

Surname <i>StemUp Model Solution</i>	Centre Number	Candidate Number
First name(s)		2



GCE AS/A LEVEL

2410U20-1



S24-2410U20-1

TUESDAY, 21 MAY 2024 – MORNING

CHEMISTRY – AS unit 2

Energy, Rate and Chemistry of Carbon Compounds

1 hour 30 minutes

Section A Section B	For Examiner’s use only		
	Question	Maximum Mark	Mark Awarded
	1. to 7.	10	
	8.	6	
	9.	10	
	10.	16	
	11.	12	
	12.	11	
	13.	15	
	Total	80	

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01

ADDITIONAL MATERIALS

- A calculator, pencil and ruler
- **Data Booklet** supplied by WJEC

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.

Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q8**.

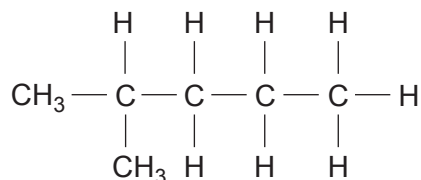


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SECTION AAnswer **all** questions.

1. Give the name of the compound shown.

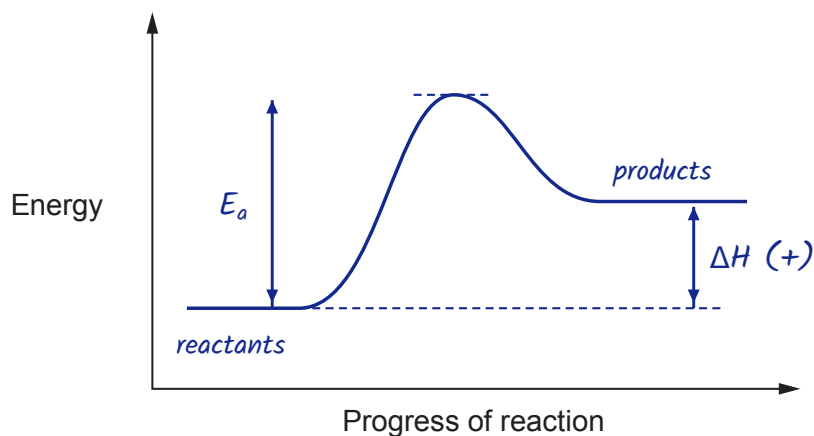
[1]

2-methylpentane

2. Draw the energy profile diagram for an endothermic reaction.

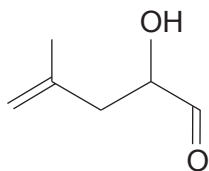
Label the activation energy, E_a , and the enthalpy change of the reaction, ΔH .

[2]



3. Give the molecular and empirical formulae of the compound shown.

[2]

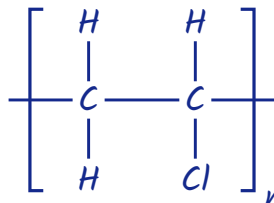
Molecular formula $\text{C}_6\text{H}_{10}\text{O}_2$ Empirical formula $\text{C}_3\text{H}_5\text{O}$ 

4. Chloroethene is polymerised to make PVC.

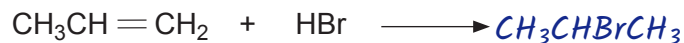
(a) State why the chloroethene monomer does not exhibit *E-Z* isomerism. [1]

One of the carbon atoms of the C=C bond has two identical groups (two H atoms) attached to it.

