Oxford Cambridge and RSA

Tuesday 16 May 2023 – Morning

AS Level Chemistry A

H032/01 Breadth in chemistry

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry A

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

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SECTION A

You should spend a maximum of 25 minutes on this section.

Write your answer to each question in the box provided.

1 Which statement explains the trend in boiling points down the halogens group?

A Covalent bonds become stronger.

B Induced dipole–dipole interactions (London forces) become stronger.

C Ionic bonds become stronger.

D Permanent dipole–dipole interactions become stronger.

Your answer ☐ **[1]**

2 A hydrocarbon contains 85.71% carbon by mass.

What is the empirical formula of the hydrocarbon?

A CH

B CH_2

C CH_4

D C_2H_4

Your answer ☐ **[1]**

3 Hydrogen can be prepared industrially by the reaction of methane with steam.
The equation is shown below.

$$CH_4(g) + 2H_2O(g) \rightarrow 4H_2(g) + CO_2(g)$$

What is the atom economy of hydrogen for this process?

A 3.8%

B 4.3%

C 15.4%

D 17.4%

Your answer ☐ **[1]**

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4 How many p-orbitals are occupied by electrons in a sulfur atom?

A 2

B 4

C 6

D 10

Your answer ☐ **[1]**

5 Which substance has the lowest oxidation number for sulfur?

A Na_2SO_4

B S_8

C SF_2

D SO_2

Your answer ☐ **[1]**

6 Successive ionisation energies, in $kJ\,mol^{-1}$, of an element in Period 3 of the periodic table are shown below.

1st	2nd	3rd	4th	5th	6th	7th	8th	9th
578	1817	2745	11578	14831	18378	23296	27460	31862

What is the formula of the oxide of the Period 3 element?

A Na_2O

B MgO

C Al_2O_3

D SiO_2

Your answer ☐ **[1]**

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7 How many oxygen atoms are in 120.2 g of SiO_2?

A 3.01×10^{23}

B 1.20×10^{24}

C 2.41×10^{24}

D 3.61×10^{24}

Your answer ☐ **[1]**

8 Magnesium nitrate, $Mg(NO_3)_2$, decomposes when heated:

$Mg(NO_3)_2(s) \rightarrow MgO(s) + 2NO_2(g) + ½O_2(g)$

0.00250 mol of $Mg(NO_3)_2$ is decomposed.

What is the volume of gas produced, measured at RTP?

A 30 cm^3

B 60 cm^3

C 120 cm^3

D 150 cm^3

Your answer ☐ **[1]**

9 Zinc reacts with aqueous silver nitrate, as shown in the equation:

$Zn(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$

0.10 g of zinc is added to 15 cm^3 of 0.25 mol dm^{-3} aqueous silver nitrate.

What is the mass of silver metal that would be formed?

A 0.16 g

B 0.20 g

C 0.33 g

D 0.40 g

Your answer ☐ **[1]**

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10 15.00 cm^3 of 18.0 mol dm^{-3} concentrated hydrochloric acid is diluted with water to prepare 250 cm^3 of dilute hydrochloric acid.

What is the concentration, in mol dm^{-3}, of the dilute hydrochloric acid?

A 0.0675

B 0.270

C 0.300

D 1.08

Your answer ☐ **[1]**

11 The standard enthalpy change of formation of water is –286 kJ mol^{-1}.

Which statement or equation is correct?

A $H_2(g) + ½O_2(g) \rightarrow H_2O(l)$ $\Delta H^{\ominus} = -143\ kJ\ mol^{-1}$

B $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $\Delta H^{\ominus} = -286\ kJ\ mol^{-1}$

C The O–H bond enthalpy is –143 kJ mol^{-1}.

D The standard enthalpy change of combustion of hydrogen is –286 kJ mol^{-1}.

Your answer ☐ **[1]**

12 Which statement about energy changes is correct?

A Combustion of an alkane is endothermic.

B In an exothermic reaction, more energy is needed to break bonds than is given out when bonds are made.

