

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

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.

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**.

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



J U N 2 4 7 4 0 4 2 0 1

Section A

Answer **all** questions in this section.

0 1

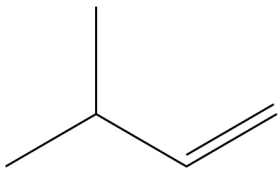
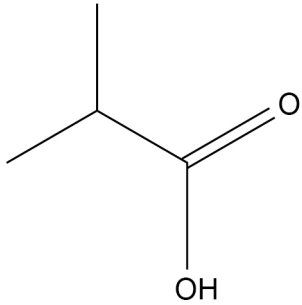
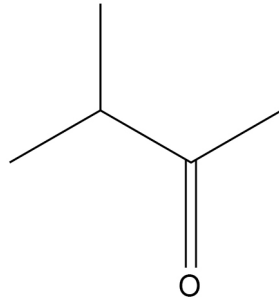
This question is about the analysis of organic compounds.

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	<i>no visible change (stays orange)</i>	no visible change
<i>Add sodium carbonate (Na₂CO₃)</i>	no visible change	bubbles of gas	no visible change
Warm with Fehling's solution	no visible change	no visible change	<i>no visible change (stays blue)</i>

[3 marks]

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]

$$\text{mass of H} = 0.500 - 0.450 = 0.050 \text{ g}$$

$$\text{C: } 0.450 / 12.0 = 0.0375 \text{ mol} \quad \text{H: } 0.050 / 1.0 = 0.050 \text{ mol}$$

$$\text{divide by smallest: } \text{C} = 0.0375 / 0.0375 = 1 \quad \text{H} = 0.050 / 0.0375 = 1.33$$

$$\text{ratio C : H} = 1 : 1.33 = 3 : 4$$

Empirical formula C_3H_4

6

Turn over for the next question

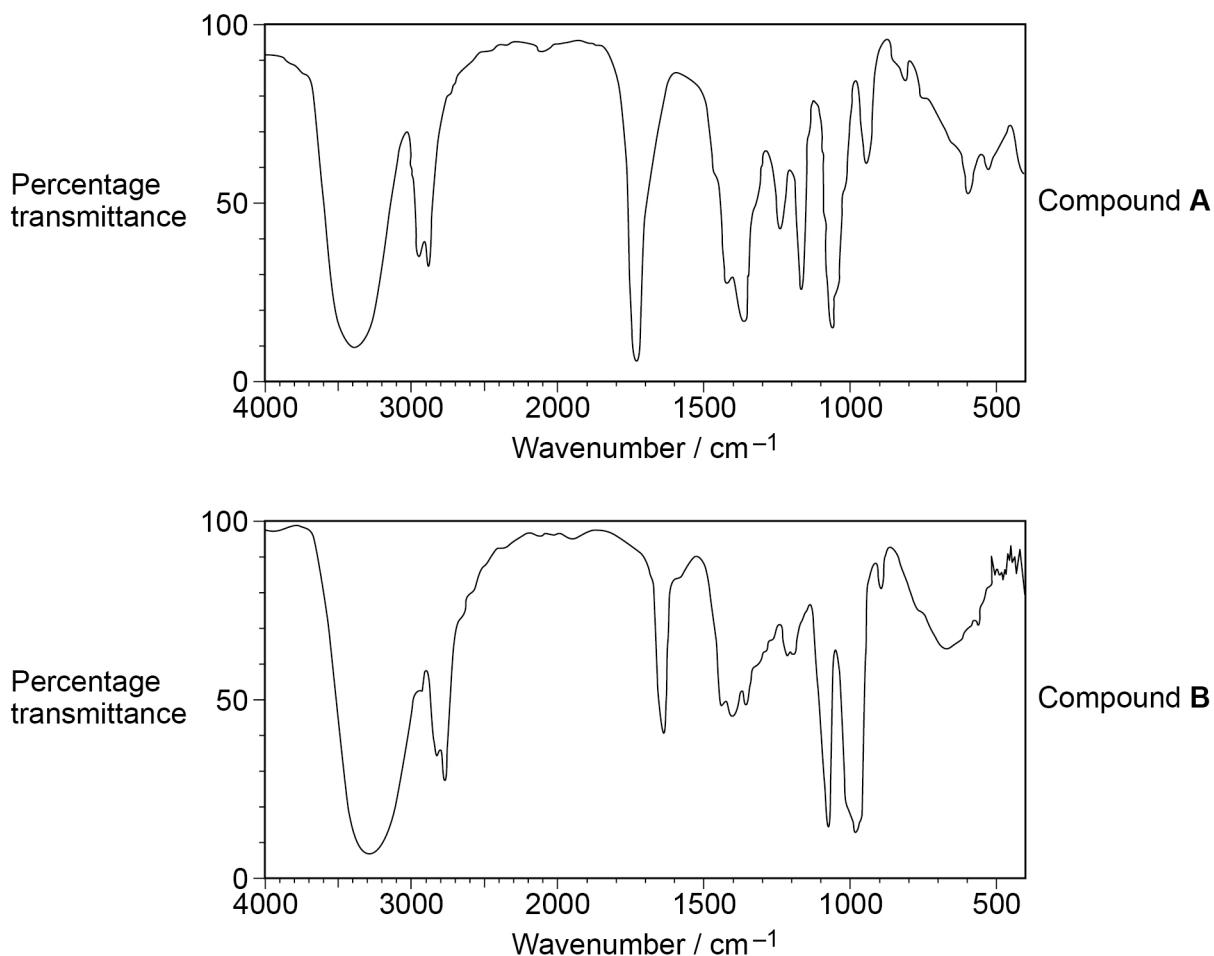
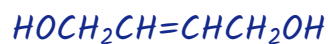
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0 2

