



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

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Candidate number

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First name(s)

Last name

StemUp Model Solution

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.

2
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

B

[1]

- 2** A hydrocarbon contains 85.71% carbon by mass.

What is the empirical formula of the hydrocarbon?

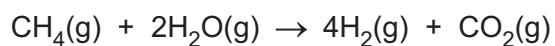
- A** CH
- B** CH₂
- C** CH₄
- D** C₂H₄

Your answer

B

[1]

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



What is the atom economy of hydrogen for this process?

- A** 3.8%
- B** 4.3%
- C** 15.4%
- D** 17.4%

Your answer

C

[1]

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

- A 2
- B 4
- C 6
- D 10

Your answer

C

[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

B

[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

C

[1]

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

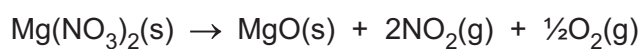
- A 3.01×10^{23}
- B 1.20×10^{24}
- C 2.41×10^{24}
- D 3.61×10^{24}

Your answer

C

[1]

8 Magnesium nitrate, $\text{Mg}(\text{NO}_3)_2$, decomposes when heated:



0.00250 mol of $\text{Mg}(\text{NO}_3)_2$ is decomposed.

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

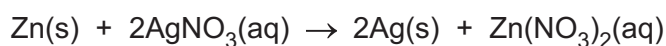
- A 30 cm^3
- B 60 cm^3
- C 120 cm^3
- D 150 cm^3

Your answer

D

[1]

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



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

C

[1]

- 10 15.00 cm³ of 18.0 mol dm⁻³ concentrated hydrochloric acid is diluted with water to prepare 250 cm³ 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

D

[1]

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

Which statement or equation is correct?

- A $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) \quad \Delta H^\ominus = -143 \text{ kJ mol}^{-1}$
B $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l}) \quad \Delta H^\ominus = -286 \text{ kJ mol}^{-1}$
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

D

[1]

- 12 Which statement about energy changes is correct?

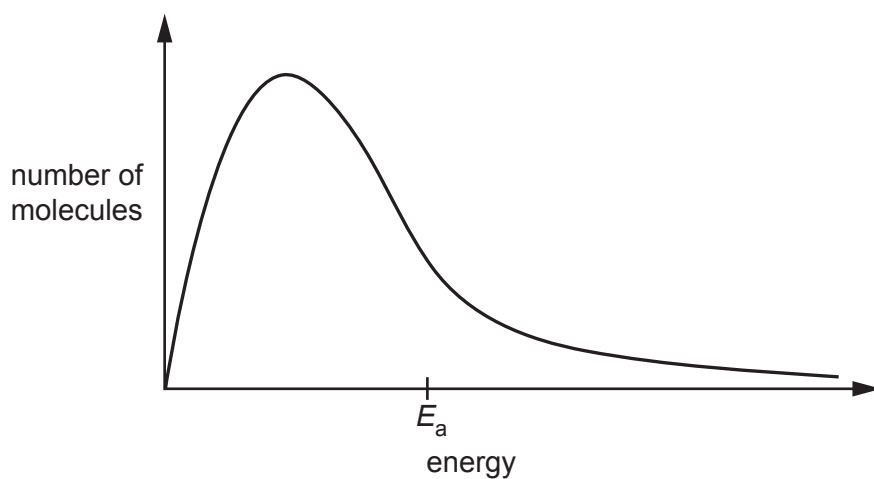
- A Combustion of an alkane is endothermic.
B In an exothermic reaction, more energy is needed to break bonds than is given out when bonds are made.
C The activation energy is a negative value.
D The enthalpy change for the condensation of a gas to a liquid is a negative value.

Your answer

D

[1]

- 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.