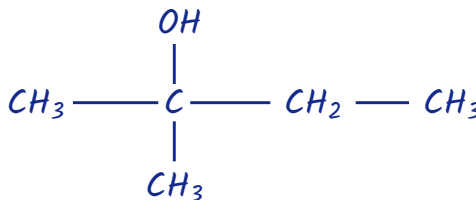
(b) Draw the repeating unit for PVC. [1]



5. Complete the equation to show the structure of the **main** product formed. [1]



6. Give the structure of a tertiary alcohol which contains 5 carbon atoms. [1]



7. Name the catalyst used in the hydrogenation of unsaturated oils to make saturated fats such as margarine. [1]

nickel



SECTION B

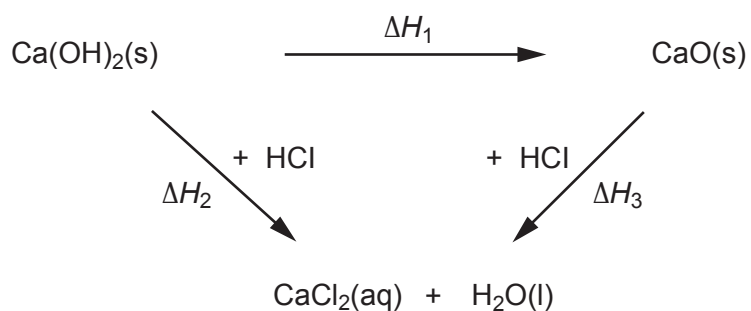
Answer **all** questions.

8. On heating, calcium hydroxide decomposes to produce calcium oxide and water.



The enthalpy change of this reaction cannot be measured directly.

Both calcium hydroxide and calcium oxide react with dilute hydrochloric acid and enthalpy changes can be found for the reactions. Hess's law can then be used to determine ΔH_1 .



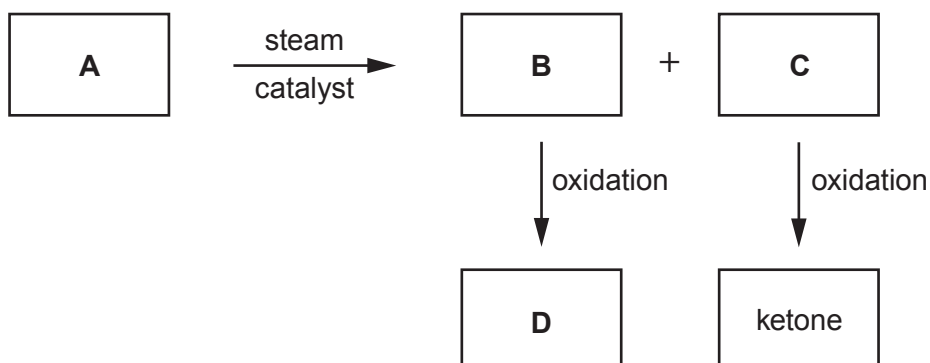
Describe the practical steps you would carry out and how you would use Hess's law to determine the enthalpy change for the decomposition of calcium hydroxide, ΔH_1 .

You should state clearly what needs to be measured but you should **not** calculate any values. [6 QER]

Use a pipette to add a known volume, e.g. 50.0 cm^3 , of dilute HCl of known concentration to a polystyrene cup (insulated container). The acid must be in excess so that all of the solid reacts. Measure the initial temperature of the acid with a thermometer every minute for a few minutes. Weigh accurately a known mass (about 1 g) of CaO and add it to the acid at a recorded time. Stir well so that the reaction is rapid and complete, and record the temperature every 30 s for several minutes. Plot temperature against time and extrapolate the cooling line back to the time of mixing to find the temperature change, ΔT , allowing for heat lost. Repeat all of the steps using a known mass of Ca(OH)_2 with the same volume and concentration of HCl. For each solid calculate the moles reacted, $n = \text{mass} \div M_r$, and the heat given out, $q = mc\Delta T$ ($m = \text{mass of solution}$, $c = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$). Then $\Delta H = -mc\Delta T \div n$, giving ΔH_2 for Ca(OH)_2 and ΔH_3 for CaO in kJ mol^{-1} . Hess's law: the enthalpy change is independent of the route, so $\Delta H_2 = \Delta H_1 + \Delta H_3$, therefore $\Delta H_1 = \Delta H_2 - \Delta H_3$.



9. Look at the reaction scheme below and other information about compounds **A** to **D**.



A is a straight chain hydrocarbon. It contains 85.7 % carbon by mass.