This question is about infrared spectroscopy.

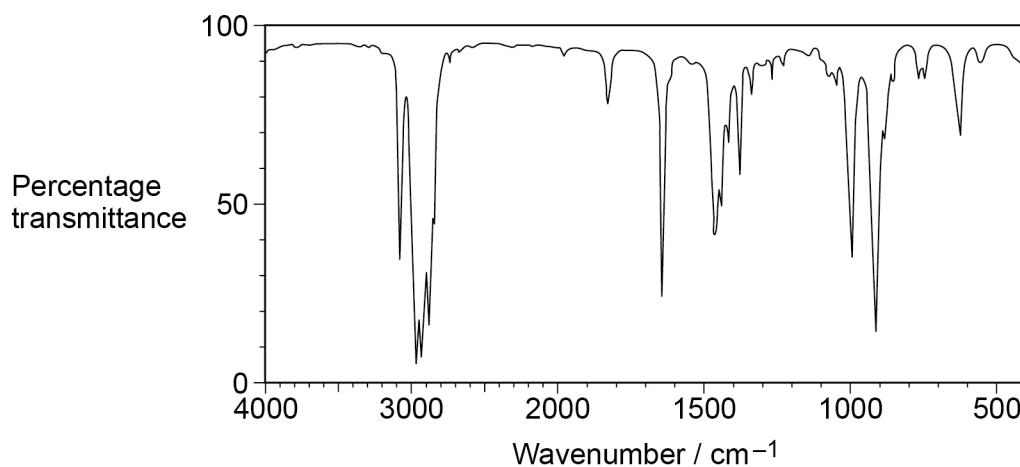
0 2 . 1

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**

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]

Compare the fingerprint region (below 1500 cm⁻¹) with the spectra of known samples of pent-1-ene and 2-methylbut-2-ene; the compound is the one that gives an exact match.

Question 2 continues on the next page

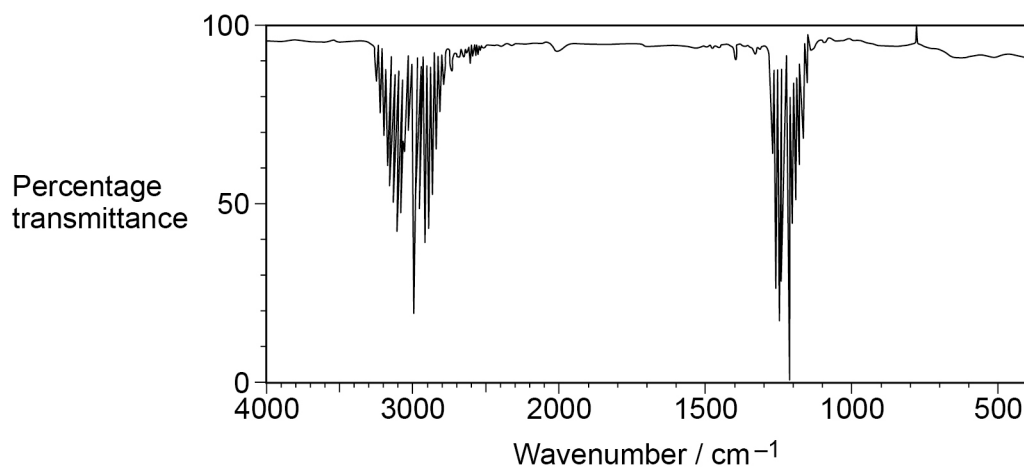
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0 2 . 3