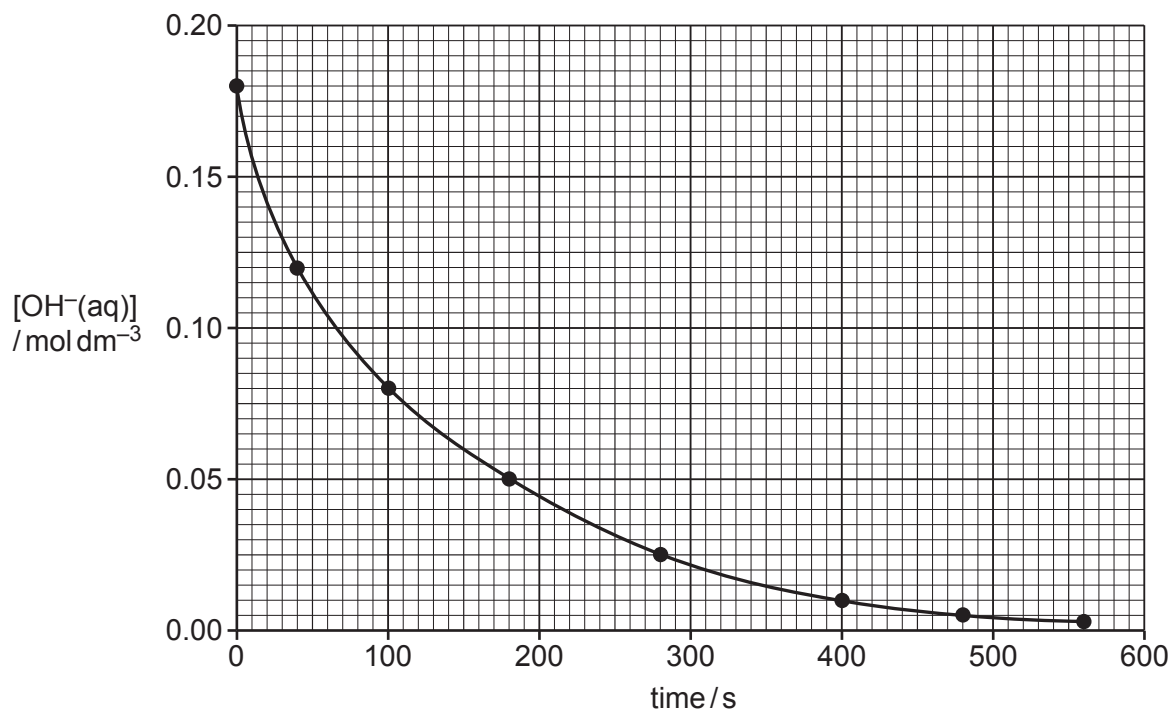
Your answer

A

[1]

- 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 $\text{mol dm}^{-3} \text{s}^{-1}$, at 200 s?

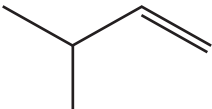
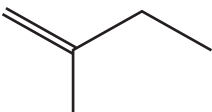
- A 2.2×10^{-4}
B 2.8×10^{-4}
C 1.8×10^{-3}
D 4.4×10^{-2}

Your answer

B

[1]

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

A	$\text{CH}_3\text{CHCH}_3\text{CHCH}_2$
B	$\text{CH}_2\text{CHCH}(\text{CH}_3)_2$
C	
D	

Your answer

D

[1]

16 How many structural isomers have the molecular formula $\text{C}_4\text{H}_9\text{Cl}$?

A 2

B 3

C 4

D 5

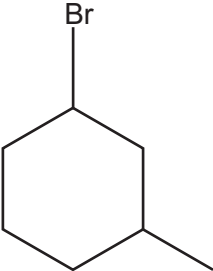
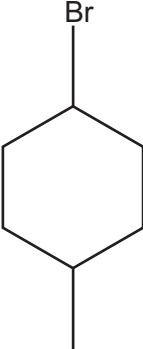
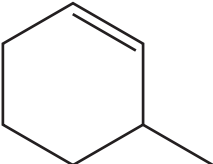
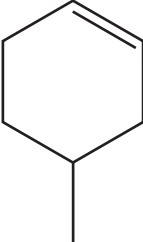
Your answer

C

[1]

17 3-Methylcyclohexanol is reacted with NaBr and H_2SO_4 .