B and **C** are structural isomers.

D is soluble in water. 0.93 g of **D** is dissolved in water to make 100 cm³ of solution. 25.0 cm³ of this solution is titrated against 0.100 mol dm⁻³ aqueous sodium hydroxide. 26.40 cm³ of sodium hydroxide is needed for neutralisation. **D** reacts with sodium hydroxide in a ratio of 1:1.

- (a) Calculate the empirical formula of **A**.

[2]

$$C : 85.7 \div 12.0 = 7.14 \qquad H : 14.3 \div 1.01 = 14.2$$

$$\text{ratio } C : H = 7.14 : 14.2 = 1 : 2$$

Empirical formula CH₂



- (b) Show that the relative molecular mass (M_r) of **D** is 88. [3]

$$n(\text{NaOH}) = 26.40 \times 0.100 \div 1000 = 2.64 \times 10^{-3} \text{ mol}$$

$$n(\text{D}) \text{ in } 25.0 \text{ cm}^3 = 2.64 \times 10^{-3} \text{ mol (1 : 1 ratio)}$$

$$n(\text{D}) \text{ in } 100 \text{ cm}^3 = 2.64 \times 10^{-3} \times 4 = 1.056 \times 10^{-2} \text{ mol}$$

$$M_r = \text{mass} \div \text{moles} = 0.93 \div 1.056 \times 10^{-2} = 88$$

- (c) Give the names of compounds **A** to **D**. [4]

A but-1-ene

B butan-1-ol

C butan-2-ol

D butanoic acid

- (d) Name a suitable reagent for the conversion of **B** to **D**. [1]

acidified potassium dichromate(VI)



10. Thiosulfate ions react with acid according to the equation shown.



A student investigates the effect of changing the concentration of thiosulfate ions on the rate of the reaction.

- (a) Describe how the student could prepare 250 cm³ of 0.10 mol dm⁻³ sodium thiosulfate solution to use in this experiment. The relative formula mass (M_r) of sodium thiosulfate, Na₂S₂O₃·5H₂O, is 248.3.

You should include the apparatus needed and any relevant masses and volumes. [4]

*Moles needed = 0.10 × 250 ÷ 1000 = 0.025 mol, so mass = 0.025 × 248.3
= 6.21 g.*

*Weigh 6.21 g of sodium thiosulfate into a beaker on a balance and dissolve it
in a small volume of deionised water, stirring with a glass rod.*

*Transfer the solution through a funnel into a 250 cm³ volumetric flask, rinsing
the beaker, rod and funnel with deionised water into the flask.*

*Make up to the mark with deionised water, stopper and invert several times to
mix.*



- (b) The student mixes known volumes of aqueous 0.10 mol dm^{-3} sodium thiosulfate and hydrochloric acid in a beaker. He places the beaker on a cross drawn on a piece of paper and measures the time taken for the cross to be obscured.

(i) State what causes the cross to become obscured.

[1]

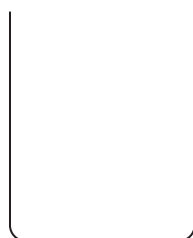
A precipitate of solid sulfur forms.

- (ii) The diagram shows a beaker and a shallow dish.

If the student replaced the beaker with a shallow dish, state the effect this would have on the time taken to obscure the cross. Explain your answer.

Assume that the student used the same volumes and concentrations in each experiment.

[1]



beaker



shallow dish

The time increases, because the depth of solution is less, so less sulfur is formed over the cross.



- (c) The student plans to change the concentration of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ by reducing the volume of aqueous sodium thiosulfate and adding water to keep the total volume constant.

The data obtained by the student for one experiment is shown in the table.