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]**

Methane absorbs infrared radiation: its C-H bonds absorb IR at around 3000 cm⁻¹ and around 1200 cm⁻¹.

5



Turn over for the next question

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Turn over ►



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]

trichlorofluoromethane

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]



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]

Ozone absorbs (removes) harmful ultraviolet (UV) radiation, which would otherwise cause skin cancer (mutations in DNA).

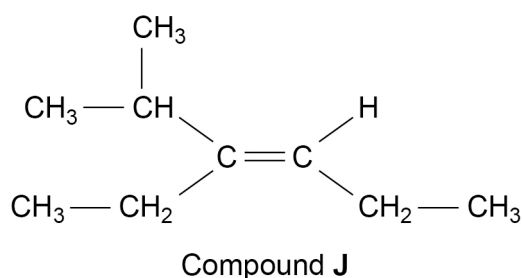
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0 4 . 1

Compound **J** is one of a pair of stereoisomers.

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]

Stereoisomers are molecules with the same structural formula but a different arrangement of their atoms (bonds) in space.

E-Z isomerism occurs because there is restricted rotation (no rotation) about the C=C double bond, and each carbon atom of the C=C has two different groups attached to it.

Using the Cahn-Ingold-Prelog rules, on each carbon of the C=C the atoms directly attached are compared, and the group whose attached atom has the higher atomic number has the higher priority.

On the right-hand carbon, CH₂CH₃ has a higher priority than H, because the atomic number of C (6) is higher than that of H (1).

On the left-hand carbon, both groups are attached by a C atom, so the atoms joined to that C are compared: in (CH₃)₂CH the C is joined to C, C, H (6, 6, 1) but in CH₃CH₂ it is joined to C, H, H (6, 1, 1). So (CH₃)₂CH has the higher priority than CH₃CH₂.

*The two higher priority groups, (CH₃)₂CH on the left and CH₂CH₃ on the right, are on opposite sides of the C=C double bond, so compound **J** is the *E* isomer.*

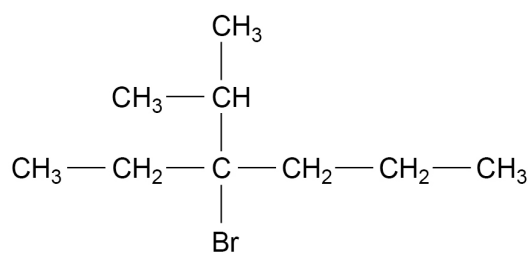
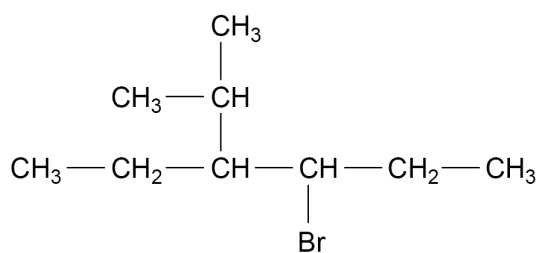


