Surname	StemUp Model Solution	Centre Number	Candidate Number
First name(s)			2

GCE AS

B410U20-1

S25-B410U20-1

Part of WJEC

TUESDAY, 20 MAY 2025 – MORNING

CHEMISTRY – AS component 2

Energy, Rate and Chemistry of Carbon Compounds

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 6.**	**10**	
Section B	**7.**	**10**	
	8.	**18**	
	9.	**12**	
	10.	**12**	
	11.	**18**	
	Total	**80**	

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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 **Q10**(a).

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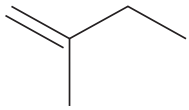
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SECTION A

Answer **all** questions.

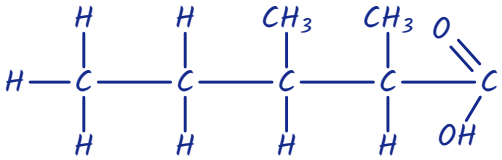
1. The skeletal formula of a compound is shown below.



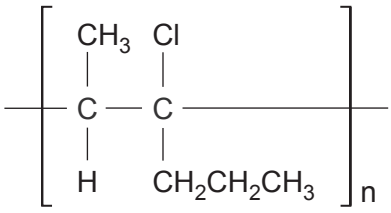
Name the compound. [1]

2-methylbut-1-ene

2. Draw the structure of 2,3-dimethylpentanoic acid. [1]



3. Name the alkene monomer that can be polymerised to give the following polymer. [1]



3-chlorohex-2-ene

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4. (a) State why ammonia is classified as a nucleophilic reagent. [1]

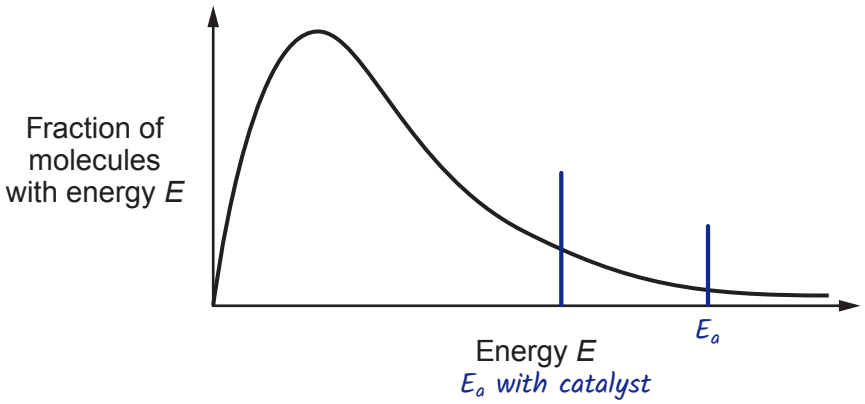
It has a lone pair of electrons (on N) that it can donate; it is electron rich.

(b) Write the equation for the standard molar enthalpy change of formation of ammonia. [2]

$\frac{1}{2}N_2(g) + 1\frac{1}{2}H_2(g) \rightarrow NH_3(g)$

5. The diagram below shows the distribution of molecular energies for a sample of gas.

Use this curve to explain how a catalyst increases the rate of reaction. [2]



A catalyst gives an alternative route with a lower activation energy (E_a moves left). Many more molecules have energy greater than E_a, so more collisions are successful per unit time.

6. Calculate the number of **molecules** in 25.6 kg of ethanoic acid (M_r 60.0). [2]

$n(CH_3COOH) = 25\,600\ g \div 60.0 = 427\ mol$

$molecules = 427 \times 6.02 \times 10^{23}$

Molecules of ethanoic acid = 2.57×10^{26}

10

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SECTION B

Answer **all** questions.

7. (a) A student was given a sample of a halogenoalkane and told to find out which halogen was present in the sample.

His method, observation and conclusion are shown below.