C The activation energy is a negative value.

D The enthalpy change for the condensation of a gas to a liquid is a negative value.

Your answer ☐ **[1]**

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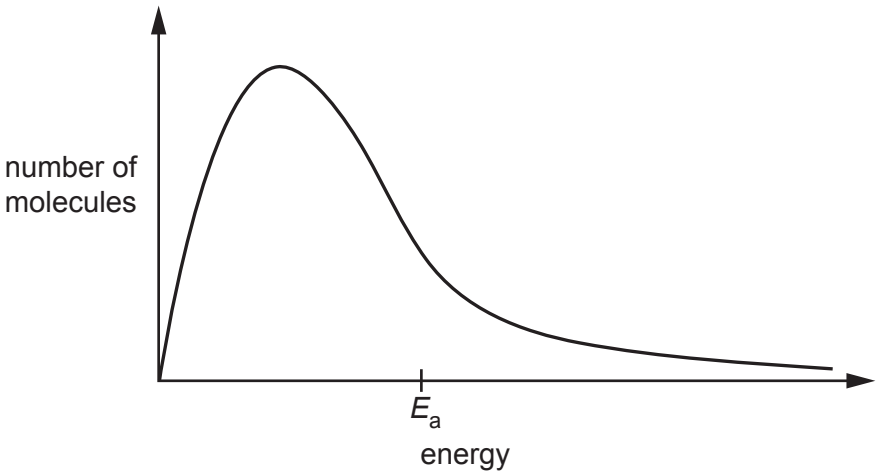
13 The Boltzmann distribution showing the activation energy, E_a, for an uncatalysed reaction is shown below.



What is the difference for the **catalysed** reaction?

A The activation energy shifts to the left.

B The activation energy shifts to the right.

C The curve flattens.

D The curve shifts to the right.

Your answer ☐ **[1]**

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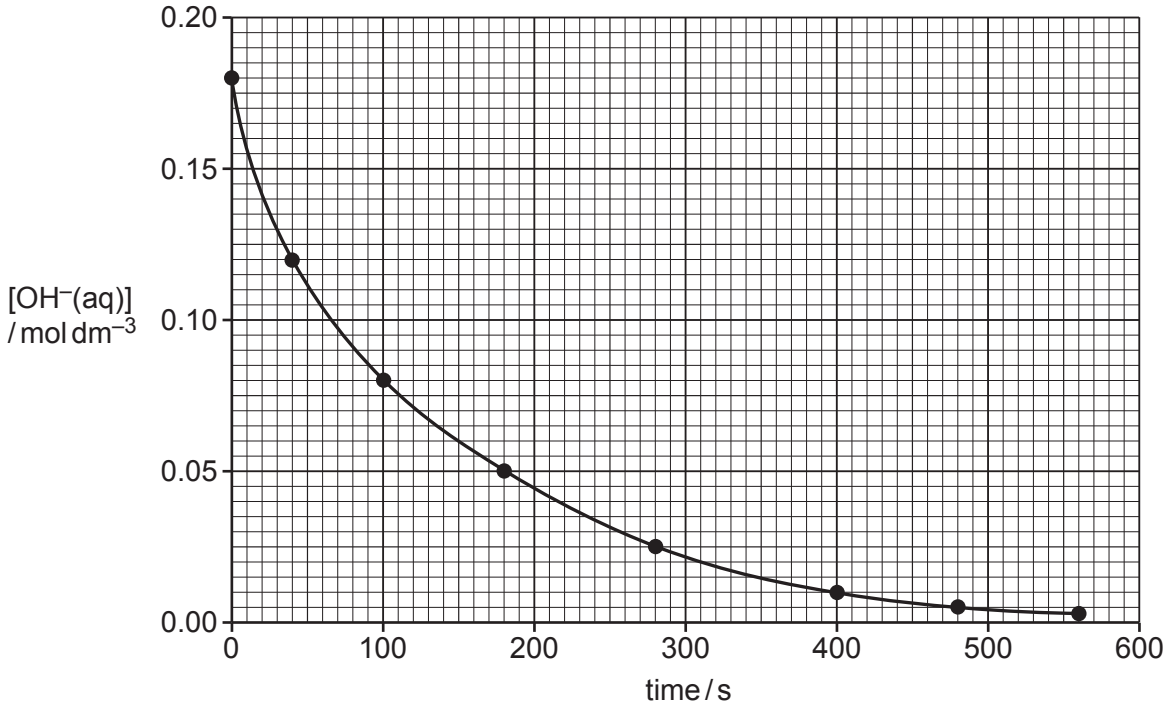
14 A student measures how the OH^- concentration changes over time for a reaction.