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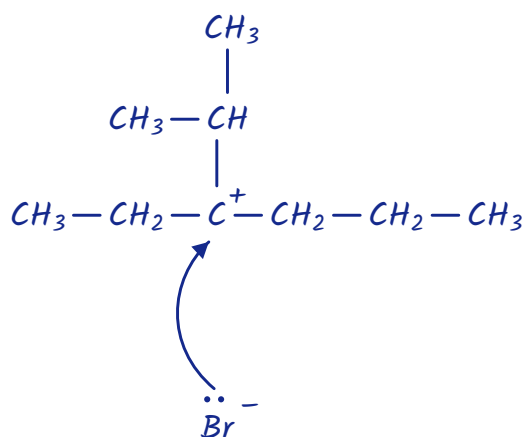
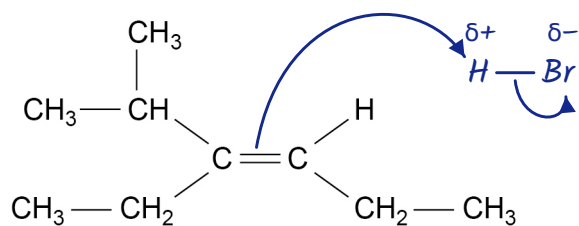
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0 4 . 2

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 Electrophilic addition

Outline of mechanism

**K**

0 4 . 3

Explain why compound **K** is the major product in the reaction in Question **04.2**.**[3 marks]**

*K is formed via the more stable carbocation: a tertiary carbocation,
whereas L comes from a secondary carbocation.*

*The tertiary carbocation is more stable as it has three electron-releasing
alkyl groups on the positive C (not two), so a greater positive inductive
effect.*

14

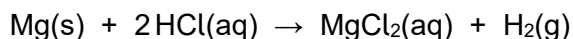
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0 5

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

0 5 . 1

Magnesium reacts with hydrochloric acid.

0.400 g of magnesium is added to 20.0 cm³ of 1.50 mol dm⁻³ hydrochloric acid.

Identify the limiting reagent.

Justify your answer.

Calculate the volume, in m³, of hydrogen produced at 101 kPa and 15 °CThe gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$ **[7 marks]**

$$n(\text{Mg}) = 0.400 / 24.3 = 0.0165 \text{ mol}$$

$$n(\text{HCl}) = (20.0 / 1000) \times 1.50 = 0.0300 \text{ mol}$$

0.0165 mol Mg needs $2 \times 0.0165 = 0.0330 \text{ mol HCl}$, so HCl is limiting

$$n(\text{H}_2) = 0.0300 / 2 = 0.0150 \text{ mol}$$

$$T = 15 + 273 = 288 \text{ K} \quad p = 101 \text{ kPa} = 101\,000 \text{ Pa}$$

$$V = nRT / p = (0.0150 \times 8.31 \times 288) / 101\,000$$

$$V = 3.55 \times 10^{-4} \text{ m}^3$$

Limiting Reagent Hydrochloric acid (HCl)Justification 0.0165 mol of Mg would need 0.0330 mol of HCl, but only

0.0300 mol of HCl is present, so the HCl is used up first (moles of HCl

are less than double the moles of Mg).

Volume of hydrogen 3.55×10^{-4} m³

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 250 cm^3

1 : 5 ratio, so volume of $O_2 = 5 \times 50 = 250\text{ cm}^3$

9

Turn over ►



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 cm³ 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 cm³ 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]