What is the organic product?

A	
B	
C	
D	

Your answer

A

[1]

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



Which compound could be the intermediate for this synthesis?

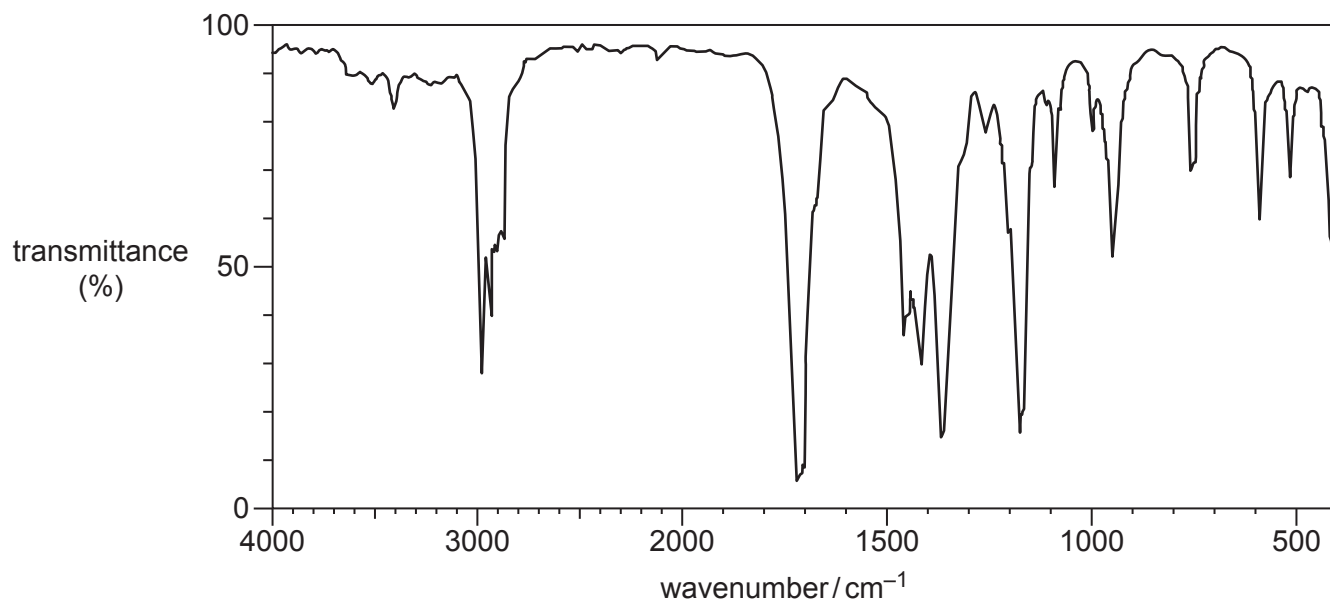
A	$ \begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}_3\text{C}-\text{C} & - & \text{C}-\text{H} \\ & \\ \text{CH}_3 & \text{H} \end{array} $
B	$ \begin{array}{c} \text{Br} & \text{H} \\ & \\ \text{H}_3\text{C}-\text{C} & - & \text{C}-\text{H} \\ & \\ \text{CH}_3 & \text{H} \end{array} $
C	$ \begin{array}{c} \text{OH} & \text{H} \\ & \\ \text{H}_3\text{C}-\text{C} & - & \text{C}-\text{H} \\ & \\ \text{CH}_3 & \text{H} \end{array} $
D	$ \begin{array}{c} \text{Br} & \text{Br} \\ & \\ \text{H}_3\text{C}-\text{C} & - & \text{C}-\text{H} \\ & \\ \text{CH}_3 & \text{H} \end{array} $

Your answer

D

[1]

19 An organic compound produces the infrared spectrum below.



Which compound could have produced this IR spectrum?