Volume $\text{S}_2\text{O}_3^{2-}(\text{aq})$ / cm^3	Volume H_2O / cm^3	Volume $\text{HCl}(\text{aq})$ / cm^3	Time / s
40	0	10	50
30	10	10	
20	20	10	
10	30	10	

- (i) **Complete the table** to show suitable volumes of thiosulfate, water and acid that the student could use to investigate the effect of changing concentration of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ on the rate of the reaction. [2]

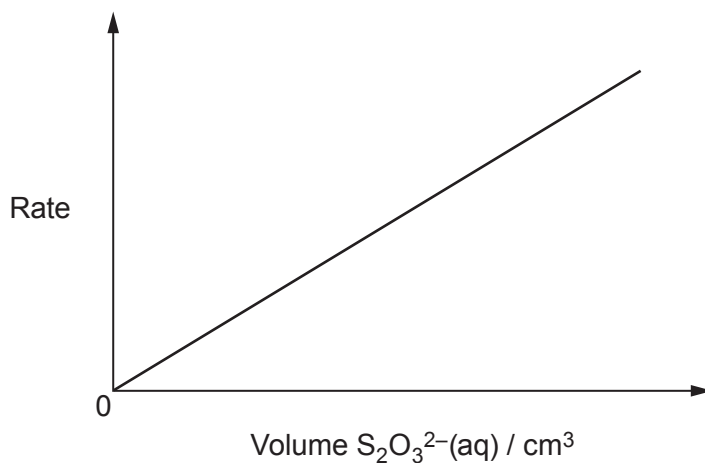
- (ii) The rate of reaction can be calculated using $\text{rate} = \frac{1000}{\text{time}}$

State the unit of rate in this reaction. [1]

s^{-1}



- (iii) The student calculates the rate of reaction using different volumes of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ and plots a graph. The graph is shown.



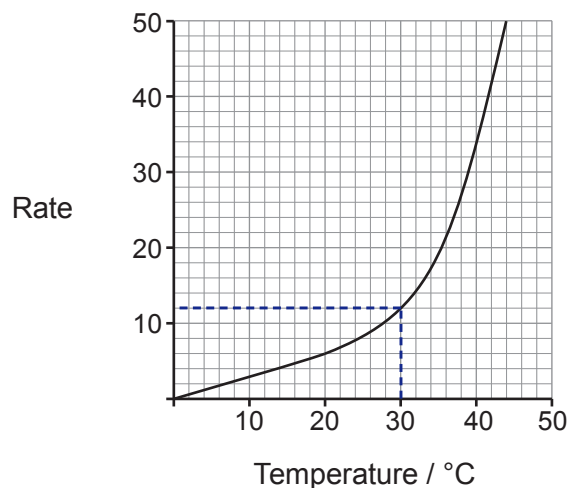
State what can be deduced from the shape of this graph.

[1]

The rate is directly proportional to the volume (concentration) of thiosulfate.



- (d) Another student uses a similar experiment to investigate the effect of changing the temperature on the rate of this reaction. He draws a graph of his data.



- (i) Use the graph to determine the time taken for the cross to be obscured at a temperature of 30 °C. Show clearly how you obtained your answer. [2]

$$\text{rate} = \frac{1000}{\text{time}}$$

from the graph, at 30 °C rate = 12

$$\text{time} = 1000 \div \text{rate} = 1000 \div 12 = 83 \text{ s}$$

Time = 83 s

- (ii) Some textbooks state that a 10 °C temperature rise approximately doubles the rate of many reactions. Use the graph to find to what extent this is true for this reaction. [2]

Only partly true. From 10 °C to 20 °C (rate 3 to 6) and from 20 °C to 30 °C (rate 6 to 12) the rate doubles, but from 30 °C to 40 °C the rate more than doubles (12 to about 33).

- (iii) Explain why the rate of the reaction is affected by an increase in temperature. [2]

The particles have more (kinetic) energy, so a greater proportion of collisions have energy greater than or equal to the activation energy.