Silver iodide, AgI

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



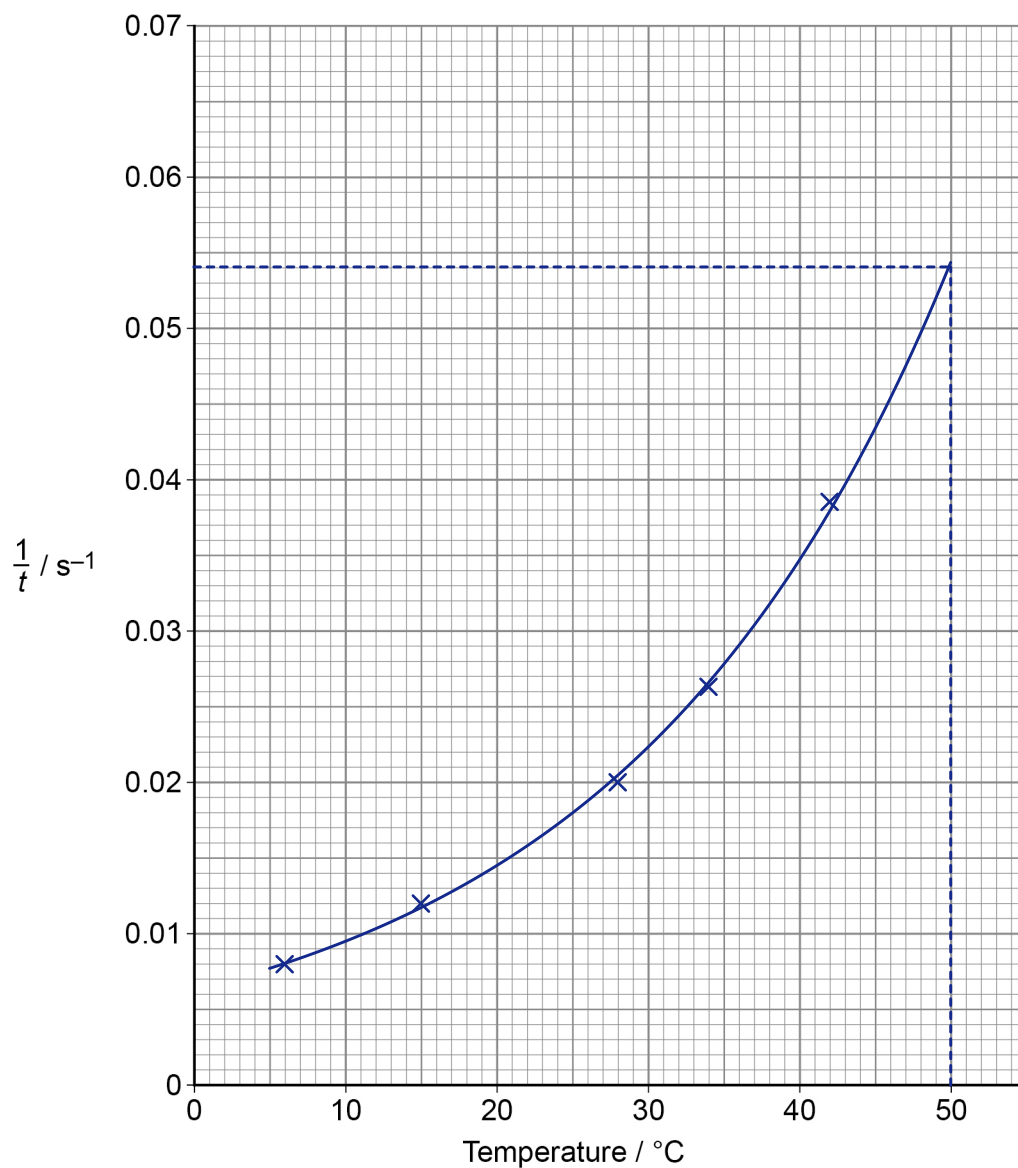
0 6 . 2

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]



$$\text{at } 50 \text{ }^{\circ}\text{C}, 1/t = 0.054 \text{ s}^{-1}$$

$$t = 1 / 0.054 = 18.5 \text{ s}$$

Time 18.5 s

Question 6 continues on the next page

Turn over ►



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 It is slower

The C-Br bond is stronger than the C-I bond (it has a higher bond

Explanation enthalpy), so the C-Br bond needs more energy to break and
breaks less easily, so fewer collisions are successful.

How graph for 1-bromobutane will differ The line for 1-bromobutane will be
below the line for 1-iodobutane.

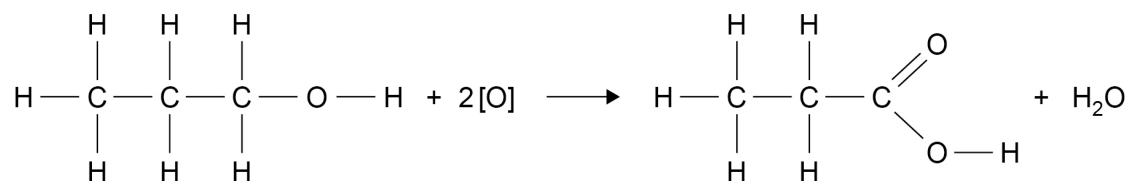
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0 7

This question is about propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$).