- Pipette 1 cm^3 of the halogenoalkane into a test tube
- Add 1 cm^3 of 1 mol dm^{-3} aqueous sodium hydroxide and warm
- Add 3 - 4 drops of 1 mol dm^{-3} dilute nitric acid
- Add 1 cm^3 of aqueous silver nitrate
- Cream precipitate is seen so halogen is bromine

(i) Suggest an improvement to the method that does not require the use of an additional reagent. Give a reason for your suggestion. [2]

Add more nitric acid (at least 1 cm^3); there must be enough to neutralise all the excess sodium hydroxide before adding silver nitrate.

(ii) Another student thought that the precipitate was white and that the halogen present in the sample was therefore chlorine.

Give a further test that the student could carry out to prove which halogen is present in the sample. Include the results for chlorine and bromine in your answer. [2]

Add dilute aqueous ammonia to the precipitate.

If the halogen is chlorine, the white precipitate fully dissolves; if it is bromine, the cream precipitate only partially dissolves.

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(b) When 6.26 g of 1-bromobutane (M_r 137) was converted into pentanenitrile, C_4H_9CN, 2.58 g of the product was obtained.

Calculate the percentage yield for this reaction. Give your answer to an **appropriate** number of significant figures. [3]

n(1-bromobutane) = 6.26 ÷ 137 = 0.0457 mol

$M_r(C_4H_9CN)$ = 83.1; 1 : 1 ratio

expected mass = 0.0457 × 83.1 = 3.80 g

percentage yield = 2.58 ÷ 3.80 × 100

Percentage yield = *67.9* %

(c) Despite a total ban on CFCs coming into effect in 2014, many companies are still in the process of replacing their cooling systems. Consequently, there are plenty of air-conditioning systems still using CFCs such as Freon, CHF_2Cl.

Explain how Freon poses a threat to the environment. [3]

In the upper atmosphere UV radiation causes homolytic fission of the C–Cl bond in Freon, forming chlorine radicals, Cl·.

The Cl· radicals catalyse the breakdown of ozone ($Cl· + O_3 \rightarrow ClO· + O_2$), depleting the ozone layer.

This lets more harmful UV rays reach the Earth's surface, causing skin cancer.

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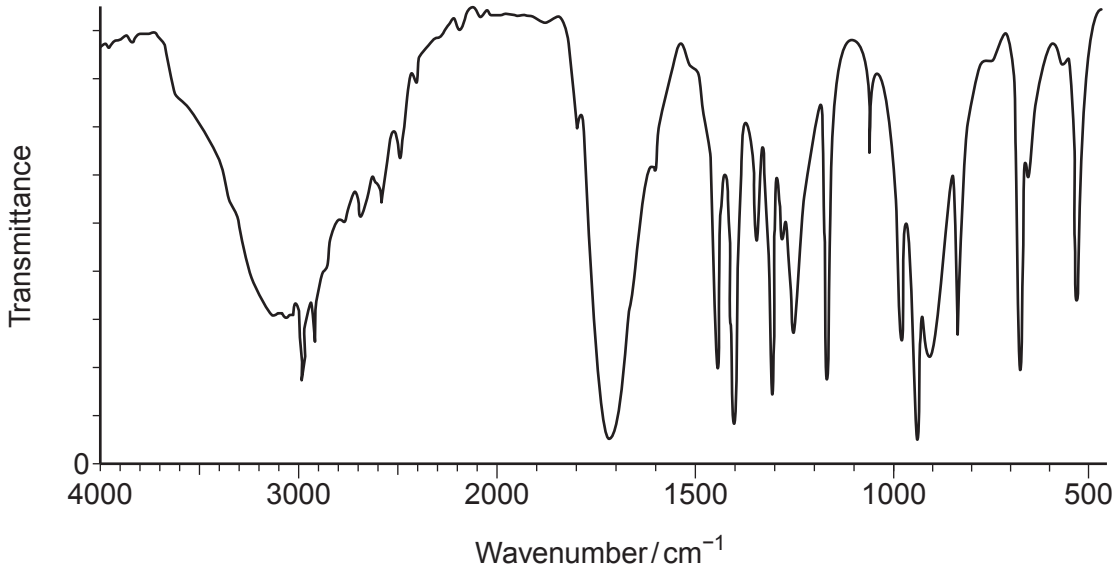
8. The information given below relates to a corrosive white solid, **X**.

