Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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9	
10	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2012

Chemistry CHEM2

Unit 2 Chemistry in Action

Thursday 19 January 2012 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

Do not write outside the box

Section A

Answer **all** questions in the spaces provided.

1 The silicon chip industry requires the production of pure silicon. Silicon is extracted from its ore, silicon dioxide (SiO_2), by a process similar to that used in the extraction of titanium.

1 (a) (i) Write an equation for the formation of $SiCl_4$ from SiO_2 using chlorine and carbon.

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(1 mark)

1 (a) (ii) Suggest how the liquid $SiCl_4$ is purified.

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(1 mark)

1 (b) The final stage in the extraction of silicon involves the use of hydrogen gas to convert the $SiCl_4$ into silicon and hydrogen chloride.

1 (b) (i) Write an equation for this reaction.

.....

(1 mark)

1 (b) (ii) State the role of hydrogen in this reaction.

.....

(1 mark)

1 (b) (iii) Give **one** risk associated with the use of hydrogen gas.

.....

(1 mark)

1 (c) The magnesium used to make magnesium ferrosilicon alloys is extracted from magnesium oxide using silicon.
Write an equation for this reaction to produce magnesium and silicon dioxide.

.....

(1 mark)

6

2 Ammonia is manufactured by the Haber process in which the following equilibrium is established.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

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

Feature 1 .....

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Feature 2 .....

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(2 marks)

2 (b) Explain why a catalyst has no effect on the position of an equilibrium.

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(2 marks)

(Extra space) .....

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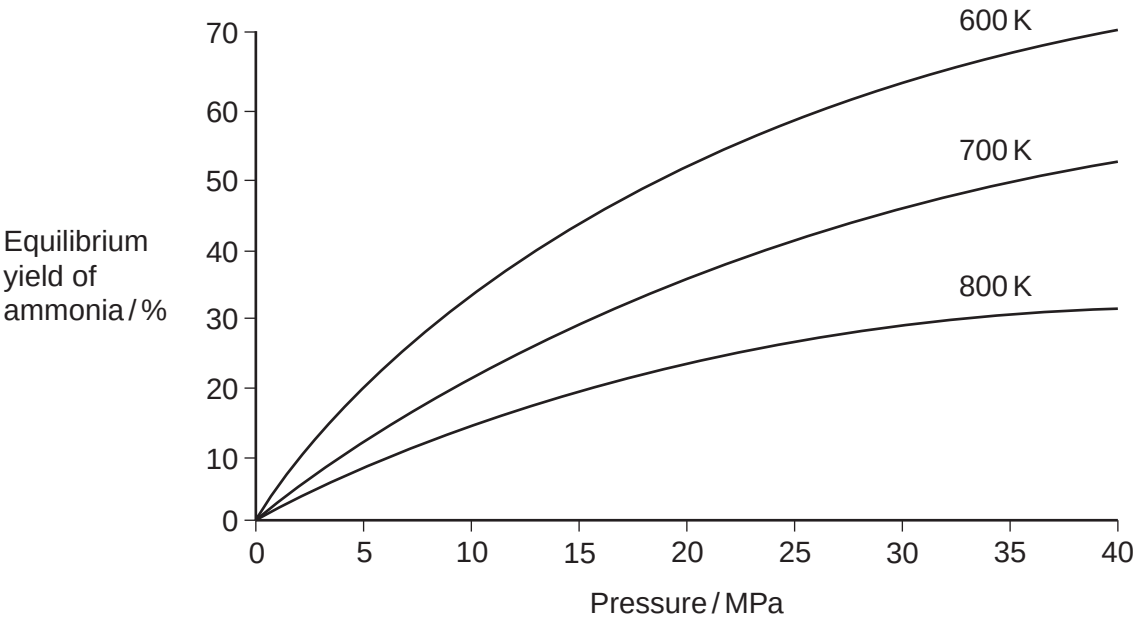
Question 2 continues on the next page

2 (c) The diagram shows how the equilibrium yield of ammonia varies with changes in pressure and temperature.



2 (c) (i) Use the diagram to state the effect of an **increase** in pressure at constant temperature on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield .....

Explanation .....

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(3 marks)

(Extra space) .....

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2 (c) (ii) Use the diagram to state the effect of an **increase** in temperature at constant pressure on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield .....

Explanation .....

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(3 marks)

(Extra space) .....