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]

Orange to green

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]

Propanal, $\text{CH}_3\text{CH}_2\text{CHO}$

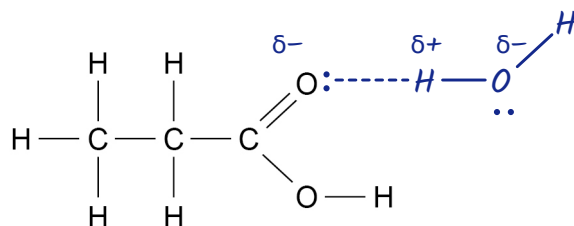
0 7

. 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]

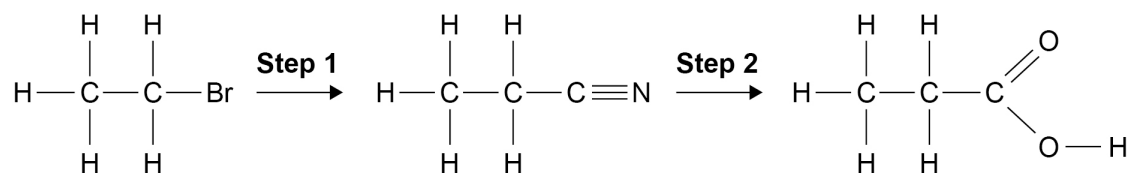


Question 7 continues on the next page

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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.

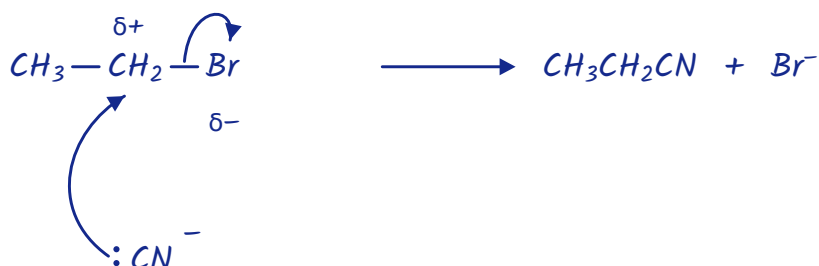
0 7 . 4

Name and outline the mechanism for **Step 1**.

[3 marks]

Name of mechanism Nucleophilic substitution

Outline of mechanism



0 7 . 5

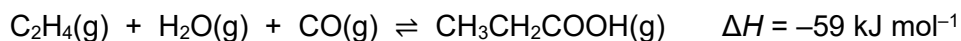
Suggest one reason why water is **not** a suitable solvent for **Step 1**.

[1 mark]

Water (or OH⁻ ions) would act as the nucleophile instead, so ethanol
(an alcohol) would be formed rather than the nitrile.



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



0 7 . 6

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

[1 mark]

$$K_c = \frac{[\text{CH}_3\text{CH}_2\text{COOH}]}{[\text{C}_2\text{H}_4] [\text{H}_2\text{O}] [\text{CO}]}$$

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	$\text{C}_2\text{H}_4(\text{g})$	$\text{H}_2\text{O}(\text{g})$	$\text{CO}(\text{g})$	$\text{CH}_3\text{CH}_2\text{COOH}(\text{g})$
Amount of substance / mol	0.062	0.078	0.062	0.420

Calculate K_c

State the units.

[4 marks]

$$[\text{C}_2\text{H}_4] = [\text{CO}] = 0.062 / 1.20 = 0.0517 \text{ mol dm}^{-3}$$

$$[\text{H}_2\text{O}] = 0.078 / 1.20 = 0.0650 \text{ mol dm}^{-3}$$

$$[\text{CH}_3\text{CH}_2\text{COOH}] = 0.420 / 1.20 = 0.350 \text{ mol dm}^{-3}$$

$$K_c = 0.350 / (0.0517 \times 0.0650 \times 0.0517) = 2017$$

$$\text{units} = (\text{mol dm}^{-3}) / (\text{mol dm}^{-3})^3 = \text{mol}^{-2} \text{ dm}^6$$

$$K_c \underline{\hspace{2cm}} 2017$$

$$\text{Units} \underline{\hspace{2cm}} \text{mol}^{-2} \text{ dm}^6$$

Question 7 continues on the next page

Turn over ►



07.8

Predict the effect of increasing the temperature on the yield of propanoic acid.

Explain your answer.