11. Compound **X** is thought to be a halogenoalkane containing only one halogen atom.

(a) Describe a chemical test by which you could identify which halogen is present in **X**. [4]

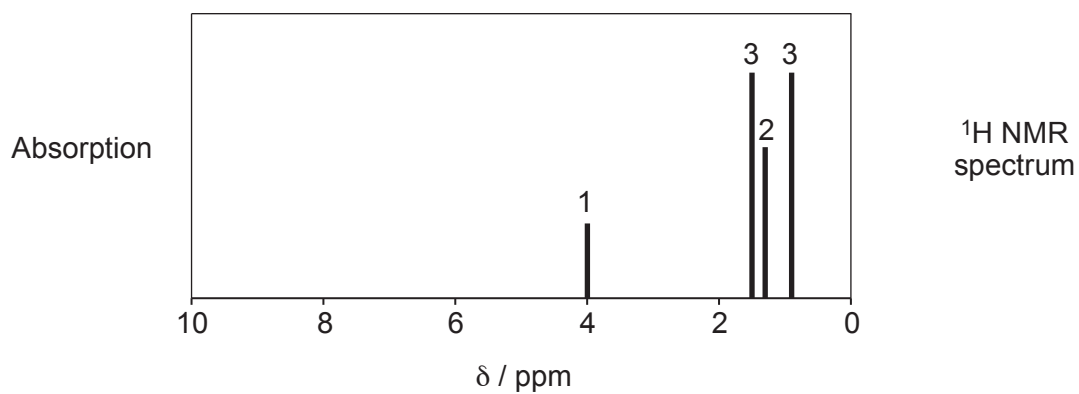
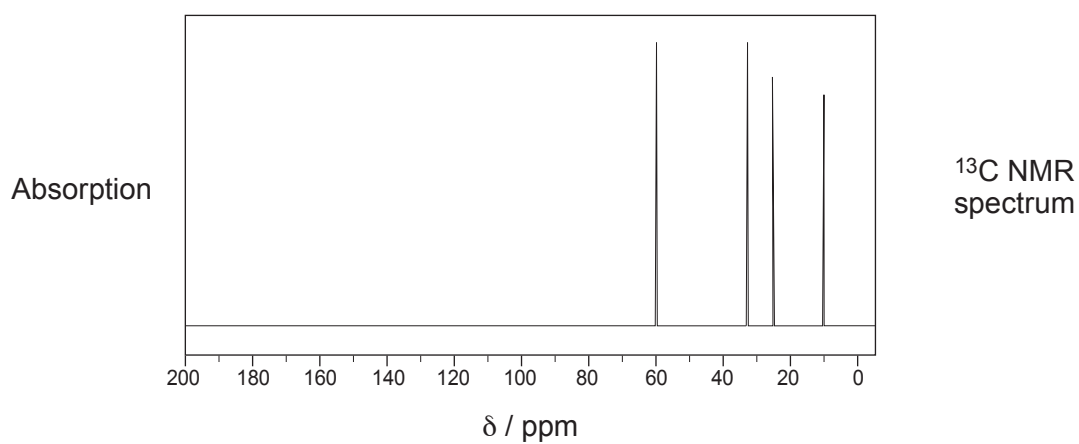
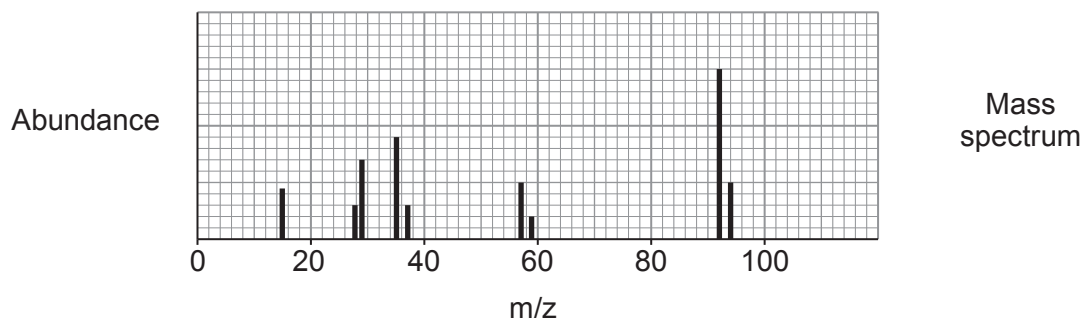
Warm X with aqueous sodium hydroxide. Then add dilute nitric acid to

neutralise the excess NaOH, followed by aqueous silver nitrate.