- A $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$
- B $\text{CH}_3\text{CHOHCH}_2\text{CH}_3$
- C $\text{CH}_3\text{CH}_2\text{COCH}_3$
- D $(\text{CH}_3)_2\text{CHCOOH}$

Your answer

C

[1]

20 Pentan-2-ol and pentan-3-ol are structural isomers with the molecular formula $\text{C}_5\text{H}_{12}\text{O}$ 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

B

[1]

12
SECTION B

21 This question is about NF_3 and BF_3 molecules.

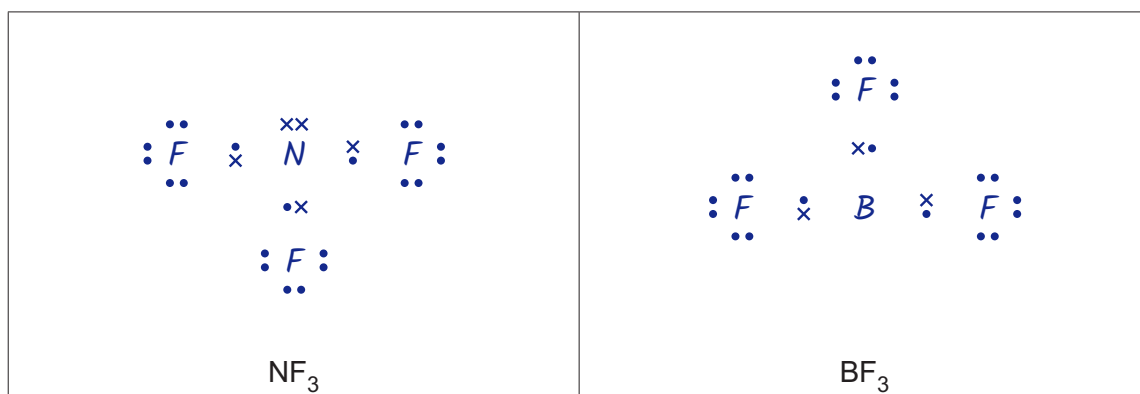
(a) NF_3 and BF_3 contain covalent bonds.

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

A shared pair of electrons (between two atoms). [1]

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

Show outer electrons only.



[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	107°	<i>pyramidal</i>
BF_3	120°	<i>trigonal planar</i>

[2]

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

NF_3 has 3 bonded pairs and 1 lone pair of electrons around N. The lone pair repels more than the bonded pairs, so the bonded pairs are pushed closer together (pyramidal, 107°).

BF_3 has 3 bonded pairs of electrons around B and no lone pairs, which repel equally and get as far apart as possible (trigonal planar, 120°).

[2]

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?

A strong acid completely (fully) dissociates (ionises) in solution, releasing all of its H^+ ions. [1]

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

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

$CuO + 2HCl \rightarrow CuCl_2 + H_2O$ [1]

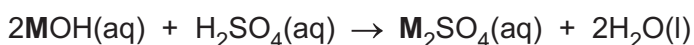
- (ii) The reaction of ammonium carbonate with dilute nitric acid.

$(NH_4)_2CO_3 + 2HNO_3 \rightarrow 2NH_4NO_3 + CO_2 + H_2O$ [2]

(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, **MOH(aq)**, is formed.
- The student makes this solution of **MOH(aq)** up to 250.0 cm³ with water.
- The student pipettes 25.0 cm³ of this **MOH(aq)** solution into a conical flask.
- The student titrates this 25.0 cm³ volume of **MOH(aq)** with 0.165 mol dm⁻³ H₂SO₄(aq).

The equation is shown below.



- (i) Name the type of flask that the student should use to make up the 250.0 cm³ solution of **MOH(aq)**.

...*volumetric*..... flask

[1]

- (ii) The student takes burette readings to the nearest 0.05 cm³.

The student's readings are shown in the table.

The rough titre has been omitted.

Complete the table below.

