Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

AS CHEMISTRY

Paper 2 Organic and Physical Chemistry

Tuesday 21 May 2024 Morning Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
Section B	
TOTAL	

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Advice

You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.

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Section A

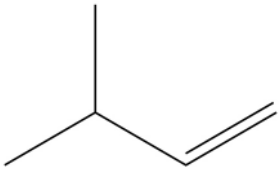
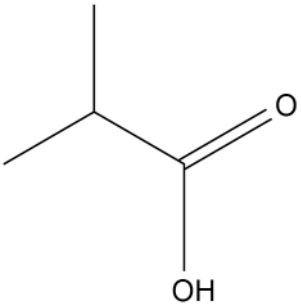
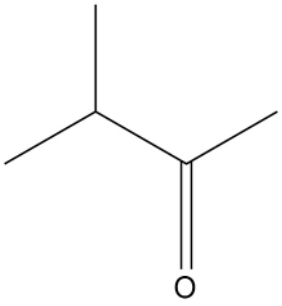
Answer **all** questions in this section.

0 1 This question is about the analysis of organic compounds.

0 1 . 1 **Table 1** shows the results of chemical tests on three organic compounds.

Complete the empty boxes in the table.

Table 1

Chemical test			
Add bromine water	orange to colourless		no visible change
	no visible change	bubbles of gas	no visible change
Warm with Fehling's solution	no visible change	no visible change	

[3 marks]

Do not write outside the box

0 1 . 2 0.500 g of a hydrocarbon is analysed.
The hydrocarbon contains 0.450 g of carbon.

Calculate the empirical formula of this hydrocarbon.

[3 marks]

Empirical formula _____

6

Turn over for the next question

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0 2 This question is about infrared spectroscopy.

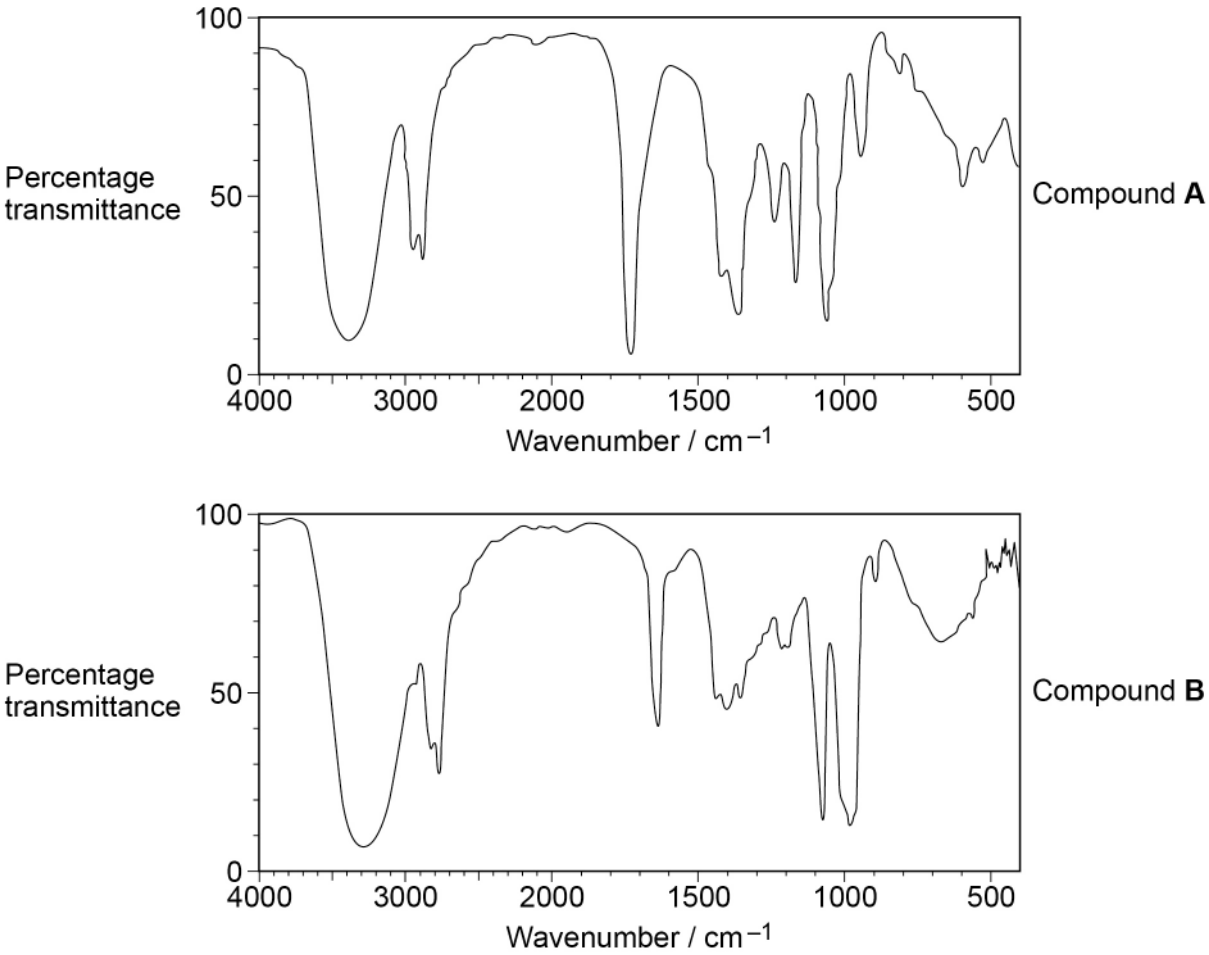
0 2 . 1 Compounds **A** and **B** both have the molecular formula $C_4H_8O_2$