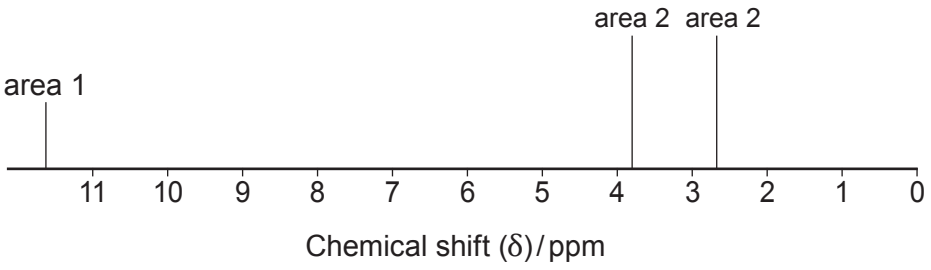
Quantitative analysis shows that its percentage composition by mass is carbon 33.2%, chlorine 32.7% and hydrogen 4.6% with the remainder being oxygen.

The mass spectrum shows two molecular ion signals at m/z 108 and m/z 110 in the ratio of 3:1.

On addition to an aqueous solution of sodium hydrogencarbonate, effervescence is seen.

Its infrared spectrum and low resolution ^{1}H NMR spectrum are shown below.





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(a) Use **all** the information to identify compound **X**. [9]

	C	H	O	Cl
% by mass	33.2	4.6	29.5	32.7
÷ A_r	÷ 12.0	÷ 1.01	÷ 16.0	÷ 35.5
moles	2.77	4.55	1.84	0.921
÷ 0.921	3.0	4.9	2.0	1.0
ratio	3	5	2	1

Empirical formula = $C_3H_5O_2Cl$ (O = 100 − 33.2 − 4.6 − 32.7 = 29.5%)

Empirical formula mass = 108.5. The two molecular ion peaks at m/z 108 and 110 (ratio 3 : 1) are due to the ^{35}Cl and ^{37}Cl isotopes, so X has one Cl and the molecular formula is $C_3H_5O_2Cl$.

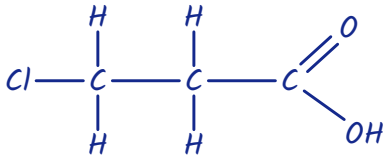
Effervescence (CO_2) with $NaHCO_3$ shows X contains a carboxylic acid group, −COOH.

IR: broad peak at about 3000 cm^{-1} is O–H in a carboxylic acid; strong peak at about 1715 cm^{-1} is C=O.

NMR: three peaks, so three different hydrogen environments (areas 1 : 2 : 2).

Peak at 11.5 δ (area 1) is the OH in −COOH; peak at 3.9 δ (area 2) is the CH_2 bonded to Cl (H–C–Cl); peak at 2.8 δ (area 2) is the CH_2 next to C=O.

So X is 3-chloropropanoic acid, CH_2ClCH_2COOH:



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(b) Ethanol is normally produced worldwide either by the hydration of ethene or the fermentation of crops such as sugarcane.