Final reading /cm³	20.25	40.85	25.85
Initial reading /cm³	0.00	20.25	5.50
Titre /cm³	 <i>20.25</i>	 <i>20.60</i>	 <i>20.35</i>

[1]

- (iii) Calculate the mean titre of H₂SO₄, to the nearest 0.05 cm³, that the student should use to analyse the results.

Use the concordant titres (within 0.10 cm³): 20.25 and 20.35

mean titre = (20.25 + 20.35) ÷ 2 = 20.30 cm³

mean titre = ...*20.30*..... cm³ [1]

- (iv) Calculate the amount, in mol, of **MOH** in 25.0 cm³ of solution and determine the identity of the Group 1 metal **M**.

$$n(\text{H}_2\text{SO}_4) = 0.165 \times 20.30 \div 1000 = 3.35 \times 10^{-3} \text{ mol}$$

$$n(\text{MOH}) \text{ in } 25.0 \text{ cm}^3 = 2 \times 3.35 \times 10^{-3} = 6.70 \times 10^{-3} \text{ mol}$$

$$n(\text{MOH}) \text{ in } 250.0 \text{ cm}^3 = 10 \times 6.70 \times 10^{-3} = 6.70 \times 10^{-2} \text{ mol}$$

$$n(\text{M}) = n(\text{MOH}) = 6.70 \times 10^{-2} \text{ mol} \quad (2\text{M} + 2\text{H}_2\text{O} \rightarrow 2\text{MOH} + \text{H}_2)$$

$$A_r(\text{M}) = \text{mass} \div \text{moles} = 2.62 \div 6.70 \times 10^{-2} = 39.1$$

$$A_r = 39.1, \text{ so the Group 1 metal M is potassium, K}$$

metal **M** = ...potassium (K)..... [4]

23 This question is about enthalpy changes.

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

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

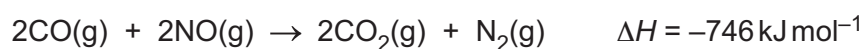
Write the equation for the complete combustion of heptane.

State symbols are **not** required.



(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.

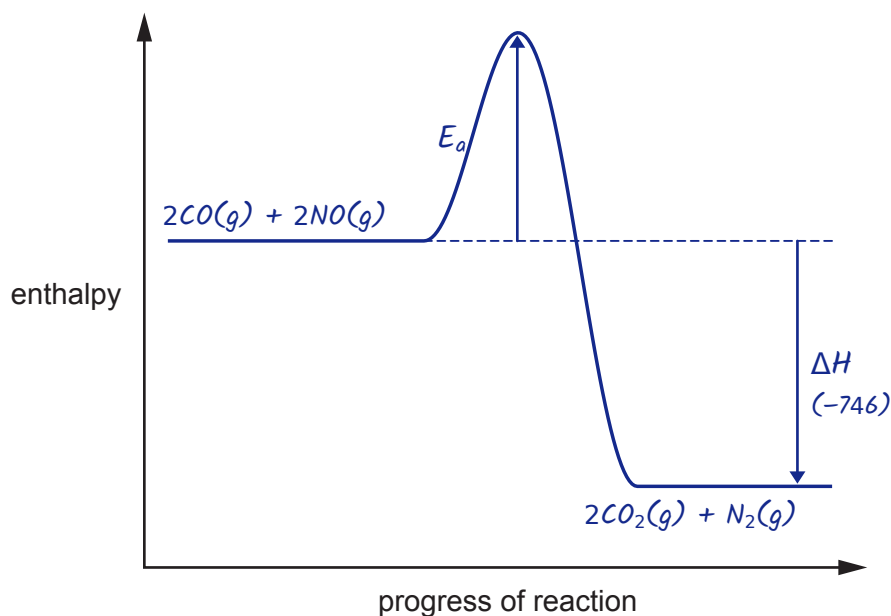


Complete the enthalpy profile diagram in **Fig. 23.1** for this reaction.

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]

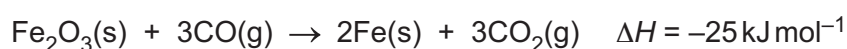
- (iii) CO and NO are removed by use of a catalyst.