Figure 1 shows the infrared spectra of compounds **A** and **B**.

Use the infrared spectra to deduce a possible structural formula for compound **A** and a possible structural formula for compound **B**.

[2 marks]

Figure 1



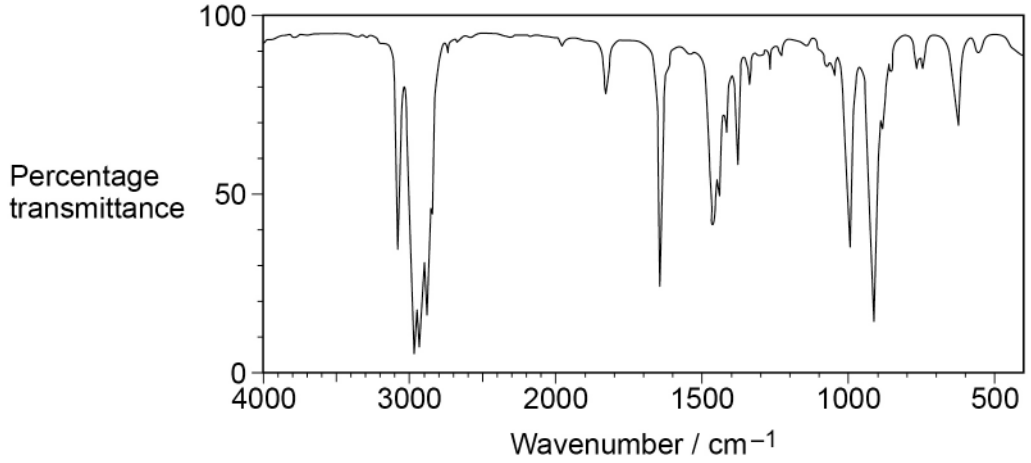
Possible structural formula of **A**

Possible structural formula of **B**

Do not write outside the box

0 2 . 2 **Figure 2** shows the infrared spectrum of either pent-1-ene or 2-methylbut-2-ene.

Figure 2



Outline how to use the infrared spectrum to determine whether the compound is pent-1-ene or 2-methylbut-2-ene.

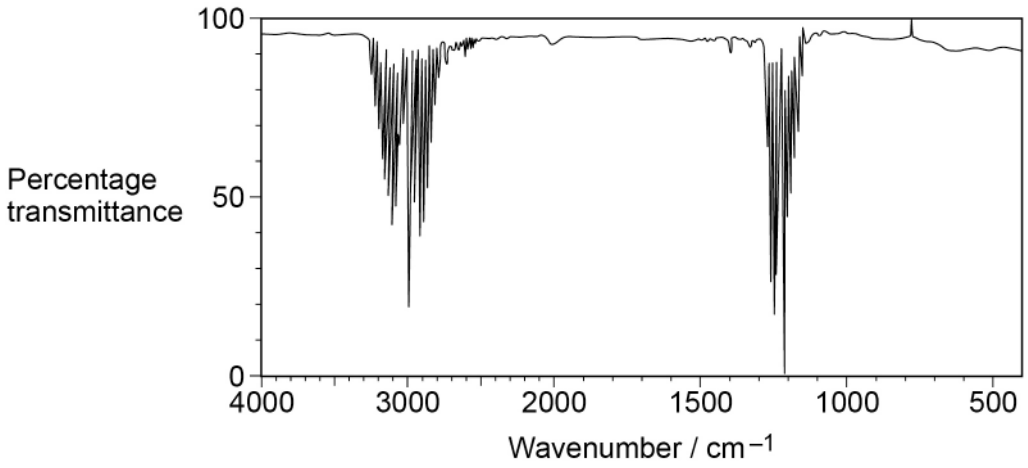
[2 marks]

Question 2 continues on the next page

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0 2 . 3 **Figure 3** shows the infrared spectrum of methane.