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2 (d) At equilibrium, with a pressure of 35 MPa and a temperature of 600 K, the yield of ammonia is 65%.

2 (d) (i) State why industry uses a temperature higher than 600 K.

.....

.....

(1 mark)

2 (d) (ii) State why industry uses a pressure lower than 35 MPa.
Do **not** include references to safety.

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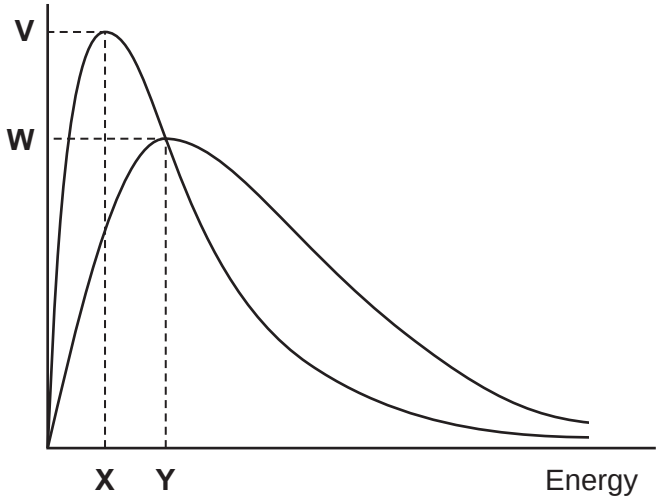
(1 mark)

12

3 The diagram shows the Maxwell–Boltzmann distribution of molecular energies in a gas at two different temperatures.



3 (a) One of the axes is labelled. Complete the diagram by labelling the other axis.

(1 mark)

3 (b) State the effect, if any, of a solid catalyst on the shape of either of these distributions.

.....

.....

(1 mark)

3 (c) In the box, write the letter, **V**, **W**, **X** or **Y**, that represents the most probable energy of the molecules at the lower temperature.

(1 mark)

3 (d) Explain what must happen for a reaction to occur between molecules of two different gases.

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(2 marks)

Do not write outside the box

3 (e) Explain why a small increase in temperature has a large effect on the initial rate of a reaction.

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(1 mark)

6

Turn over for the next question

4 (a) Iron is extracted from iron(III) oxide using carbon at a high temperature.

4 (a) (i) State the type of reaction that iron(III) oxide undergoes in this extraction.

.....

(1 mark)

4 (a) (ii) Write a half-equation for the reaction of the iron(III) ions in this extraction.

.....

(1 mark)

4 (b) At a high temperature, carbon undergoes combustion when it reacts with oxygen.

4 (b) (i) Suggest why it is **not** possible to measure the enthalpy change directly for the following combustion reaction.

$$C(s,graphite) + \tfrac{1}{2}O_2(g) \longrightarrow CO(g)$$

.....

.....

(1 mark)

4 (b) (ii) State Hess's Law.

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(1 mark)

4 (b) (iii) State the meaning of the term *standard enthalpy of combustion*.

.....

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(3 marks)

(Extra space) .....

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4 (c) Use the standard enthalpies of formation in the table below and the equation to calculate a value for the standard enthalpy change for the extraction of iron using carbon monoxide.

	$Fe_2O_3(s)$	$CO(g)$	$Fe(l)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 822	– 111	+14	– 394

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l) + 3CO_2(g)$$

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(3 marks)

(Extra space) .....

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4 (d) (i) Write an equation for the reaction that represents the standard enthalpy of formation of carbon dioxide.

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(1 mark)

4 (d) (ii) State why the value quoted in part **(c)** for the standard enthalpy of formation of $CO_2(g)$ is the same as the value for the standard enthalpy of combustion of carbon.

.....

.....

(1 mark)

12

Turn over ▶

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

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

I_2 .....

HIO_3.....

(2 marks)

5 (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)

5 (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)

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

5 (c) (i) Identify the black solid.

.....

(1 mark)

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

.....

(1 mark)

5 (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)

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

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

.....

(1 mark)

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

.....

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(1 mark)

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

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(1 mark)

Question 5 continues on the next page

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

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

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

.....

.....

(1 mark)

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

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(1 mark)

5 (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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15

Do not write outside the box

6 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

6 (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)

6 (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

Turn over ▶

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

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

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

decreases. / increases. / stays the same.