*A white precipitate shows chlorine, a cream precipitate shows bromine and a
yellow precipitate shows iodine.*



- (b) A simplified form of the mass spectrum, the ^{13}C NMR spectrum and the low resolution ^1H NMR spectrum of halogenoalkane **X** are shown.



Use this information to find the structure of halogenoalkane **X**. Show your reasoning.

You must use information from **all** the spectra.

[8]

Mass spectrum: molecular ion peaks at $m/z = 92$ and 94 , so $M_r = 92/94$. Their heights are in the ratio $3 : 1$ (as are the peaks at 35 and 37), the ratio of $^{35}\text{Cl} : ^{37}\text{Cl}$, so **X** contains chlorine.

Fragments: peak at 15 is CH_3^+ and peak at 29 is C_2H_5^+ .

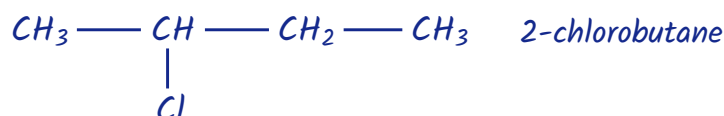
^{13}C NMR: 4 peaks, so 4 different carbon environments. $92 - 35 = 57 = \text{C}_4\text{H}_9$, so the molecular formula is $\text{C}_4\text{H}_9\text{Cl}$. The peak at about 60 ppm is the C bonded to Cl.

^1H NMR: 4 peaks, so 4 different hydrogen environments, with relative peak heights $1 : 3 : 2 : 3$ (9 H).

Peak at 4.0 ppm (1H) is HC-Cl ; peak at 1.5 ppm (3H) is the $-\text{CH}_3$ next to the CHCl ; peak at 1.3 ppm (2H) is $\text{R-CH}_2\text{-R}$; peak at 0.9 ppm (3H) is R-CH_3 .

This only fits $\text{CH}_3\text{CHClCH}_2\text{CH}_3$, so **X** is 2-chlorobutane.

Structure of **X**



12. (a) State what is meant by the enthalpy change of combustion.

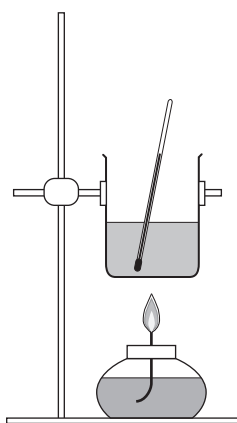
[2]

The enthalpy change when 1 mole of a substance is burned completely in excess oxygen.

- (b) (i) The equation that corresponds to the enthalpy change of combustion of propan-1-ol is shown.



The apparatus below can be used to determine the enthalpy change for this reaction.



A student used this apparatus and obtained the following results.

Initial mass of spirit burner with propan-1-ol = 126.16 g

Final mass of spirit burner with propan-1-ol = 126.02 g

Initial temperature of water = 21.0 °C

Final temperature of water = 33.5 °C

Volume of water in beaker = 100 cm³



Use these results in parts I and II.

- I. Calculate the number of moles of propan-1-ol used up in the reaction. [1]

$$\text{mass burned} = 126.16 - 126.02 = 0.14 \text{ g}$$

$$M_r(\text{C}_3\text{H}_7\text{OH}) = 60.1$$

$$n = 0.14 \div 60.1 = 0.00233 \text{ mol}$$

Number of moles = 0.00233 mol

- II. Calculate the enthalpy change of combustion of propan-1-ol, $\Delta_c H$, under these conditions of temperature and pressure. [3]

$$\Delta T = 33.5 - 21.0 = 12.5 \text{ }^\circ\text{C}$$

$$q = mc\Delta T = 100 \times 4.18 \times 12.5 = 5225 \text{ J} = 5.225 \text{ kJ}$$

$$\Delta H = -q \div n = -5.225 \div 0.00233$$

$$\Delta H = -2242 \text{ kJ mol}^{-1}$$

$\Delta_c H = \frac{-}{\text{sign}} \frac{2242}{\text{value}} \text{ kJ mol}^{-1}$

- (ii) Another student suggested that leaving the spirit burner to burn for longer would increase the accuracy of the experiment.