Figure 3



Use information from **Figure 3** to explain why methane acts as a greenhouse gas.

[1 mark]

5

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

Do not write outside the box

0 3 This question is about $CFCl_3$

$CFCl_3$ used to be the propellant in most aerosol cans.

0 3 . 1 Use IUPAC rules to name $CFCl_3$

[1 mark]

0 3 . 2 Give an equation for each of the **two** propagation steps in the conversion of $CHFCl_2$ into $CFCl_3$

[2 marks]

Equation 1

Equation 2

0 3 . 3 In the presence of ultraviolet radiation, $CFCl_3$ breaks down in the upper atmosphere to form chlorine free radicals.

Give an equation for this reaction.

[1 mark]

Do not write outside the box

0 3 . 4 Chlorine free radicals catalyse the decomposition of ozone.

Give **two** equations to show how chlorine free radicals decompose ozone.

[2 marks]

Equation 1

Equation 2

0 3 . 5 The production and use of CFCs have been banned in many countries because they decrease the amount of ozone in the upper atmosphere.

State why ozone in the upper atmosphere is important for life on Earth.

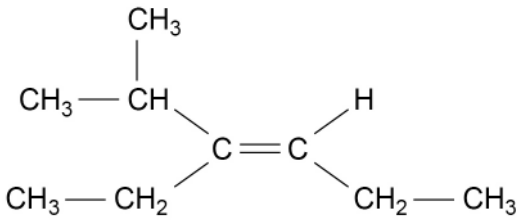
[1 mark]

7

Turn over for the next question

Do not write outside the box

0 4 . 1 Compound **J** is one of a pair of stereoisomers.



Compound **J**

Explain:

- what stereoisomers are
- how *E*-*Z* stereoisomerism occurs
- how the Cahn-Ingold-Prelog rules can be used to decide whether compound **J** is an *E* or *Z* isomer.

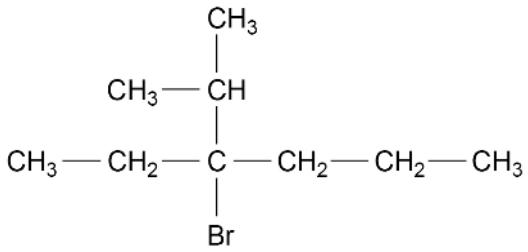
[6 marks]

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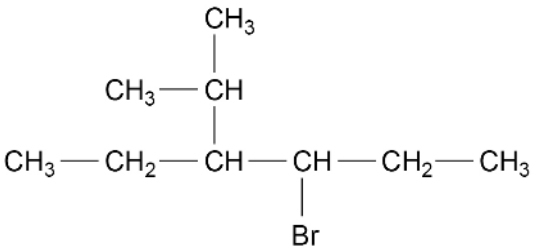
Question 4 continues on the next page

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0 4 . 2 Compound **J** reacts with hydrogen bromide to form compounds **K** and **L**.



Compound **K**



Compound **L**

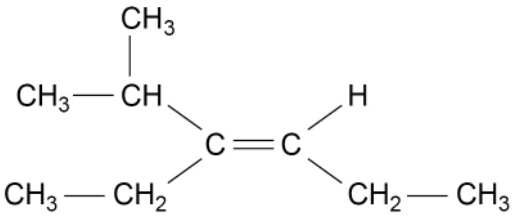
K is the major product.

Name and outline the mechanism for the formation of **K**.

[5 marks]

Name of mechanism _____

Outline of mechanism



Do not write outside the box

0 4 . 3 Explain why compound **K** is the major product in the reaction in Question **04.2**.

[3 marks]

14

Turn over for the next question

Do not write outside the box

0 5 This question is about the volumes of gases involved in some reactions.

0 5 . 1 Magnesium reacts with hydrochloric acid.

$$Mg(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

0.400 g of magnesium is added to 20.0 cm^3 of 1.50 mol dm^{-3} hydrochloric acid.