The student plots the graph below.



What is the rate of reaction, in $mol\,dm^{-3}\,s^{-1}$, at 200 s?

A 2.2×10^{-4}

B 2.8×10^{-4}

C 1.8×10^{-3}

D 4.4×10^{-2}

Your answer ☐ **[1]**

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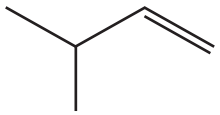
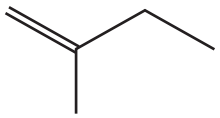
15 Which formula does **not** represent 3-methylbut-1-ene?

A	$CH_3CHCH_3CHCH_2$
B	$CH_2CHCH(CH_3)_2$
C	
D	

Your answer ☐ **[1]**

16 How many structural isomers have the molecular formula C_4H_9Cl?

A 2

B 3

C 4

D 5

Your answer ☐ **[1]**

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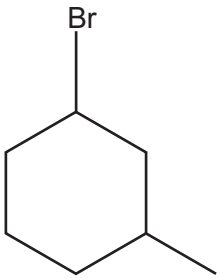
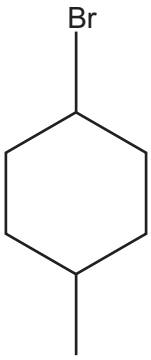
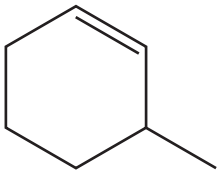
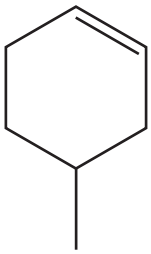
17 3-Methylcyclohexanol is reacted with NaBr and H_2SO_4.

What is the organic product?

A	
B	
C	
D	

Your answer ☐ **[1]**

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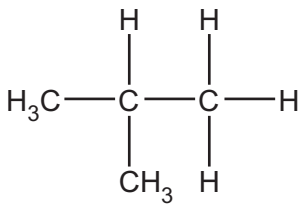
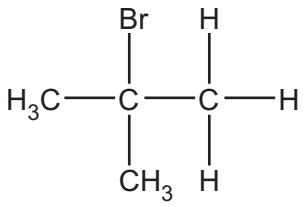
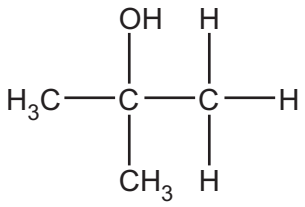
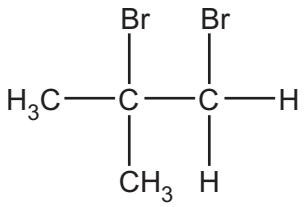
18 A student has planned the two-stage synthesis shown below.

Which compound could be the intermediate for this synthesis?