State whether you agree with this student. Explain your answer. [1]

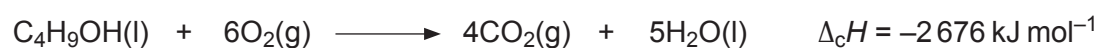
Agree: more fuel burns and the temperature rise is greater, so the
percentage error is lower.



- (c) Enthalpy changes of combustion can be used to determine average bond enthalpies.
Some average bond enthalpies are given in the table.

Bond	Average bond enthalpy / kJ mol ⁻¹
O = O	496
C — H	412
C — C	348
C = O	805
O — H	463

The equation that corresponds to the enthalpy change of combustion of butan-1-ol is shown below.



Use the enthalpy change of combustion of butan-1-ol and the average bond enthalpies in the table to calculate the average bond enthalpy of a C—O bond. [4]

$$\text{bonds broken} = 3(\text{C}-\text{C}) + 9(\text{C}-\text{H}) + (\text{C}-\text{O}) + (\text{O}-\text{H}) + 6(\text{O}=\text{O})$$

$$= 3(348) + 9(412) + (\text{C}-\text{O}) + 463 + 6(496)$$

$$= 1044 + 3708 + (\text{C}-\text{O}) + 463 + 2976 = 8191 + (\text{C}-\text{O})$$

$$\text{bonds formed} = 8(\text{C}=\text{O}) + 10(\text{O}-\text{H}) = 8(805) + 10(463)$$

$$= 6440 + 4630 = 11070$$

$$\Delta H = \text{bonds broken} - \text{bonds formed}$$

$$-2676 = 8191 + (\text{C}-\text{O}) - 11070$$

$$(\text{C}-\text{O}) = -2676 - 8191 + 11070 = 203 \text{ kJ mol}^{-1}$$

Average bond enthalpy [C—O] = ... 203 kJ mol⁻¹



13. (a) Two students were discussing how to prepare chloroethane. One student suggested reacting chlorine with ethane but the other student said that the yield from this reaction was poor and that it was better to react hydrogen chloride with ethene.

(i) State the **type** of reaction involved in each case. [2]

ethane and chlorine

radical substitution

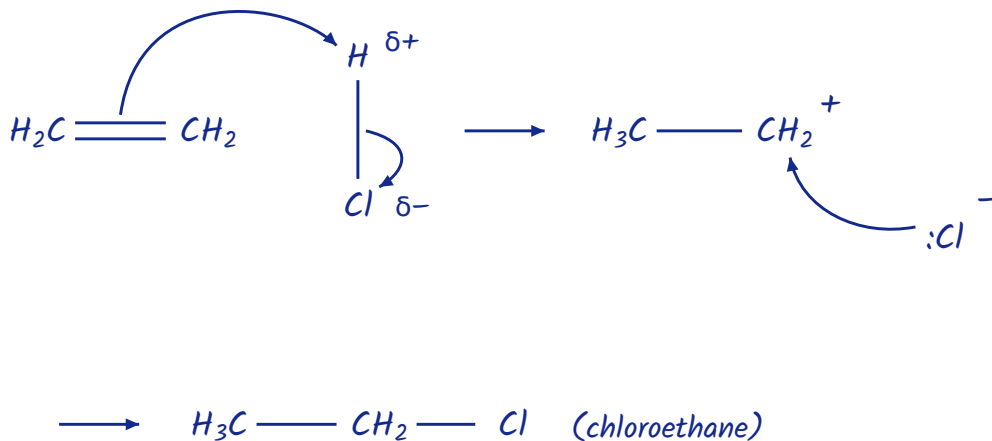
ethene and hydrogen chloride

(electrophilic) addition

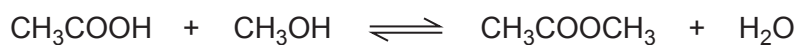
(ii) Suggest why the reaction between ethene and hydrogen chloride gives the better yield. [1]

Only one product is formed, whereas radical substitution gives many possible products.