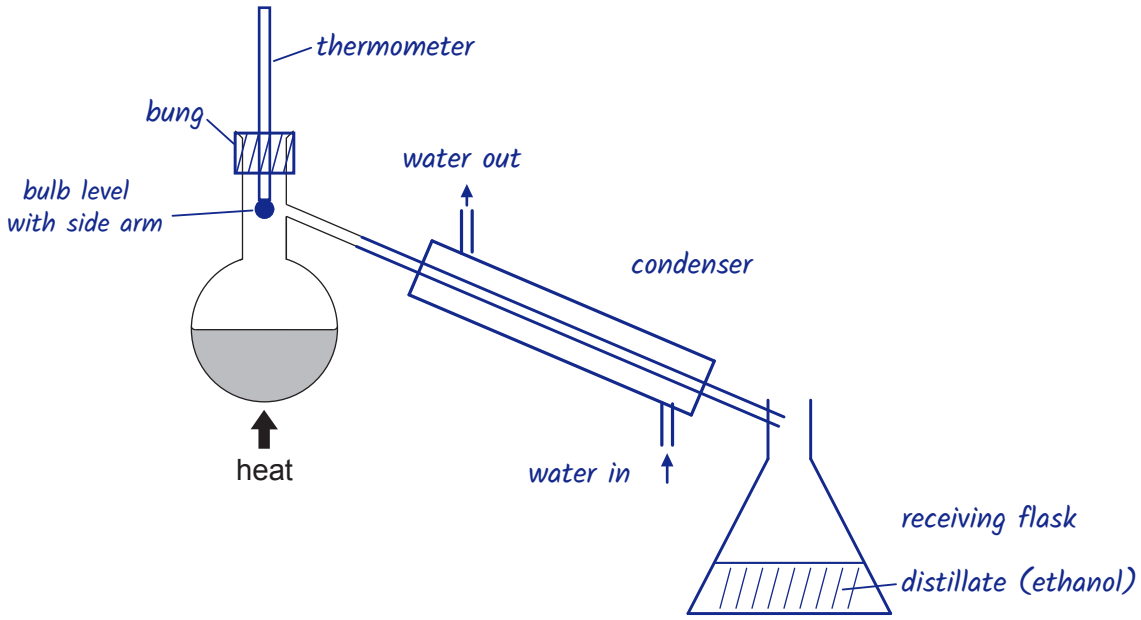
(i) The hydration of ethene is typically carried out using a catalyst of phosphoric acid at a pressure of 70 atm.

State the temperature used in this reaction. [1]

325 °C

(ii) Using the fermentation method, the ethanol is separated by distillation.

Complete and label the diagram of the apparatus used in a laboratory to carry out a simple distillation. [3]



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(c) Ethanol can be used to make many useful compounds.

(i) It can be dehydrated to form ethene.

Name a suitable dehydrating agent for this reaction. [1]

concentrated sulfuric acid

(ii) It can be oxidised by acidified potassium dichromate(VI) to form ethanoic acid.

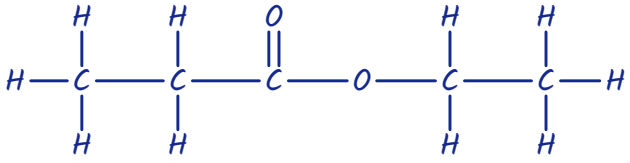
State what you would observe during this reaction. [1]

the orange solution turns green

(iii) I. Classify the type of reaction taking place when ethanol reacts with propanoic acid using sulfuric acid as a catalyst. [1]

esterification (condensation)

II. Draw the structure of the organic product formed in this reaction. [1]



(ethyl propanoate)

(d) Ethanoic acid reacts with sodium hydroxide to form sodium ethanoate and water.

Write an equation for this reaction. [1]

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

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9. (a) A student was asked to measure the enthalpy change that occurs when sodium nitrate is dissolved in water.

She was told to use the following method.

- Weigh 8.70 g of sodium nitrate
- Accurately measure 50.0 cm^3 of water into a polystyrene cup (placed in another polystyrene cup to provide insulation)
- Place a 0.2 °C graduated thermometer in the water and measure its temperature every minute, stirring before reading the temperature
- At the third minute add the sodium nitrate, but do not record the temperature
- Stir the mixture thoroughly, then record the temperature after four minutes
- Continue stirring and record the temperature every minute for a further six minutes

Her results are shown below.

Time / min	0	1	2	3	4	5	6	7	8	9	10
Temp / °C	19.8	20.0	20.0	–	14.8	12.2	12.6	13.0	13.2	13.3	13.4

(i) Give the reason why she accurately measured the volume of the water. [1]

The mass of water (1.00 g cm^{-3}) is used in $q = mc\Delta T$ to calculate the amount of heat transferred.