Identify the limiting reagent.

Justify your answer.

Calculate the volume, in m^3, of hydrogen produced at 101 kPa and 15 °C

The gas constant, R = 8.31 J K^{-1} mol^{-1}

[7 marks]

Limiting Reagent _____

Justification _____

_____

_____

Volume of hydrogen _____ m^3

Do not write outside the box

0 5 . 2 Propane (C_3H_8) undergoes complete combustion in a plentiful supply of oxygen.

Give an equation for the complete combustion of propane.

Use this equation to calculate the minimum volume, in cm^3, of oxygen gas needed for the complete combustion of 50 cm^3 of propane gas.
Assume that the volumes of both gases are measured at the same temperature and pressure.

[2 marks]

Equation for combustion

Volume of oxygen gas _____ cm^3

9

Do not write outside the box

0 6 A student investigates the effect of changing the temperature on the rate of hydrolysis of 1-iodobutane.

The student follows this method:

- Add 5 cm^3 of ethanol and 4 drops of 1-iodobutane to a test tube.
- Mark this test tube with a cross (below the level of the liquid).
- Add 5 cm^3 of 0.05 mol dm^{-3} silver nitrate solution to a separate test tube.
- Place a stopper in both test tubes.
- Place both test tubes in a beaker of water at a known temperature (between 5 and 60 °C).
- After 5 minutes, pour the silver nitrate solution into the test tube containing 1-iodobutane and start a timer.
- Look through the transparent reaction mixture in the test tube towards the cross.
- Stop the timer when the cross is no longer visible due to the yellow precipitate formed.

0 6 . 1 Identify the yellow precipitate formed in the reaction.

[1 mark]

The student repeats the experiment at different temperatures.

Table 2 shows the student's results.

Table 2

Temperature / °C	Time *t* / s	$\frac{1}{t}$ / s^{-1}
6	125	0.0080
15	83	0.0120
28	50	0.0200
34	38	0.0263
42	26	0.0385

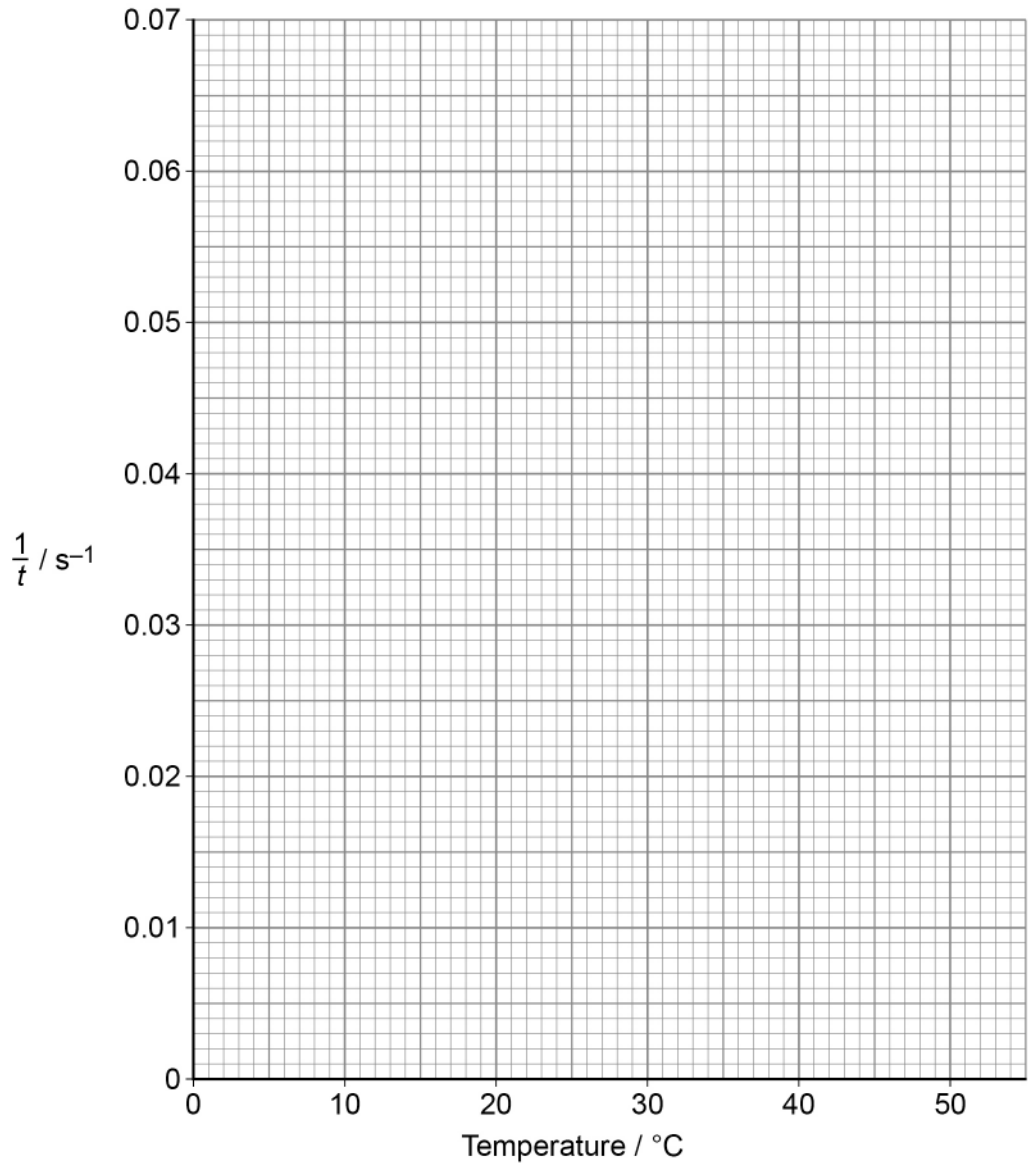
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0 6 . 2 Plot the values of $\frac{1}{t}$ against temperature on the grid.