A	
B	
C	
D	

Your answer ☐ **[1]**

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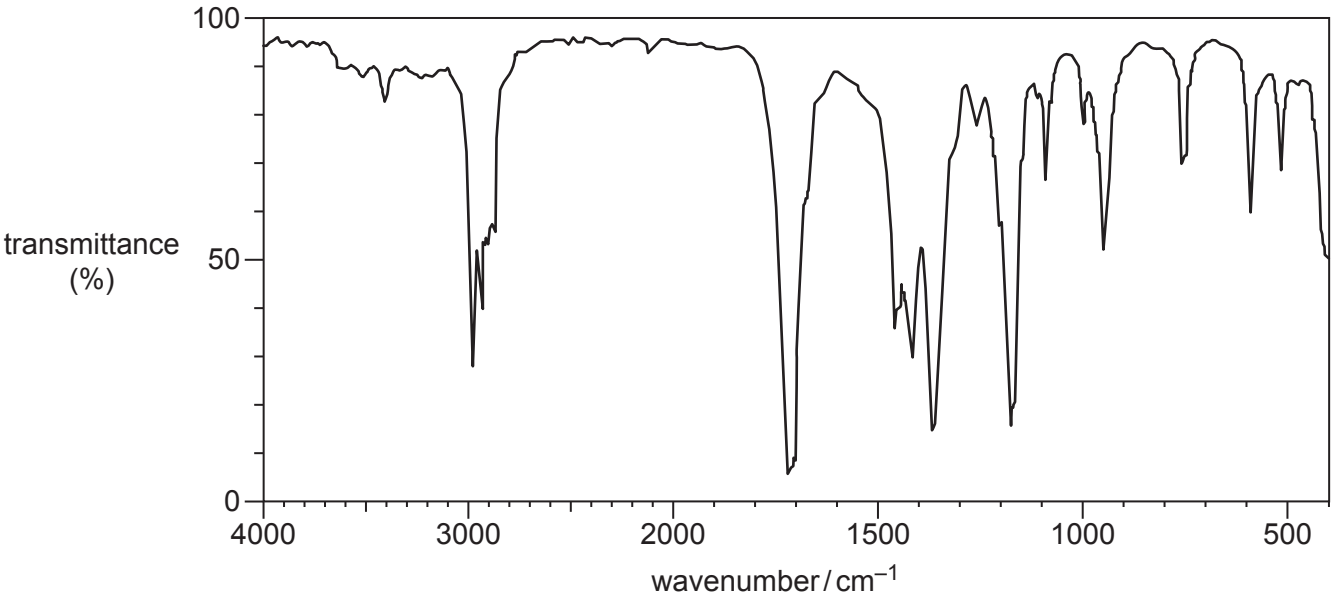
19 An organic compound produces the infrared spectrum below.



Which compound could have produced this IR spectrum?

A $CH_3CH_2CH{=}CH_2$

B $CH_3CHOHCH_2CH_3$

C $CH_3CH_2COCH_3$

D $(CH_3)_2CHCOOH$

Your answer ☐ **[1]**

20 Pentan-2-ol and pentan-3-ol are structural isomers with the molecular formula $C_5H_{12}O$ and M_r = 88.

The isomers can be distinguished from the fragment ions in their mass spectra.

Which fragment ion would you expect to be present in only **one** of these isomers?

A m/z = 29

B m/z = 45

C m/z = 59

D m/z = 73

Your answer ☐ **[1]**

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SECTION B

21 This question is about NF_3 and BF_3 molecules.

(a) NF_3 and BF_3 contain covalent bonds.

(i) What is meant by a **covalent bond**?

..... **[1]**

(ii) Draw 'dot-and-cross' diagrams for NF_3 and BF_3.

Show outer electrons only.

NF_3	BF_3

[2]

(b) Molecules of NF_3 and BF_3 have different shapes and bond angles.

(i) Predict the different shapes of, and bond angles in, NF_3 and BF_3 molecules.

	Bond angle	**Name of shape**
NF_3		
BF_3		

[2]

(ii) Explain why NF_3 and BF_3 molecules have different shapes and bond angles.

.....

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..... **[2]**

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22 This question is about reactions involving acids.

(a) Hydrochloric acid and nitric acid are classified as strong acids.

What is meant by a **strong** acid?

.....

..... **[1]**

(b) Write equations for the reactions below. State symbols are **not** required.