(ii) Give the reason why the temperature of the water was measured for two minutes before adding the sodium nitrate. [1]

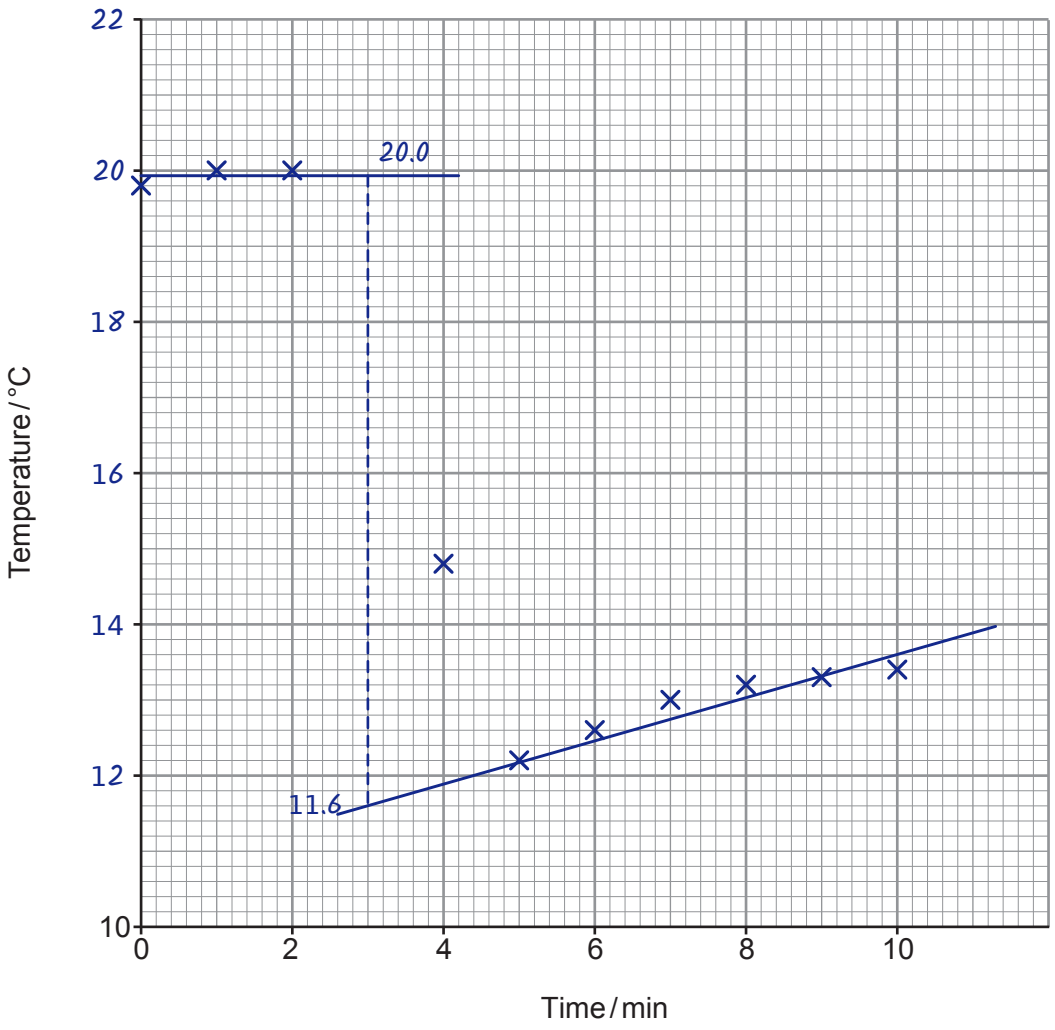
To make sure the initial temperature of the water is constant before adding the sodium nitrate.