Draw a line of best fit.

Use your graph to predict the time, in s, when the cross is no longer visible at 50 °C

[3 marks]



Time _____ s

Question 6 continues on the next page

Do not write outside the box

0 6 . 3 The student repeats the investigation using 1-bromobutane instead of 1-iodobutane.

State and explain how the rate of reaction for 1-bromobutane compares with the rate for 1-iodobutane.

Predict how the graph will differ for 1-bromobutane compared to 1-iodobutane.

[3 marks]

How rate of reaction for 1-bromobutane will compare _____

_____

Explanation _____

_____

_____

How graph for 1-bromobutane will differ _____

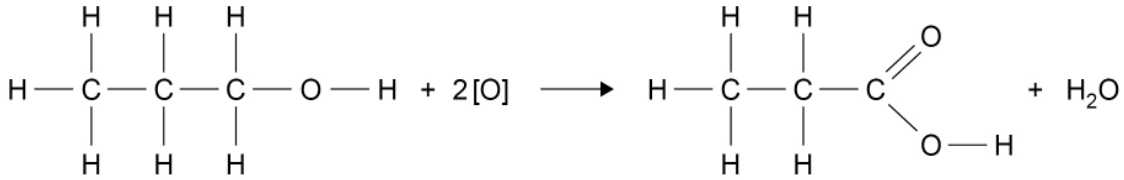
_____

7

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0 7 This question is about propanoic acid (CH_3CH_2COOH).

The equation for the oxidation of propan-1-ol under reflux to form propanoic acid is shown.



0 7 . 1 Acidified potassium dichromate(VI) is used as the oxidising agent.

State the colour change in this reaction.

[1 mark]

0 7 . 2 A second organic product, **X**, is formed in small quantities.
The boiling point of **X** is 49 °C

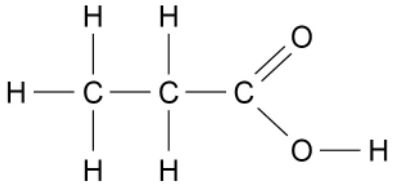
Identify **X**.

[1 mark]

0 7 . 3 Propanoic acid molecules cannot be separated from the reaction mixture by simple distillation because propanoic acid forms hydrogen bonds with water molecules.

Complete the diagram to show how the propanoic acid molecule interacts with **one** water molecule through hydrogen bonding.
Include in the diagram all the partial charges and lone pairs of electrons involved in this hydrogen bond.

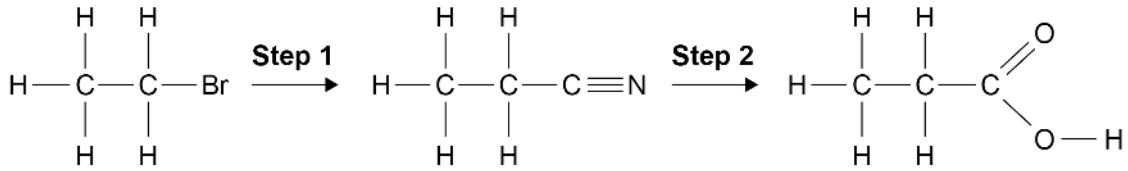
[3 marks]



Question 7 continues on the next page

Do not write outside the box

An alternative method of preparing propanoic acid is shown.