[3 marks]

Effect on yield *The yield decreases*

Explanation *The forward reaction is exothermic ($\Delta H = -59 \text{ kJ mol}^{-1}$), so when the temperature is increased the equilibrium shifts to the left, in the endothermic direction, to oppose the increase in temperature (to lower the temperature).*

17



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**.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 $\frac{0.15}{0.40} \times 100$

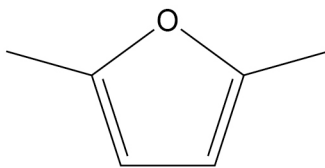


D $\frac{0.15}{0.65} \times 100$



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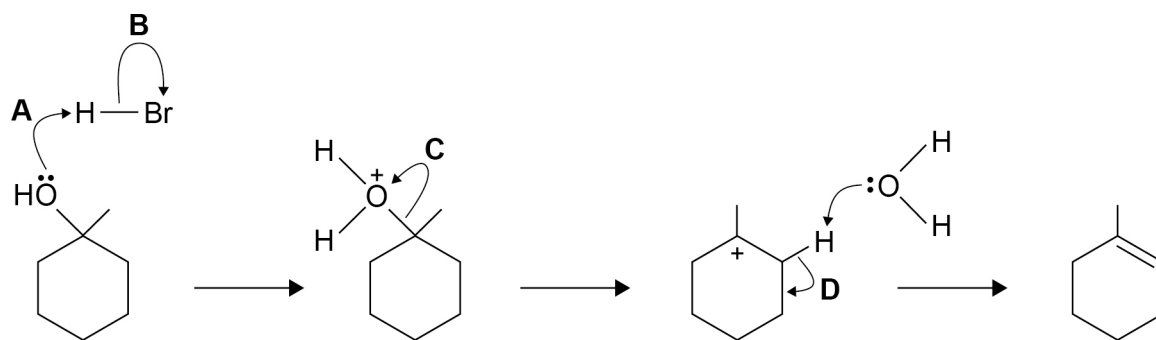


0 9What is the M_r of this compound?**[1 mark]****A** 94.0 ☐**B** 96.0 ☒**C** 98.0 ☐**D** 100.0 ☐**1 0**

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. ☐

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 ☐

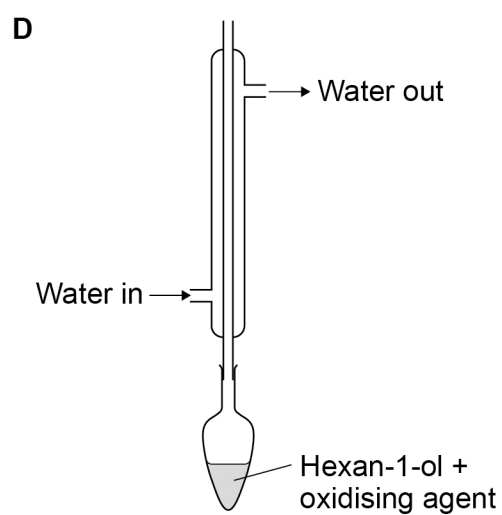
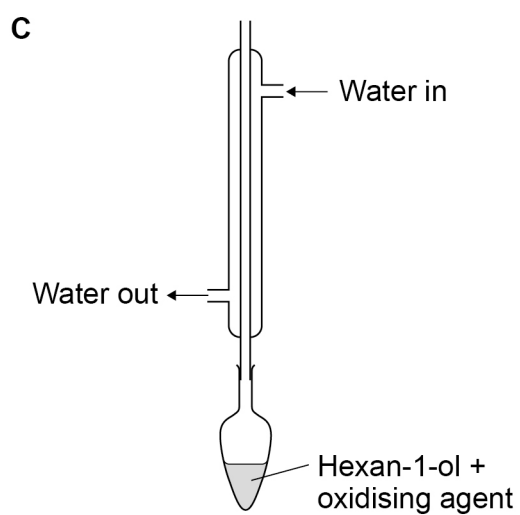
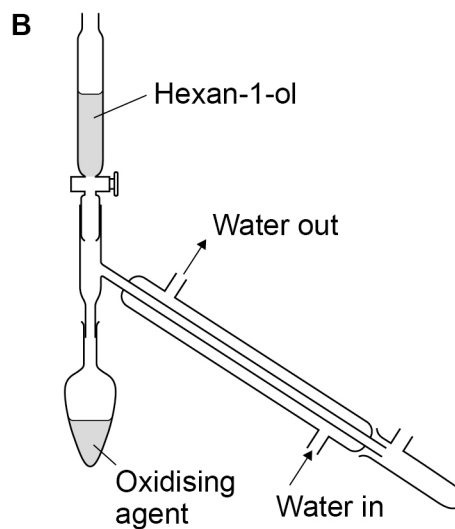
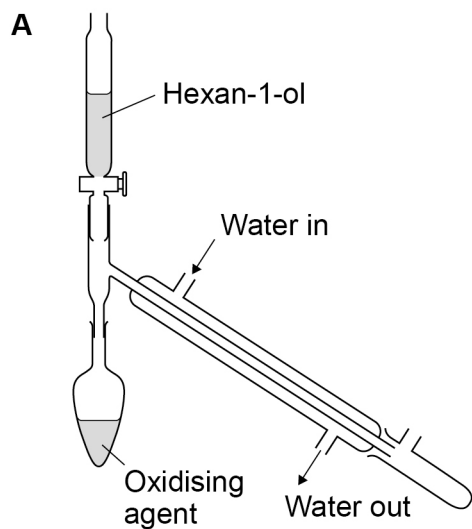
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1 3

