decimal places, cannot distinguish between compounds **1** and **3** but can distinguish between compounds **1** and **2**.

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(2 marks)

(b) A simple chemical test, using either Fehling's solution or Tollens' reagent, can be used to distinguish between compound **1** and compound **3**.
Choose one of these two reagents and state what you would observe with each of compound **1** and compound **3**.

Chosen reagent .....

Observation with compound **1**.....

.....

Observation with compound **3**.....

.....

(2 marks)

4 Group 2 elements and their compounds have a wide range of uses.

(a) For parts **(a)(i)** to **(a)(iii)**, draw a ring around the correct answer to complete each sentence.

(a) (i) From $Mg(OH)_2$ to $Ba(OH)_2$, the solubility in water

decreases. / increases. / stays the same.

(1 mark)

(a) (ii) From Mg to Ba, the first ionisation energy

decreases. / increases. / stays the same.

(1 mark)

(a) (iii) From Mg to Ba, the atomic radius

decreases. / increases. / stays the same.

(1 mark)

(b) Explain why calcium has a higher melting point than strontium.

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(2 marks)

(Extra space) .....

(c) Acidified barium chloride solution is used as a reagent to test for sulfate ions.

(c) (i) State why sulfuric acid should **not** be used to acidify the barium chloride.

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(1 mark)

(c) (ii) Write the **simplest ionic** equation for the reaction that occurs when acidified barium chloride solution is added to a solution containing sulfate ions.

.....

(1 mark)

5 It is possible to convert but-1-ene into its structural isomer but-2-ene.

(a) State the type of structural isomerism shown by but-1-ene and but-2-ene.

.....

(1 mark)

(b) The first stage in this conversion involves the reaction of hydrogen bromide with but-1-ene.

$$CH_3CH_2CH{=}CH_2 + HBr \longrightarrow CH_3CH_2CHBrCH_3$$

Outline a mechanism for this reaction.

(4 marks)

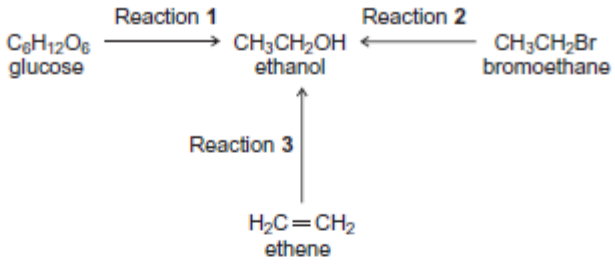
(c) The second stage is to convert 2-bromobutane into but-2-ene.

$$CH_3CH_2CHBrCH_3 + KOH \longrightarrow CH_3CH{=}CHCH_3 + KBr + H_2O$$

Outline a mechanism for this reaction.

(3 marks)

6 Three different ways of producing ethanol are shown below.



(a) Reaction **1** produces a 15% aqueous solution of ethanol.
It is claimed that the ethanol produced in this way is a carbon-neutral biofuel.

Write an equation for Reaction **1** and name the process.

Write an equation for the complete combustion of ethanol.

Explain why the ethanol produced by this process may **not** be a *carbon-neutral* biofuel.

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(5 marks)

(Extra space)

(b) Give a reagent and conditions for Reaction **2**.

$$CH_3CH_2Br \xrightarrow{\text{Reaction 2}} CH_3CH_2OH$$

Name and outline a mechanism for Reaction **2**.

Suggest **one** reason, other than safety, why this method is **not** used in industry to make ethanol.

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(6 marks)

(c) Reaction **3** is used in industry.

$$H_2C{=}CH_2 \xrightarrow{\text{Reaction 3}} CH_3CH_2OH$$

Identify a suitable catalyst for Reaction **3**.

Identify the type of reaction.

Give **two** conditions, in addition to the presence of a catalyst, necessary for Reaction **3** to produce a high yield of ethanol.

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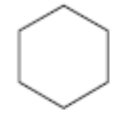
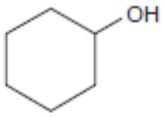
(4 marks)

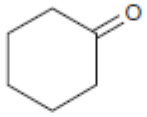
7 Consider the five cyclic compounds, **A**, **B**, **C**, **D** and **E**.