(iii) Give the mechanism for the reaction between ethene and hydrogen chloride. [4]



- (b) The equation for the reaction between ethanoic acid and methanol to form an ester is shown.



- (i) In the preparation of this ester, 25 g of ethanoic acid reacted with excess methanol. If the percentage yield of the reaction was 34 %, calculate the mass of ester formed. [3]

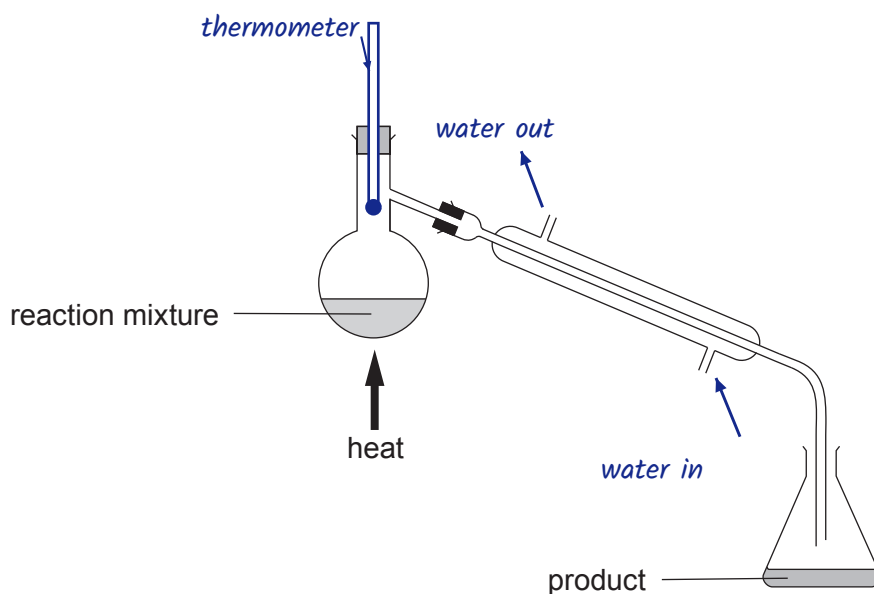
$$n(\text{CH}_3\text{COOH}) = 25 \div 60.0 = 0.417 \text{ mol}$$

$$n(\text{ester}) = 0.417 \times 34 \div 100 = 0.142 \text{ mol} \quad (1 : 1)$$

$$\text{mass} = 0.142 \times 74.0 = 10.5 \text{ g}$$

Mass = ... 10.5 g

- (ii) The diagram shows the method used to separate the ester from the reaction mixture.



Draw on the diagram

- the position of the thermometer
- the direction of water flowing through the condenser

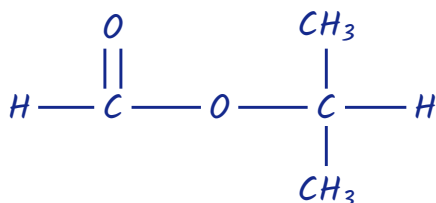
[2]



- (iii) Addition of concentrated sulfuric acid increases the yield of ester. Explain this observation. [2]

Concentrated sulfuric acid is a dehydrating agent and removes water from the right-hand side, so the position of equilibrium shifts to the right to oppose the change, forming more ester.

- (c) Draw the structure of the ester formed when propan-2-ol reacts with methanoic acid. [1]



END OF PAPER



[illegible]

[illegible]