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

[1 mark]



A ☐

B ☒

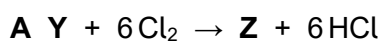
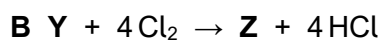
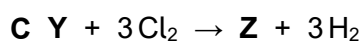
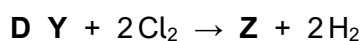
C ☐

D ☐

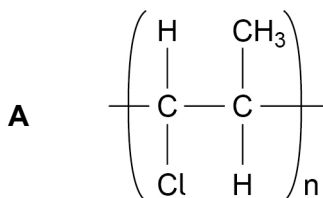
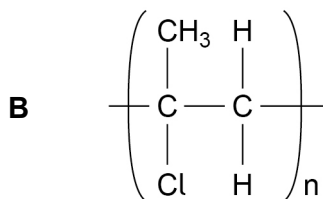
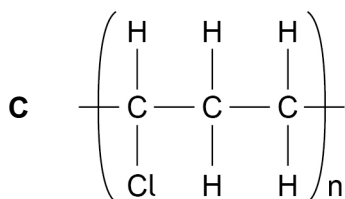
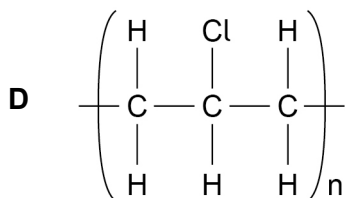


1 41,1-Dichloroethane (**Y**) reacts with chlorine to form hexachloroethane (**Z**).

Which is the correct equation for this reaction?

[1 mark]☐☒☐☐**1 5**

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

[1 mark]☒☐☐☐

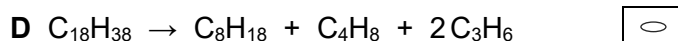
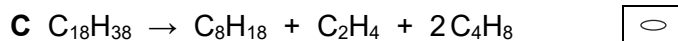
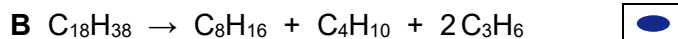
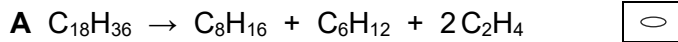
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1 6

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]**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 ☒



Use this information to answer Questions 19 and 20.



19

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

[1 mark]

A -211.7

☐

B -419.7

☐

C -2220

☒

D -2878

☐

20

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

☐

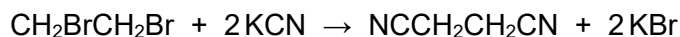
Turn over for the next question

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2 1

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



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

Relative formula masses, M_r

$$\text{CH}_2\text{BrCH}_2\text{Br} = 187.8$$

$$\text{KCN} = 65.1$$

$$\text{NCCH}_2\text{CH}_2\text{CN} = 80.0$$

$$\text{KBr} = 119.0$$

[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, $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

[1 mark]**A** 70.0 g☒**B** 71.7 g☐**C** 420 g☐**D** 430 g☐**15****END OF QUESTIONS**

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3 6



2 4 6 A 7 4 0 4 / 2