Step 1 involves the reaction of bromoethane with sodium cyanide under reflux in a suitable solvent.

0 7 . 4 Name and outline the mechanism for **Step 1**.

[3 marks]

Name of mechanism _____

Outline of mechanism

0 7 . 5 Suggest one reason why water is **not** a suitable solvent for **Step 1**.

[1 mark]

_____

_____

Do not write outside the box

A third way of making propanoic acid uses the reaction between ethene, steam and carbon monoxide in the presence of a catalyst.

$$C_2H_4(g) + H_2O(g) + CO(g) \rightleftharpoons CH_3CH_2COOH(g) \qquad \Delta H = -59 \text{ kJ mol}^{-1}$$

0 7 . 6 Give an expression for the equilibrium constant (K_c) for this reaction.

[1 mark]

K_c =

0 7 . 7 **Table 3** shows the amount of each substance in an equilibrium mixture in a container of volume 1.20 dm^3 at a constant temperature.

Table 3

Substance	$C_2H_4(g)$	$H_2O(g)$	$CO(g)$	$CH_3CH_2COOH(g)$
Amount of substance / mol	0.062	0.078	0.062	0.420

Calculate K_c

State the units.

[4 marks]

K_c _____

Units _____

Question 7 continues on the next page

Turn over ►

Do not write outside the box

0 7 . 8 Predict the effect of increasing the temperature on the yield of propanoic acid.

Explain your answer.

[3 marks]

Effect on yield _____

Explanation _____

_____

_____

_____

_____

17

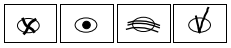
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Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.
For each question completely fill in the circle alongside the appropriate answer.

CORRECT METHOD 

WRONG METHODS 

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked. Do **not** use additional sheets for this working.

0 8 The equation shows how **P** reacts with **Q** to make **R** and **S**.

$$\mathbf{P} + 2\mathbf{Q} \rightarrow \mathbf{R} + \mathbf{S}$$

When a mixture of 0.25 mol of **P** and 0.40 mol of **Q** react, 0.15 mol of **R** is obtained.

What is the percentage yield of **R** in this reaction?

[1 mark]

A $\frac{0.15}{0.20} \times 100$ ⬭

B $\frac{0.15}{0.25} \times 100$ ⬭

C $\frac{0.15}{0.40} \times 100$ ⬭

D $\frac{0.15}{0.65} \times 100$ ⬭

Do not write outside the box

0 9 What is the M_r of this compound?



[1 mark]

A 94.0 ⬭

B 96.0 ⬭

C 98.0 ⬭

D 100.0 ⬭

1 0 Which statement explains why the rate of a reaction increases when a catalyst is added to a reaction mixture at a constant temperature?

[1 mark]

A The collision frequency increases because there is an increase in the activation energy. ⬭

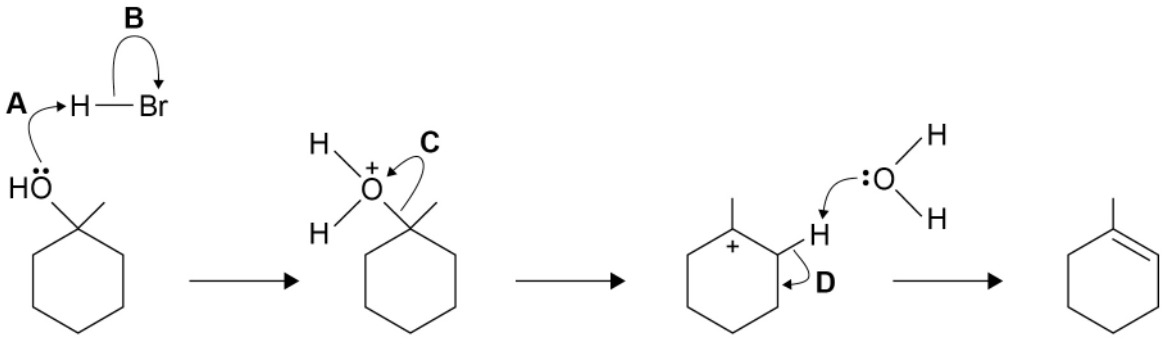
B The collision frequency increases because there is an increase in the mean energy of the particles. ⬭

C The proportion of successful collisions increases because there is a decrease in the activation energy. ⬭

D The proportion of successful collisions increases because there is an increase in the mean energy of the particles. ⬭

Do not write outside the box

1 1 Which labelled curly arrow shows an **incorrect** movement of an electron pair?