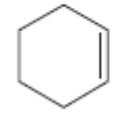
cyclohexane
A



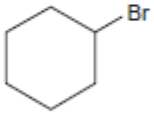
cyclohexanol
B



cyclohexanone
C



cyclohexene
D

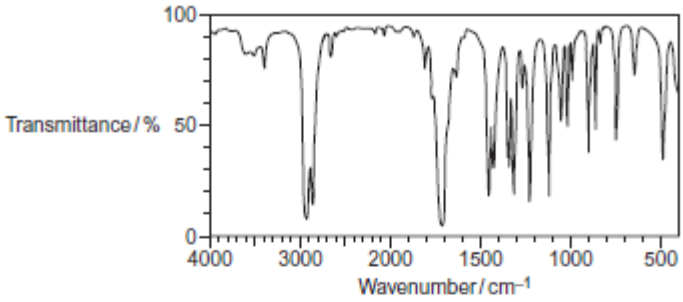


bromocyclohexane
E

(a) The infrared spectra of compounds **A**, **B**, **C** and **D** are shown opposite.

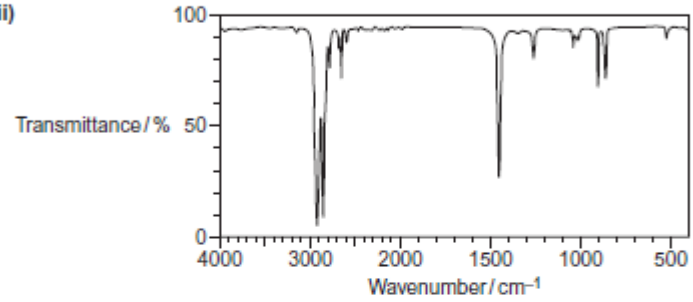
Write the correct letter, **A**, **B**, **C** or **D**, in the box next to each spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

(a) (i)



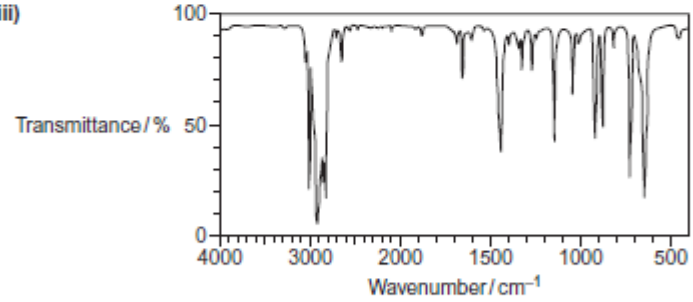
(1 mark)

(a) (ii)



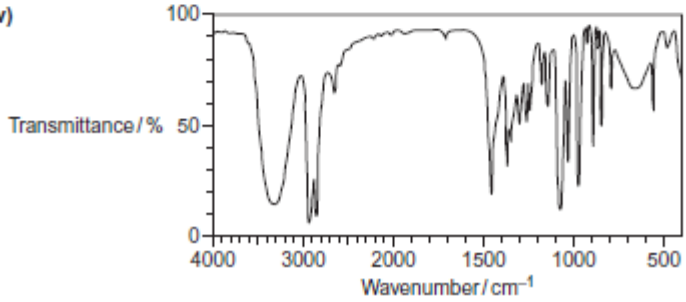
(1 mark)

(a) (iii)



(1 mark)

(a) (iv)



(1 mark)

(b) A simple chemical test can be used to distinguish between cyclohexane (**A**) and cyclohexene (**D**).
Give a reagent for this test and state what you would observe with each compound.

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(3 marks)

(Extra space) .....

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.....

(c) Cyclohexanol (**B**) can be converted into cyclohexanone (**C**).

Give a reagent or combination of reagents that can be used for this reaction and state the type of reaction.

State the class of alcohols to which cyclohexanol belongs.

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(3 marks)

(d) Cyclohexane (**A**) can be converted into bromocyclohexane (**E**) by a reaction that is similar to the reaction of methane either with chlorine or with bromine.

Name and outline a mechanism for the reaction of methane (CH_4) with bromine to form bromomethane (CH_3Br). Give **one** condition for this reaction to occur.
Write an equation for each step in your mechanism.

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(5 marks)