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(iii) Plot the results on the grid below. [2]



(iv) Determine the maximum temperature **change** by drawing appropriate lines of best fit. [3]

ΔT = 11.6 − 20.0 (both extrapolated to 3 min)

Maximum temperature change = −8.4 °C

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(v) Explain why the value determined in part (iv) is a more accurate temperature change than one found using the lowest temperature recorded in the experiment. [1]

Extrapolation estimates the temperature that would have been reached if the sodium nitrate dissolved instantly; it takes into account heat absorbed from the surroundings during dissolving.

(vi) The student calculated the enthalpy change to be 19.2 kJ mol^{-1}. The data book value for this enthalpy change is 20.5 kJ mol^{-1}.

Express the difference between these two values as a percentage of the data book value. [1]

$(20.5 - 19.2) \div 20.5 \times 100$

$= 1.3 \div 20.5 \times 100$

Percentage difference = 6.3 %

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(b) Sulfur dioxide can be formed in the atmosphere when hydrogen sulfide, emitted in gases from volcanoes, reacts with the air.

The equation and the enthalpy change for the reaction are as follows.

$$2H_2S(g) + 3O_2(g) \longrightarrow 2H_2O(l) + 2SO_2(g) \qquad \Delta H = -1126 \text{ kJ mol}^{-1}$$

(i) Use this enthalpy change of reaction and the standard enthalpy changes of formation ($\Delta_f H^\theta$) given in the table below to calculate the standard enthalpy change of formation of sulfur dioxide. [2]

Substance	$\Delta_f H^\theta$ / kJ mol^{-1}
$H_2S(g)$	−20.2
$O_2(g)$	0
$H_2O(l)$	−286

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

$-1126 = [2(-286) + 2\Delta_f H(SO_2)] - [2(-20.2) + 0]$

$-1126 = -572 + 2\Delta_f H(SO_2) + 40.4$

$2\Delta_f H(SO_2) = -1126 + 572 - 40.4 = -594.4$

$\Delta_f H(SO_2) = -297.2$

$\Delta_f H^\theta =$ −297 kJ mol^{-1}

(ii) Suggest why scientists are concerned about this reaction. [1]

Sulfur dioxide dissolves in rainwater to cause acid rain, which damages buildings, trees and aquatic life.

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10. (a) Hydrogen peroxide, H_2O_2, decomposes slowly to give water and oxygen.

$$2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$$

If a catalyst such as manganese(IV) oxide is used, the rate of decomposition increases significantly.

A student was asked to determine the initial rate of decomposition of a solution of H_2O_2 at a constant temperature of 40 °C using a manganese(IV) oxide catalyst.

Outline how the student should do this.

Your answer should include

- a method for the experiment, including essential apparatus
- a description of how the results would be used to determine the initial rate

[6 QER]

Method: measure a fixed volume (e.g. 25.0 cm^3) of the hydrogen peroxide solution with a pipette (or measuring cylinder) into a conical flask.

Stand the flask in a thermostatically controlled water bath at 40 °C and leave it to reach 40 °C (check with a thermometer).

Weigh out a known mass of manganese(IV) oxide powder. Add it to the flask, immediately put in a bung connected by a delivery tube to a gas syringe, and start a stopwatch.

Record the volume of oxygen in the gas syringe at regular time intervals (e.g. every 10 s) until no more gas is produced.

Use of results: plot a graph of volume of oxygen (y-axis) against time (x-axis) and draw a smooth curve of best fit.

Draw a tangent to the curve at t = 0. The gradient of this tangent (change in volume ÷ change in time) is the initial rate, in $cm^3\ s^{-1}$.

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(b) State how the overall rate of decomposition would compare with the initial rate of decomposition.

Explain your answer using particle theory. [2]

The overall rate is lower than the initial rate, because as the decomposition proceeds the concentration of H_2O_2 decreases.

There are fewer H_2O_2 molecules in a given volume, so there are fewer successful collisions per unit time.

(c) State the type of catalyst used in this experiment. [1]

heterogeneous

(d) Another student said that lead(IV) oxide is a more efficient catalyst.

Briefly describe how the student could determine which is the better catalyst in the decomposition of hydrogen peroxide. [3]

Do the experiment with each catalyst using the same mass of catalyst, the same volume and concentration of H_2O_2 and the same temperature.