[1 mark]

A ⬭

B ⬭

C ⬭

D ⬭

1 2 A halogenoalkane reacts with ethanolic potassium hydroxide to form these alkenes by elimination:

- 2-ethylpent-1-ene
- *E*-3-methylhex-2-ene
- *Z*-3-methylhex-2-ene
- *E*-3-methylhex-3-ene
- *Z*-3-methylhex-3-ene

Which halogenoalkane would form these alkenes in this reaction?

[1 mark]

A 1-bromo-2-ethylpentane ⬭

B 2-bromo-3-methylhexane ⬭

C 3-bromo-3-methylhexane ⬭

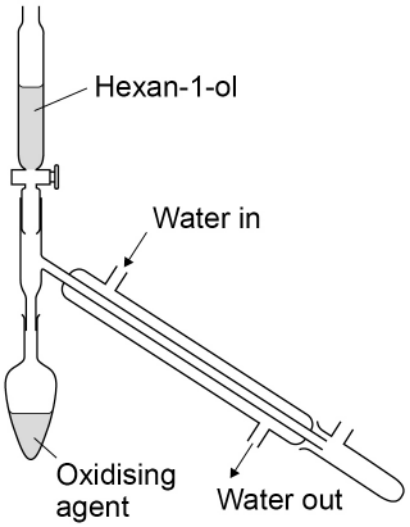
D 3-bromo-4-methylhexane ⬭

Do not write outside the box

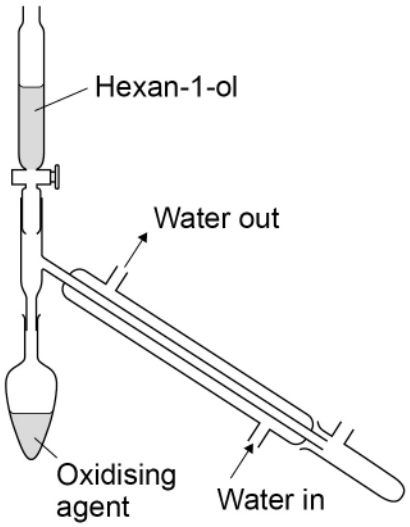
1 3 Which diagram shows the correct apparatus for the conversion of hexan-1-ol to hexanal?

[1 mark]

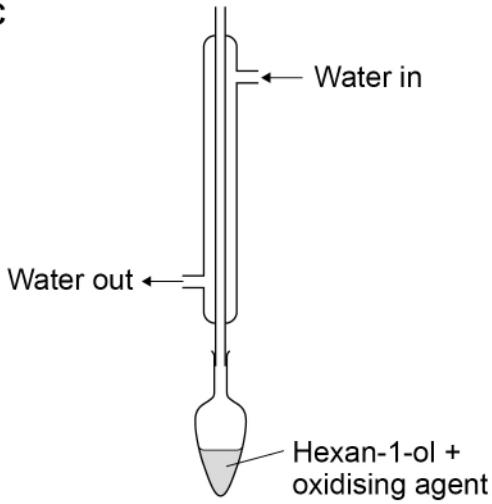
A



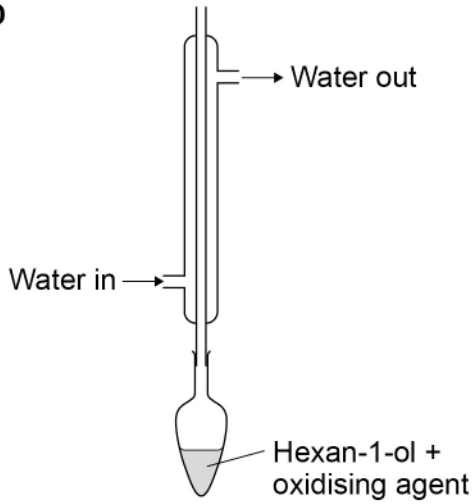
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

Do not write outside the box

1 4 1,1-Dichloroethane (**Y**) reacts with chlorine to form hexachloroethane (**Z**).

Which is the correct equation for this reaction?