Explain the role of the catalyst.

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

The catalyst provides an alternative route (pathway) with a lower activation energy than E_a in Fig. 23.1 (a lower peak on the profile). So more molecules (particles) have energy that exceeds the activation energy, increasing the rate of removal without the catalyst being used up. [2]

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



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

Substance	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{Fe}_2\text{O}_3(\text{s})$	-824
$\text{CO}(\text{g})$	-111

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

Temperature *298 K (25 °C)*

Pressure *100 kPa* [1]

- (ii) Calculate the standard enthalpy change of formation for $\text{CO}_2(\text{g})$.

$$\Delta H = \sum \Delta_f H(\text{products}) - \sum \Delta_f H(\text{reactants})$$

$$-25 = [2(0) + 3\Delta_f H(\text{CO}_2)] - [(-824) + 3(-111)]$$

$$-25 = 3\Delta_f H(\text{CO}_2) - (-1157)$$

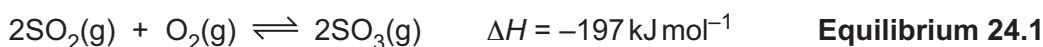
$$3\Delta_f H(\text{CO}_2) = -25 + (-1157) = -1182 \text{ kJ mol}^{-1}$$

$$\Delta_f H(\text{CO}_2) = -1182 \div 3 = -394 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\ominus(\text{CO}_2(\text{g})) = \text{.....} \text{ -394 } \text{ kJ mol}^{-1} \text{ [3]}$$

- 24 The reaction between sulfur dioxide, $\text{SO}_2(\text{g})$ and oxygen, $\text{O}_2(\text{g})$, to form sulfur trioxide, $\text{SO}_3(\text{g})$, is a key step in the industrial manufacture of sulfuric acid.

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



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

All of the species (reactants and products, SO_2 , O_2 and SO_3) are in the same state (phase); they are all gases. [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.

Pressure: increasing the pressure shifts the equilibrium position to the right, increasing the yield of SO_3 . This is because the right-hand side has fewer gaseous moles ($3 \text{ mol of gas} \rightarrow 2 \text{ mol of gas}$), so the equilibrium shifts to reduce the pressure.

Temperature: increasing the temperature shifts the equilibrium position to the left, decreasing the yield of SO_3 . This is because the forward reaction is exothermic (ΔH is negative), so the equilibrium shifts in the endothermic direction to oppose the increase in temperature.

Catalyst: a catalyst does not shift the position of equilibrium, so it has no effect on the yield of SO_3 . It increases the rates of the forward and reverse reactions by the same amount, so equilibrium is reached faster. [5]

- (c) A mixture of $\text{SO}_2(\text{g})$ and $\text{O}_2(\text{g})$ is allowed to reach equilibrium at a constant temperature.

The equilibrium concentrations are shown in the table.

Substance	Equilibrium concentration / mol dm^{-3}
$\text{SO}_2(\text{g})$	3.0×10^{-3}
$\text{O}_2(\text{g})$	3.5×10^{-3}
$\text{SO}_3(\text{g})$	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**.

$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} = \frac{(5.0 \times 10^{-2})^2}{(3.0 \times 10^{-3})^2 \times (3.5 \times 10^{-3})}$$

$$= 79365 = 7.9 \times 10^4 \text{ (2 s.f.)}$$

$$K_c = \dots 7.9 \times 10^4 \dots \text{ dm}^3 \text{ mol}^{-1} \text{ [2]}$$

- (ii) In the industrial production of SO_3 , an excess of $\text{O}_2(\text{g})$ is used rather than a 2:1 proportion of $\text{SO}_2(\text{g})$ to $\text{O}_2(\text{g})$ which would match the stoichiometry in **Equilibrium 24.1**.

Suggest, in terms of equilibrium, why an excess of $\text{O}_2(\text{g})$ is used industrially.