(i) The reaction of copper(II) oxide with dilute hydrochloric acid.

..... **[1]**

(ii) The reaction of ammonium carbonate with dilute nitric acid.

..... **[2]**

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(c) A student carries out an investigation to identify an unknown Group 1 metal **M**.

- The student reacts 2.62 g of the Group 1 metal, **M**, with water.
  A solution of the alkali, **M**OH(aq), is formed.
- The student makes this solution of **M**OH(aq) up to 250.0 cm^3 with water.
- The student pipettes 25.0 cm^3 of this **M**OH(aq) solution into a conical flask.
- The student titrates this 25.0 cm^3 volume of **M**OH(aq) with 0.165 mol dm^{-3} H_2SO_4(aq).

The equation is shown below.

$$2\mathbf{M}OH(aq) + H_2SO_4(aq) \rightarrow \mathbf{M}_2SO_4(aq) + 2H_2O(l)$$

(i) Name the type of flask that the student should use to make up the 250.0 cm^3 solution of **M**OH(aq).

..... flask **[1]**

(ii) The student takes burette readings to the nearest 0.05 cm^3.

The student's readings are shown in the table.

The rough titre has been omitted.

Complete the table below.

Final reading / cm^3	20.25	40.85	25.85
Initial reading / cm^3	0.00	20.25	5.50
Titre / cm^3	.....	.....	.....

[1]

(iii) Calculate the mean titre of H_2SO_4, to the nearest 0.05 cm^3, that the student should use to analyse the results.

mean titre = ... cm^3 **[1]**

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(iv) Calculate the amount, in mol, of **M**OH in 25.0 cm^3 of solution and determine the identity of the Group 1 metal **M**.

metal **M** = ... **[4]**

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23 This question is about enthalpy changes.

(a) In a petrol engine, alkanes undergo combustion.

(i) Heptane is one of the alkanes in petrol.

Write the equation for the complete combustion of heptane.

State symbols are **not** required.

..... **[2]**

(ii) In a petrol engine, polluting gases such as CO and NO are formed. These are mostly removed before being emitted from the exhaust.

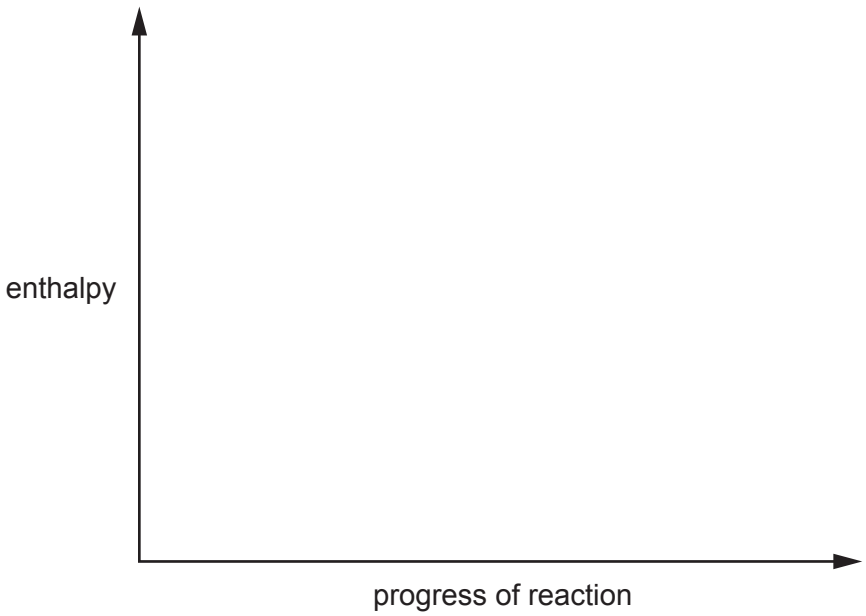
The equation for the removal of CO and NO is shown below.

$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g) \qquad \Delta H = -746\,kJ\,mol^{-1}$

Complete the enthalpy profile diagram in **Fig. 23.1** for this reaction.