[1 mark]

A **Y** + $6\,Cl_2$ → **Z** + $6\,HCl$ ⬭

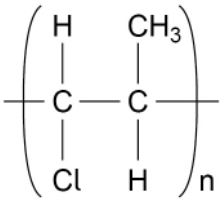
B **Y** + $4\,Cl_2$ → **Z** + $4\,HCl$ ⬭

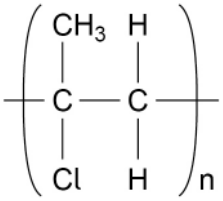
C **Y** + $3\,Cl_2$ → **Z** + $3\,H_2$ ⬭

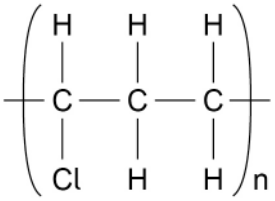
D **Y** + $2\,Cl_2$ → **Z** + $2\,H_2$ ⬭

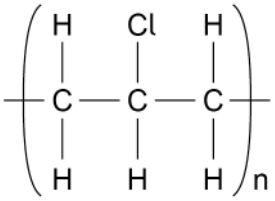
1 5 Which is the structure of poly(1-chloropropene)?

[1 mark]

A  ⬭

B  ⬭

C  ⬭

D  ⬭

Turn over ►

Do not write outside the box

1 6 Octadecane is a straight-chain alkane containing 18 carbon atoms per molecule. It is cracked to produce oct-1-ene and two other compounds.

Which equation represents this reaction?

[1 mark]

A $C_{18}H_{36} \rightarrow C_8H_{16} + C_6H_{12} + 2C_2H_4$ ⬭

B $C_{18}H_{38} \rightarrow C_8H_{16} + C_4H_{10} + 2C_3H_6$ ⬭

C $C_{18}H_{38} \rightarrow C_8H_{18} + C_2H_4 + 2C_4H_8$ ⬭

D $C_{18}H_{38} \rightarrow C_8H_{18} + C_4H_8 + 2C_3H_6$ ⬭

1 7 Which of these alkanes has the highest boiling point?

[1 mark]

A decane ⬭

B hexane ⬭

C 2,3-dimethyloctane ⬭

D 2,3-dimethylbutane ⬭

1 8 High resolution mass spectrometry can be used to determine the precise relative molecular mass of compounds.

Which compound has a precise relative molecular mass that is different from the precise relative molecular mass of butanone?

[1 mark]

A but-3-en-1-ol ⬭

B cyclobutanol ⬭

C methylpropanal ⬭

D prop-2-enoic acid ⬭

Do not write outside the box

Use this information to answer Questions **19** and **20**.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H = -393.5 \text{ kJ mol}^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H = -285.8 \text{ kJ mol}^{-1}$

$3\,C(s) + 4\,H_2(g) \rightarrow C_3H_8(g)$ $\quad \Delta H = -104.0 \text{ kJ mol}^{-1}$

$4\,C(s) + 5\,H_2(g) \rightarrow C_4H_{10}(g)$ $\quad \Delta H = -125.2 \text{ kJ mol}^{-1}$

1 9 What is the enthalpy of combustion, in kJ mol^{-1}, of propane?

[1 mark]

A −211.7 ⬭

B −419.7 ⬭

C −2220 ⬭

D −2878 ⬭

2 0 What is the enthalpy change, in kJ mol^{-1}, when butane reacts to form propane, hydrogen and carbon?

[1 mark]

A +21.2 ⬭

B +17.5 ⬭

C −17.5 ⬭

D −21.2 ⬭

Turn over for the next question

Do not write outside the box

2 1 This is the equation for the conversion of 1,2-dibromoethane to butanedinitrile.

$$CH_2BrCH_2Br + 2\,KCN \rightarrow NCCH_2CH_2CN + 2\,KBr$$

What is the percentage atom economy for the production of butanedinitrile in this reaction?

Relative formula masses, M_r

$CH_2BrCH_2Br = 187.8$
$KCN = 65.1$
$NCCH_2CH_2CN = 80.0$
$KBr = 119.0$

[1 mark]

A 100% ⬭

B 40.2% ⬭

C 31.6% ⬭

D 25.2% ⬭

2 2 A sample of cyclohexane contains 3.011×10^{24} atoms of carbon.

What is the mass of this sample?

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

[1 mark]

A 70.0 g ⬭

B 71.7 g ⬭

C 420 g ⬭

D 430 g ⬭

15

END OF QUESTIONS

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