Excess O_2 shifts the equilibrium position to the right (towards SO_3), so
more of the SO_2 is converted into SO_3 , increasing the yield.
 [1]

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.

Pentane has a longer carbon chain (more electrons) than butane, so there is more surface contact (greater surface area) between molecules. So pentane has stronger (more) London forces (induced dipole-dipole interactions) between molecules, and more energy is needed to break them.

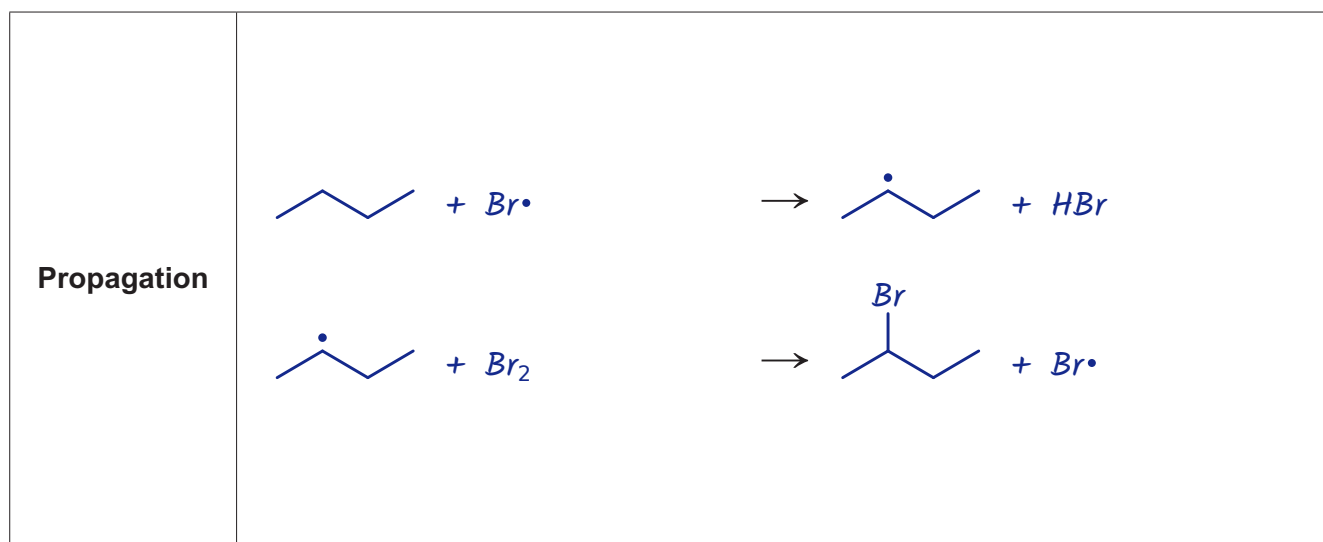
[2]

(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.