Measure the volume of oxygen formed after a set time (or the time taken to produce a given volume of gas).

The better catalyst gives more gas in that time (or takes less time to give that volume), i.e. a faster rate.

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11. (a) There are many isomers with the formula C_5H_{10}. Information about five of these isomers, **A**, **B**, **C**, **D** and **E**, is given below.

- **A** and **B** are straight-chain isomers and react with hydrogen and a catalyst to give the same hydrocarbon
- **B** is the only one that shows *E*–*Z* isomerism
- **C** does not react with hydrogen or hydrogen bromide
- **D** and **E** are branched-chain isomers and react with hydrogen and a catalyst to give the same hydrocarbon
- **D** and **E** react with hydrogen bromide to form the same bromoalkane as the major product in each case
- One of the compounds is a cycloalkane

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(i) Use the information to deduce **possible** identities for each isomer. Explain your reasoning. [8]

A and B are straight-chain alkenes that both give pentane with H_2: A is pent-1-ene, $CH_2=CHCH_2CH_2CH_3$, and B is pent-2-ene, $CH_3CH=CHCH_2CH_3$ (E or Z).
B shows E–Z isomerism because each carbon of its C=C has two different groups attached; A does not, as one end of its C=C has two groups the same (two H atoms).
C does not react with hydrogen or hydrogen bromide, so it cannot be an alkene: it must be saturated, so C is the cycloalkane, e.g. cyclopentane (or methylcyclobutane / dimethylcyclopropane).
D and E are branched alkenes that both give 2-methylbutane with H_2: they are 2-methylbut-1-ene, $CH_2=C(CH_3)CH_2CH_3$, and 2-methylbut-2-ene, $(CH_3)_2C=CHCH_3$.
It is not possible to tell which is D and which is E, because both react with HBr to give 2-bromo-2-methylbutane as the major product (via the same tertiary carbocation) and both give 2-methylbutane with H_2.
(3-methylbut-1-ene is ruled out as its major product with HBr is 2-bromo-3-methylbutane.)

(ii) Name the catalyst in the reaction between isomers **A** and **B** and hydrogen. [1]

nickel

(iii) Classify the reaction mechanism when isomers **D** and **E** react with hydrogen bromide. [1]

electrophilic addition

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(b) A technician requires a sample of hexane. It is kept in a metal storage cupboard. The bottle on the shelf where it is usually found has an incomplete label.

The technician carries out the following procedure and is satisfied that the liquid is hexane.

She injects a 0.142 g sample of the liquid into a sealed gas syringe and places it in an oven at 383 K. The liquid vaporises. The volume of the gas produced is 52.0 cm^3 at a pressure of 101 kPa.

(i) Show that the technician is correct. [4]

$pV = nRT$, so $n = pV \div RT$

$n = (1.01 \times 10^5\ Pa \times 5.20 \times 10^{-5}\ m^3) \div (8.31 \times 383\ K)$

$n = 1.65 \times 10^{-3}\ mol$

$M_r = mass \div n = 0.142 \div 1.65 \times 10^{-3} = 86.1$

M_r of hexane, $C_6H_{14} = (6 \times 12.0) + (14 \times 1.01) = 86.1$, so the liquid is hexane and the technician is correct.

(ii) Suggest why the bottle of hexane is kept in a metal storage cupboard. [1]

Hexane is (highly) flammable; a metal cupboard is fire resistant.

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(iii) Explain how useful ^{13}C NMR spectra and low resolution ^{1}H NMR spectra would be to distinguish between hexane and pentane. [3]

^{13}C NMR is of no use: hexane and pentane both have three carbon environments, so both spectra show 3 lines with chemical shifts in the range 5 to 40 ppm.

Low resolution ^{1}H NMR is useful: both show 3 peaks (δ 0.1 to 2.0) but with different peak areas: hexane $CH_3 : CH_2 : CH_2 = 3 : 2 : 2$, pentane 3 : 2 : 1.

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END OF PAPER

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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