(1 mark)

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

decreases. / increases. / stays the same.

(1 mark)

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

decreases. / increases. / stays the same.

(1 mark)

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

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(2 marks)

(Extra space) .....

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Do not write outside the box

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

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

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(1 mark)

7 (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.

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(1 mark)

7

Turn over for the next question

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

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

.....

(1 mark)

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

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

Outline a mechanism for this reaction.

(4 marks)

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

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

Outline a mechanism for this reaction.

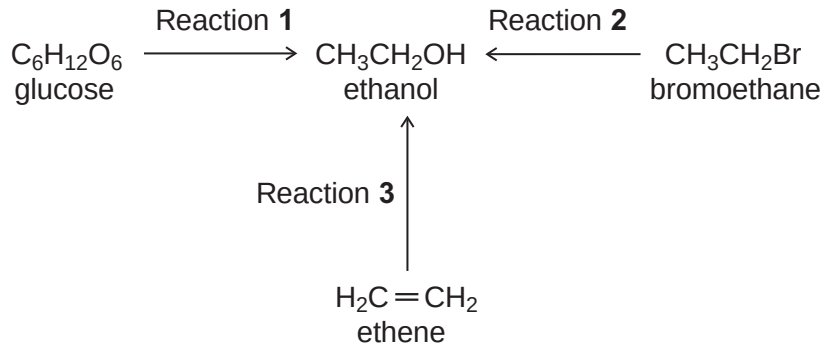
(3 marks)

8

Section B

Answer **all** questions in the spaces provided.

9 Three different ways of producing ethanol are shown below.



9 (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) .....

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Question 9 continues on the next page

Turn over ▶

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

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

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)

(Extra space) .....

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

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

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)

(Extra space) .....

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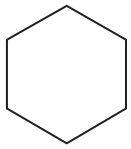
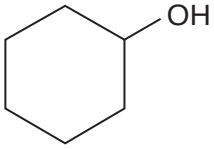
15

Turn over for the next question

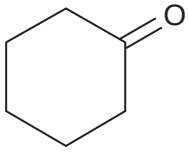
10 Consider the five cyclic compounds, **A**, **B**, **C**, **D** and **E**.



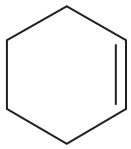
cyclohexane
A



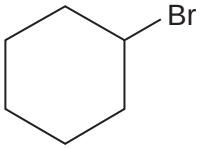
cyclohexanol
B



cyclohexanone
C



cyclohexene
D



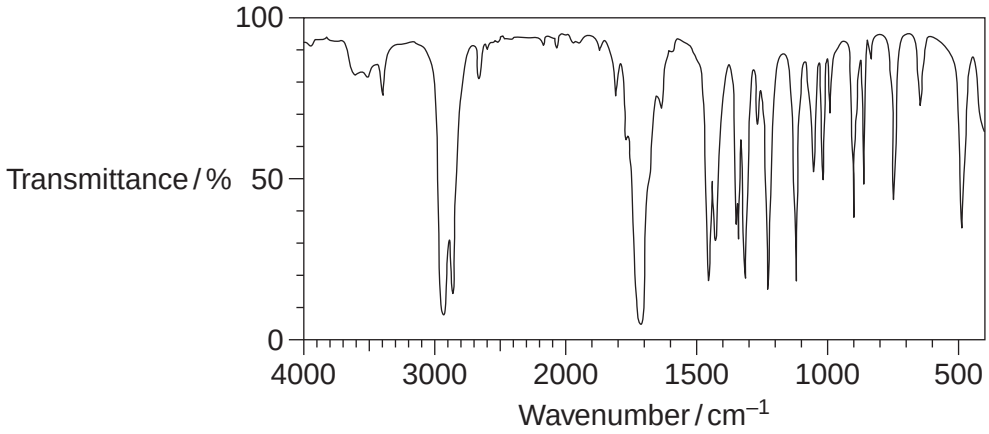
bromocyclohexane
E

10 (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.