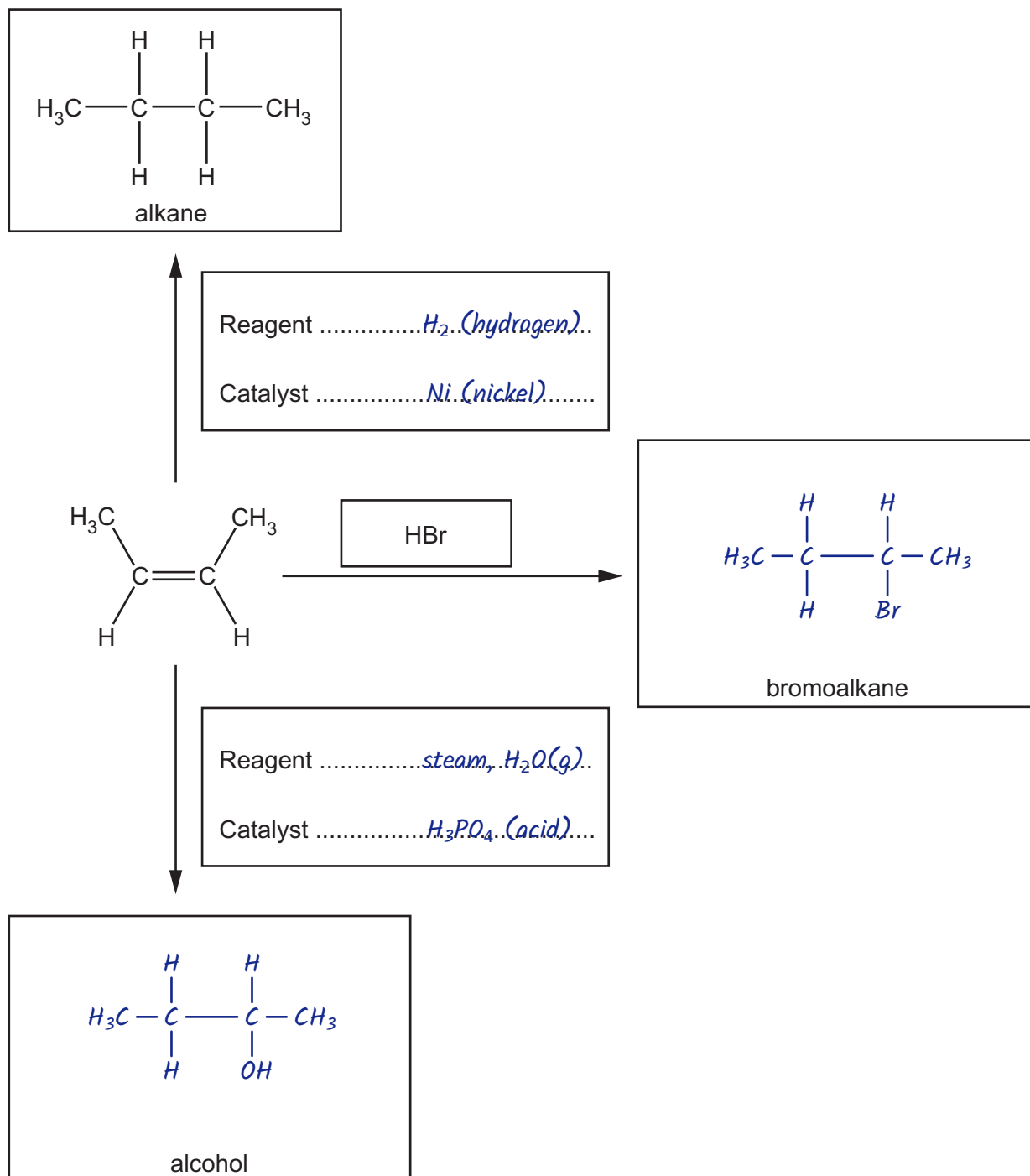


[2]

(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]

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.

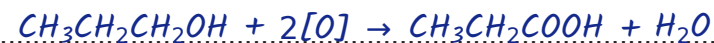
In your equations, use [O] to represent the oxidising agent and show any organic compounds as structures.

The isomers are propan-1-ol, $CH_3CH_2CH_2OH$ (a primary alcohol), and propan-2-ol, $CH_3CH(OH)CH_3$ (a secondary alcohol). Both are oxidised by acidified potassium dichromate(VI), $K_2Cr_2O_7 / H_2SO_4$ (orange to green).

Propan-1-ol, heated gently with distillation (the product is distilled off as it forms); forms an aldehyde, propanal.



Propan-1-ol, heated under reflux with excess oxidising agent: forms a carboxylic acid, propanoic acid.



Propan-2-ol, heated under reflux: forms a ketone, propanone.



[5]

END OF QUESTION PAPER

This image shows a blank sheet of white paper designed for handwriting practice. It features a solid vertical line on the left side, creating a narrow margin. The rest of the page is filled with evenly spaced horizontal dashed lines, providing guides for letter height and placement. There are no other markings, text, or illustrations on the page.

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