On your diagram:
- Label the enthalpy change of reaction, ΔH.
- Include the formulae of the reactants and products.
- Label the activation energy, E_a.

Fig. 23.1



[2]

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(iii) CO and NO are removed by use of a catalyst.

Explain the role of the catalyst.

Refer to your enthalpy profile diagram in **Fig. 23.1** in your answer.

.....

.....

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..... **[2]**

(b) Iron(III) oxide reacts with carbon monoxide as shown:

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \quad \Delta H = -25\,kJ\,mol^{-1}$

Standard enthalpy changes of formation, $\Delta_f H^{\ominus}$, are given in the table.

Substance	$\Delta_f H^{\ominus}$ **/ kJ mol^{-1}**
$Fe_2O_3(s)$	–824
CO(g)	–111

(i) State the conditions of temperature and pressure for standard enthalpy changes.

Temperature .....

Pressure ..... **[1]**

(ii) Calculate the standard enthalpy change of formation for $CO_2(g)$.

$\Delta_f H^{\ominus}(CO_2(g))$ = ... kJ mol^{-1} **[3]**

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24 The reaction between sulfur dioxide, $SO_2(g)$ and oxygen, $O_2(g)$, to form sulfur trioxide, $SO_3(g)$, is a key step in the industrial manufacture of sulfuric acid.

This is a reversible reaction, shown in **Equilibrium 24.1**:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ\,mol^{-1}$ **Equilibrium 24.1**

(a) Why is **Equilibrium 24.1** a homogeneous equilibrium?

.....

..... **[1]**

(b) Le Chatelier's principle can be used to predict how different conditions affect the equilibrium position in **Equilibrium 24.1**.

Explain how changing pressure, temperature and using a catalyst affect the equilibrium yield of SO_3.

In your answer, use le Chatelier's principle and other chemical concepts, where appropriate.

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..... **[5]**

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(c) A mixture of $SO_2(g)$ and $O_2(g)$ is allowed to reach equilibrium at a constant temperature.

The equilibrium concentrations are shown in the table.

Substance	**Equilibrium concentration / mol dm^{-3}**
$SO_2(g)$	3.0×10^{-3}
$O_2(g)$	3.5×10^{-3}
$SO_3(g)$	5.0×10^{-2}

(i) Write the expression for K_c and calculate the numerical value for K_c in **Equilibrium 24.1** at this constant temperature.

Give your answer to an **appropriate** number of significant figures and in **standard form**.

K_c = ... dm^3 mol^{-1} **[2]**

(ii) In the industrial production of SO_3, an excess of $O_2(g)$ is used rather than a 2:1 proportion of $SO_2(g)$ to $O_2(g)$ which would match the stochiometry in **Equilibrium 24.1**.

Suggest, in terms of equilibrium, why an excess of $O_2(g)$ is used industrially.

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..... **[1]**

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25 This question is about hydrocarbons.

(a) The boiling points of 2 hydrocarbons are shown below.

Hydrocarbon	Boiling point / °C
butane	0
pentane	36

Explain the difference in the boiling points of butane and pentane.

.....

.....

.....

.....

..... **[2]**

(b) Butane reacts with bromine by radical substitution to form a mixture of organic products.

The reaction needs UV radiation for the initiation stage.

Write equations for the propagation stage that follows to form 2-bromobutane.

Use skeletal formulae and 'dots' (•) to show the position of any radicals.

Propagation	→ →

[2]

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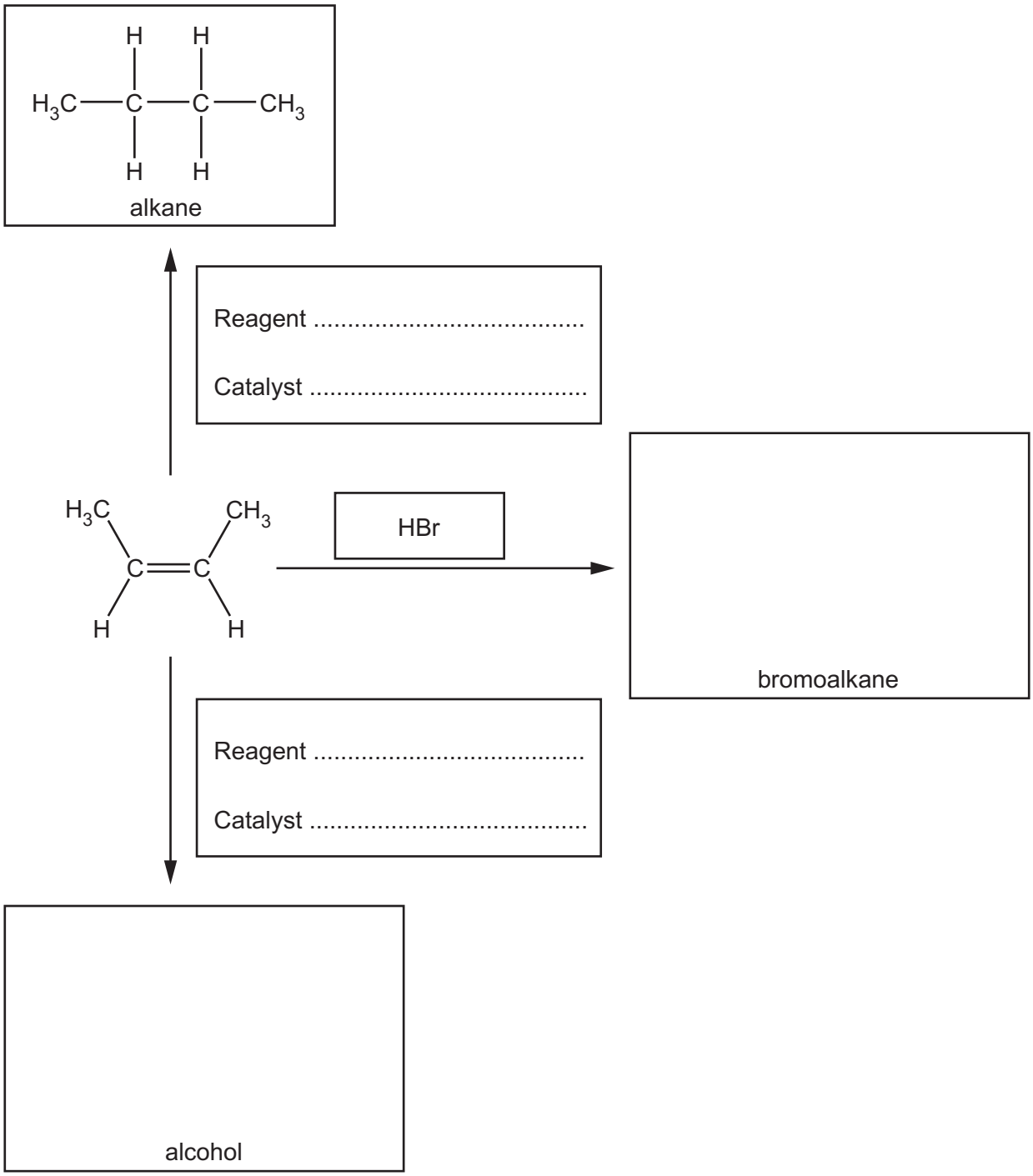
(c) Alkenes are used in organic synthesis.

Three reactions of an alkene are shown in the flowchart.

Complete the flowchart to show the missing reagents, catalysts and the structures of organic products.



[4]

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26 This question is about the oxidation of two alcohols that are structural isomers of C_3H_8O.

Compare the oxidation of these two structural isomers using different reaction conditions.

For each reaction include:
- the reaction conditions
- the functional group of any organic product
- a balanced equation.

In your equations, use [O] to represent the oxidising agent and show any organic compounds as structures.

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..... **[5]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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