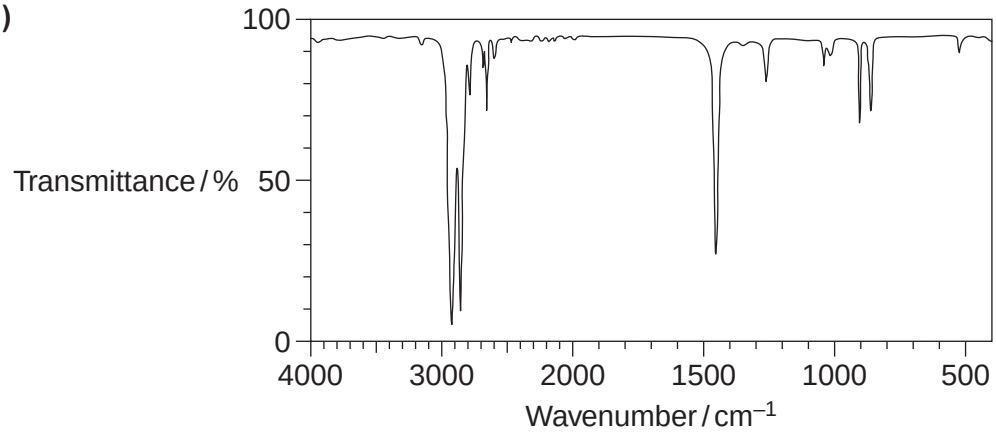
Do not write outside the box

10 (a) (i)



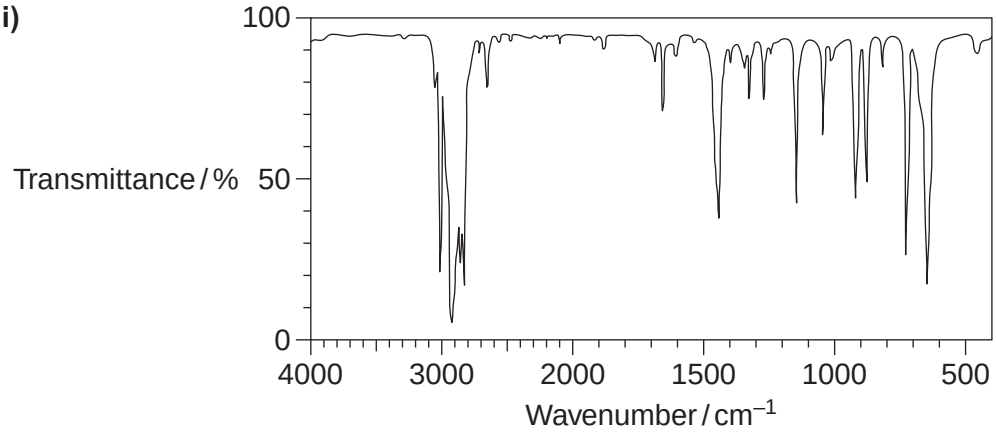
(1 mark)

10 (a) (ii)



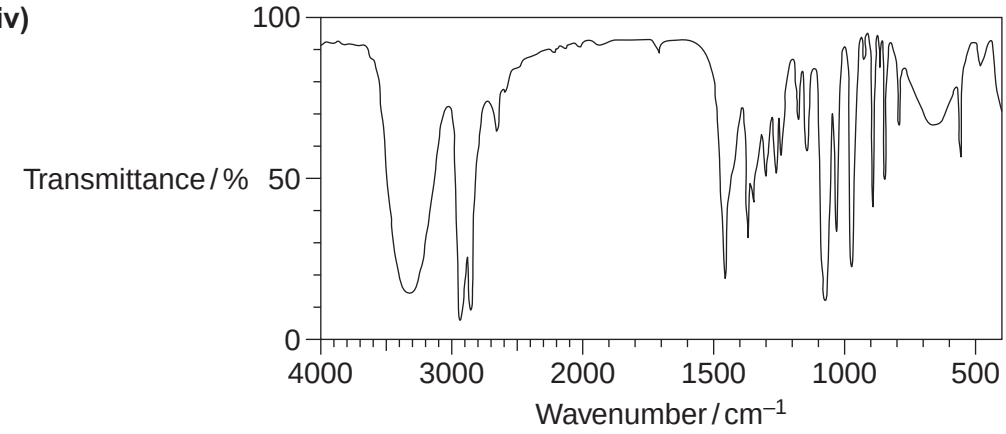
(1 mark)

10 (a) (iii)



(1 mark)

10 (a) (iv)



(1 mark)

Question 10 continues on the next page

Turn over ▶

10 (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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10 (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)

(Extra space) .....

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10 (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)

(Extra space) .....

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15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED