Surname	StemUp Model Solution	Centre Number	Candidate Number
Other Names			2

GCE AS

B410U20-1

S18-B410U20-1

CHEMISTRY – AS component 2
Energy, Rate and Chemistry of Carbon Compounds

FRIDAY, 25 MAY 2018 – MORNING

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 6.**	**10**	
Section B	**7.**	**21**	
	8.	**14**	
	9.	**21**	
	10.	**14**	
	Total	**80**	

B410U201
01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

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

Section A Answer **all** questions in the spaces provided.
Section B Answer **all** questions in the spaces provided.

Candidates are advised to allocate their time appropriately between **Section A (10 marks)** and **Section B (70 marks)**.

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 **Q.7***(e)*.

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.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. Ethanol is produced industrially by hydration of ethene. The reaction is typically carried out using a catalyst at 300 °C and 70 atm pressure.

Name the catalyst used in this reaction. [1]

phosphoric acid (H_3PO_4, on a silica support)

2. But-2-ene can exist as *E*- and *Z*- isomers.

(a) Draw the **skeletal** formula for *Z*-but-2-ene. [1]



(b) Explain why but-2-ene can form *E*- and *Z*- isomers but but-1-ene cannot. [2]

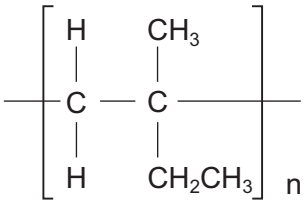
There is restricted rotation about the C=C double bond, so the groups on each carbon cannot swap sides.

In but-2-ene each carbon of the C=C has two different groups (CH_3 and H) attached, but in but-1-ene one carbon of the C=C has two identical groups (two H atoms), so no E and Z forms exist.

3. Explain the meaning of the term heterolytic bond fission. [1]

The covalent bond breaks so that one atom receives both of the bonding electrons, forming a positive ion and a negative ion.

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



2-methylbut-1-ene

stemup.co.uk

Examiner only

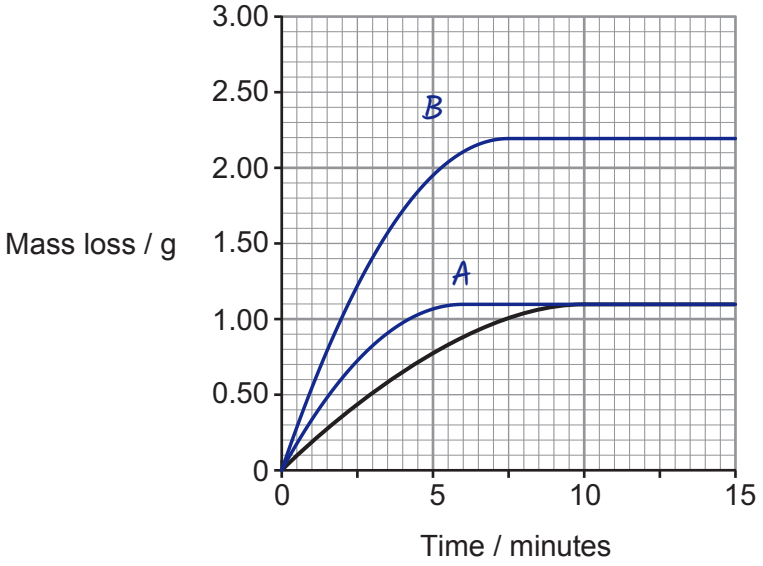
5. Explain how a catalyst speeds up a reaction. [2]

It provides an alternative route with a lower activation energy.

Therefore more particles have the minimum energy needed to react, giving more successful collisions.

6. The rate of the reaction between calcium carbonate and acid can be found by measuring the loss in mass of the reactants over time.

The graph below shows the results obtained when a large excess of calcium carbonate was added to 50.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid at room temperature.



(a) **On the grid**, sketch the curve that would be obtained if the experiment were repeated at 60 °C with all other conditions being unchanged. Label this curve **A**. [1]

(b) **On the grid**, sketch the curve that would be obtained if the experiment were repeated using 2.00 mol dm^{-3} hydrochloric acid with all other conditions being unchanged. Label this curve **B**. [1]

10

B410U201 03

stemup.co.uk

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

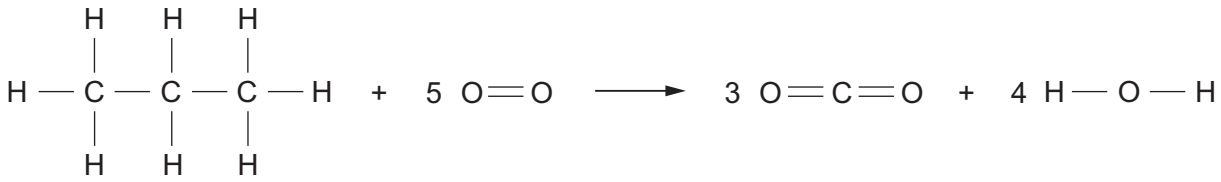
7. *(a)* Alkanes are derived from petroleum and many are used as fuels. Some of the compounds found in petroleum contain sulfur.

State and explain **one** reason why sulfur compounds should be removed from fuels before they are used. [2]

Sulfur burns (combines with oxygen) to form sulfur dioxide, SO_2.

SO_2 reacts with rainwater to form acid rain, which damages buildings, trees and aquatic life.

(b) Propane is a constituent of liquefied petroleum gas (LPG). Propane burns in air to form carbon dioxide and water. The equation for the reaction is as follows.



The enthalpy change for the reaction is –1690 kJ mol^{-1}.

Use this and the data given in the table below to calculate the average bond enthalpy for the C—H bond. [3]

Bond	Average bond enthalpy / kJ mol^{-1}
C—C	348
O—H	463
O=O	496
C=O	743

bonds broken = 8(C–H) + 2(348) + 5(496) = 8(C–H) + 3176

bonds formed = 6(743) + 8(463) = 8162

ΔH = broken – formed: –1690 = 8(C–H) + 3176 – 8162

8(C–H) = 3296, so C–H = 3296 ÷ 8 = 412

C—H bond enthalpy = ... 412 ..... kJ mol^{-1}

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(c) When methane and chlorine are combined in sunlight a reaction occurs with chloromethane formed as the main organic product.

(i) Name the type of reaction mechanism which occurs in this case. [1]

(free) radical substitution

(ii) Write the mechanism for this reaction to form chloromethane. Include one termination step. [4]

Initiation: $Cl_2 \rightarrow 2Cl\cdot$ (UV light / sunlight)

Propagation: $Cl\cdot + CH_4 \rightarrow \cdot CH_3 + HCl$

Propagation: $\cdot CH_3 + Cl_2 \rightarrow CH_3Cl + Cl\cdot$

Termination: $\cdot CH_3 + Cl\cdot \rightarrow CH_3Cl$

(d) Butane is another common alkane. Two other compounds with a similar molecular mass to butane are ethanoic acid and propan-1-ol.

The boiling temperatures in °C for butane, ethanoic acid and propan-1-ol are

–1, 97 and 118, **but not necessarily in that order**.

Deduce the boiling temperature of **each** compound, giving reasons in support of your conclusions. [3]

Butane −1 °C, propan-1-ol 97 °C, ethanoic acid 118 °C.

Butane is non-polar, so it shows no hydrogen bonding between its molecules, only weak van der Waals forces, so it has the lowest boiling temperature.

Both other compounds form hydrogen bonds, but ethanoic acid has more / stronger hydrogen bonds (and more dipoles, C=O as well as O–H) between molecules than propan-1-ol, so it boils highest.

© WJEC CBAC Ltd.

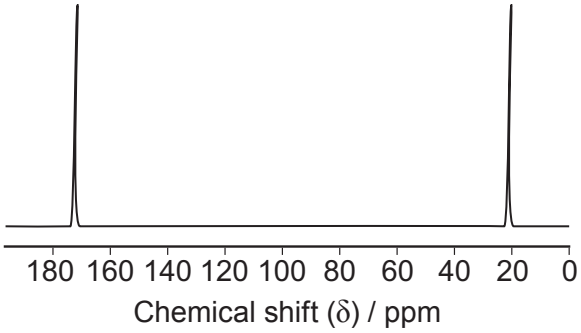
stemup.co.uk

(e) Compounds **A** and **B** are two of butane, ethanoic acid and propan-1-ol.

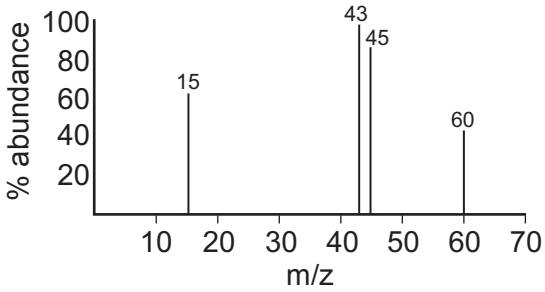
Their ^{13}C NMR spectra and simplified mass spectra are shown below.

Compound **A**

^{13}C NMR spectrum

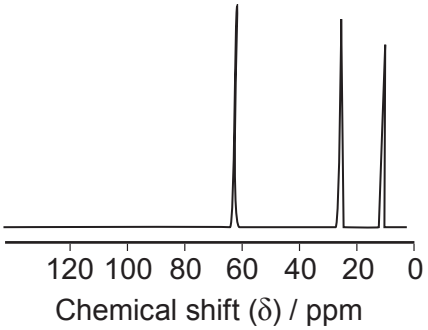


Mass spectrum

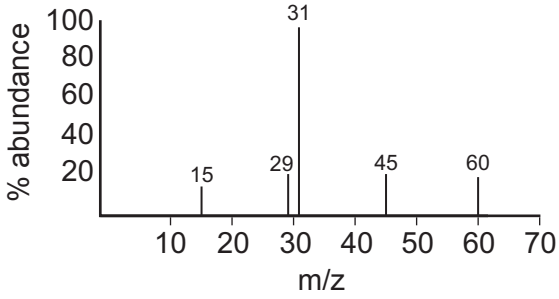


Compound **B**

^{13}C NMR spectrum



Mass spectrum



© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

Use the information to identify compounds **A** and **B** clearly explaining your reasoning. Describe the main features that would be seen in the ^{13}C NMR spectrum and the mass spectrum of the **remaining** compound. [6 QER]

A is ethanoic acid, CH_3COOH. Its ^{13}C NMR spectrum has 2 peaks, so 2 carbon environments: about 178 ppm (C=O of COOH) and about 20 ppm (CH_3). Its mass spectrum has the molecular ion at m/z 60 (M_r 60), m/z 45 from $COOH^+$, m/z 43 from CH_3CO^+ and m/z 15 from CH_3^+.

B is propan-1-ol, $CH_3CH_2CH_2OH$. It has 3 peaks, so 3 carbon environments: about 64 ppm (C–OH), about 26 ppm and about 10 ppm. Its molecular ion is also at m/z 60, with m/z 45 from $CH_2CH_2OH^+$, m/z 31 (base peak) from CH_2OH^+ and m/z 29 from $CH_3CH_2^+$. Ethanoic acid has no peaks at 29 or 31, and propan-1-ol has no peak at 43.

The remaining compound is butane, $CH_3CH_2CH_2CH_3$. Its ^{13}C NMR spectrum would show only 2 peaks (CH_3 and CH_2 environments), both between 5 and 40 ppm, as there is no C–O or C=O.

Its mass spectrum would have the molecular ion at m/z 58 (not 60), with fragment peaks at m/z 43 ($C_3H_7^+$), 29 ($C_2H_5^+$) and 15 (CH_3^+), and no peaks at m/z 45 or 31 as it has no oxygen.

(f) State and explain how you would expect the infrared spectrum of ethanoic acid to differ from that of propan-1-ol. [2]

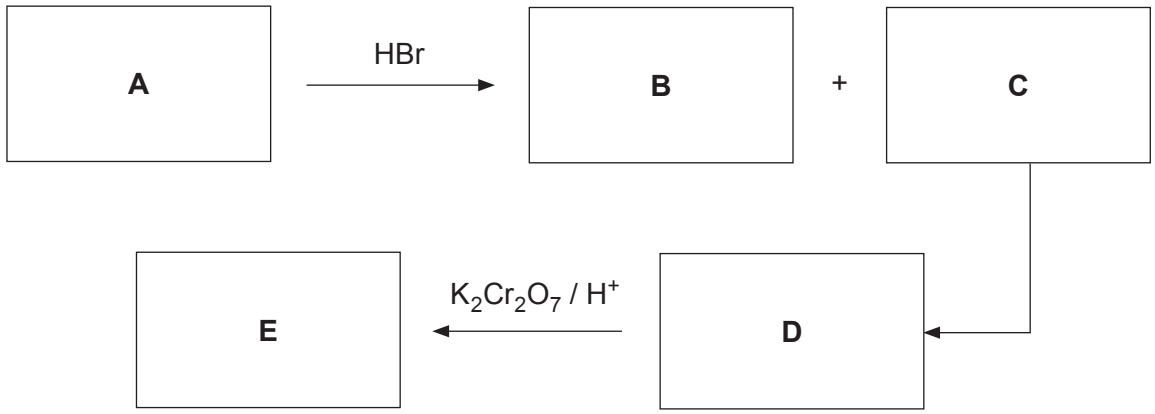
Only ethanoic acid would have a strong absorption at 1650 to 1750 cm^{-1} due to the C=O bond.

Ethanoic acid's O–H absorption would be very broad at 2500 to 3200 cm^{-1}, while the O–H in propan-1-ol absorbs at 3200 to 3550 cm^{-1}.

© WJEC CBAC Ltd.

stemup.co.uk

8. *(a)* Study the reaction scheme shown below and the other information about compounds **A**-**E** that follows.



Compound **A** is a straight-chained gaseous hydrocarbon.

Compounds **B** and **C** are isomers.

Compound **E** reacts with sodium hydroxide in a 1:1 molar ratio.

0.412 g of compound **E** in aqueous solution requires 23.40 cm^3 of sodium hydroxide solution of concentration 0.200 mol dm^{-3} for complete neutralisation.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(i) Calculate the relative molecular mass of compound **E**. [2]

moles NaOH = $0.200 \times 23.40 \div 1000 = 4.68 \times 10^{-3}$ mol

1:1 ratio, so moles of E = 4.68×10^{-3} mol

$M_r = 0.412 \div 4.68 \times 10^{-3} = 88.0$

Relative molecular mass = 88.0

(ii) Identify compounds **A**-**E** giving your reasoning. [7]

E is an acid since it is neutralised by NaOH; M_r 88 fits C_3H_7COOH. E is butanoic acid, $CH_3CH_2CH_2COOH$.

D must be a primary alcohol since it is oxidised by acidified dichromate to a carboxylic acid: D is butan-1-ol, $CH_3CH_2CH_2CH_2OH$.

A must be an alkene since it reacts with HBr (electrophilic addition). It is straight-chained and gives two isomeric products, so the C=C is at the end of the chain: A is but-1-ene, $CH_2=CHCH_2CH_3$.

B and C must be bromoalkanes since they are formed from the alkene: B is 2-bromobutane, $CH_3CHBrCH_2CH_3$ (the major product), and C is 1-bromobutane, $CH_2BrCH_2CH_2CH_3$, which is hydrolysed to the primary alcohol D.

(iii) Name the type of reaction taking place when compound **B** is converted back to compound **A**. [1]

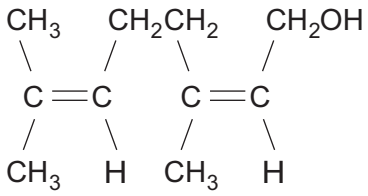
elimination

B410U201 09

stemup.co.uk

Examiner only

(b) Geraniol is one of the main constituents of rose oil and is widely used in perfumes and flavourings. Its structure is shown below.



(i) Name the functional groups present in the compound. [1]

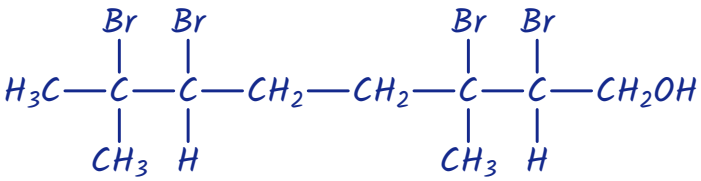
alkene (C=C) and alcohol (primary hydroxyl, OH)

(ii) State the **molecular** formula of the compound. [1]

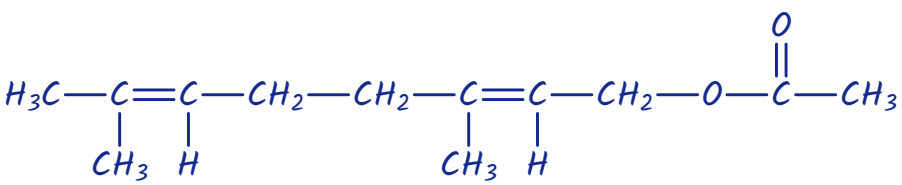
$C_{10}H_{18}O$

(iii) Draw the structure of an organic product formed when geraniol reacts with

I. Br_2 [1]



II. CH_3COOH in the presence of sulfuric acid [1]



© WJEC CBAC Ltd.

stemup.co.uk

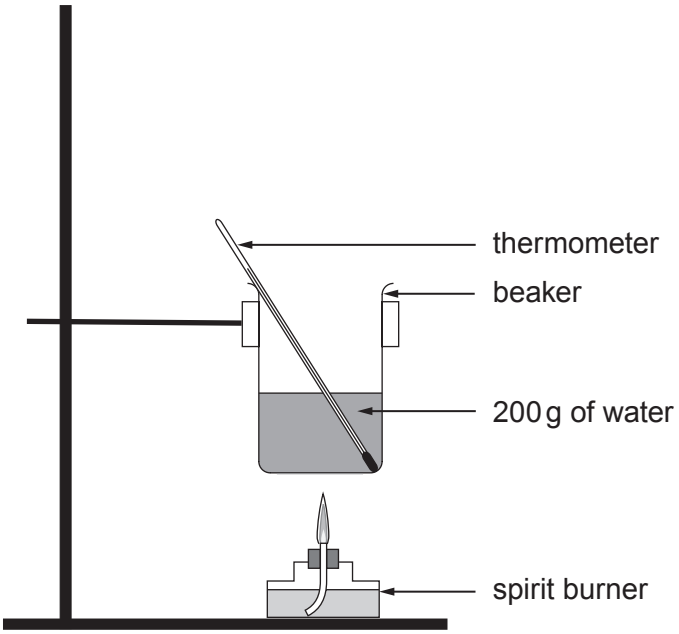
BLANK PAGE

© WJEC CBAC Ltd.

stemup.co.uk

9. Pentan-2-ol, $CH_3CH_2CH_2CH(OH)CH_3$, is one of the isomers of $C_5H_{11}OH$. It has a relative molecular mass of 88.1.

A student carried out an experiment on a sample of pentan-2-ol to determine its enthalpy of combustion using the apparatus shown below.



The spirit burner was lit and allowed to burn for a few minutes before it was extinguished.

The following results were recorded.

Initial temperature of the water	18.6 °C
Final temperature of the water	25.4 °C
Initial mass of spirit burner and pentan-2-ol	97.60 g
Final mass of spirit burner and pentan-2-ol	97.42 g

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(a) Calculate a value for the enthalpy change of combustion of pentan-2-ol in kJ mol^{-1}. [4]

$q = mc\Delta T = 200 \times 4.2 \times (25.4 - 18.6) = 200 \times 4.2 \times 6.8 = 5712$ J

mass burned = 97.60 − 97.42 = 0.18 g

$n = 0.18 \div 88.1 = 2.043 \times 10^{-3}$ mol

$\Delta H = -q \div n = -5712 \div 2.043 \times 10^{-3} = -2\,796\,000$ J mol^{-1}

$= -2796$ kJ mol^{-1}

$\Delta_c H$ = ..−2796.. kJ mol^{-1}

(b) (i) Each reading on the thermometer is accurate to ±0.1 °C. Calculate the percentage error in the temperature **difference** recorded. [1]

total error = 2 × 0.1 = 0.2 °C

(0.2 ÷ 6.8) × 100 = 2.9 %

Percentage error = ..2.9.. %

(ii) Suggest how, using the same apparatus, the experiment could be improved to **reduce this percentage error**. Explain your answer. [2]

Use less water (e.g. 50 cm^3) or burn the alcohol for longer.

The temperature rise would be larger, so the same ±0.2 °C error is a smaller percentage of it.

(c) (i) Suggest an experimental improvement that would reduce error due to heat loss. [1]

Reduce the distance between the flame and the beaker, and shield the flame from draughts.

(ii) Suggest **one** reason, other than heat loss, why the value obtained for the enthalpy change of combustion is smaller than the theoretical value. [1]

Incomplete combustion of the alcohol (soot forms), or heat absorbed by the beaker (its thermal capacity).

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(d) Another isomer of $C_5H_{11}OH$ is 2-methylbutan-2-ol, $(CH_3)_2C(OH)CH_2CH_3$. Standard enthalpy changes of combustion, $\Delta_c H^\theta$, can be found using standard enthalpy changes of formation, $\Delta_f H^\theta$.

The table shows some standard enthalpy changes of formation.

Substance	$\Delta_f H^\theta$ / kJ mol^{-1}
$(CH_3)_2C(OH)CH_2CH_3(l)$	–380
$O_2(g)$	0
$CO_2(g)$	–394
$H_2O(l)$	–286

(i) Write an equation for the complete combustion of $C_5H_{11}OH$. [1]

$C_5H_{11}OH + 7½O_2 \rightarrow 5CO_2 + 6H_2O$

(ii) Use the values in the table and the equation in part (i) to calculate the standard enthalpy change of combustion, $\Delta_c H^\theta$, of 2-methylbutan-2-ol. [2]

$\Sigma \Delta_f H$ reactants $= -380 + 0 = -380$ kJ mol^{-1}

$\Sigma \Delta_f H$ products $= 5(-394) + 6(-286) = -3686$ kJ mol^{-1}

$\Delta H = -3686 - (-380) = -3306$ kJ mol^{-1}

$\Delta_c H^\theta =$ −3306 kJ mol^{-1}

(iii) State why $O_2(g)$ has a value of zero for its standard enthalpy change of formation, $\Delta_f H^\theta$. [1]

Oxygen gas is an element in its standard state, so no energy change is needed to form it.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(e) A student was given separate samples of pentan-2-ol and 2-methylbutan-2-ol but was not told which was which.

Describe a chemical test that the student could use to clearly distinguish between the alcohols. Give any reagent(s) used and expected observation(s) for both compounds. [3]

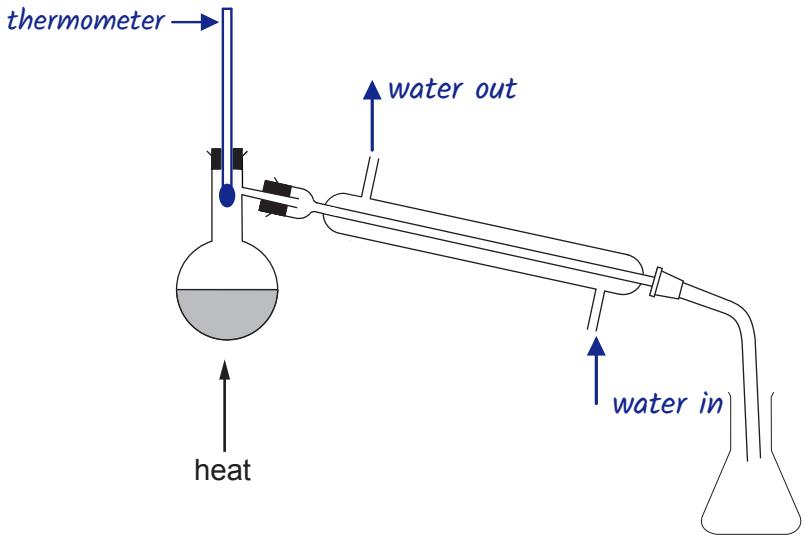
Heat each alcohol under reflux with acidified potassium dichromate(VI) solution ($K_2Cr_2O_7$ / H_2SO_4).

Pentan-2-ol (a secondary alcohol) is oxidised to a ketone: the colour changes from orange to green.

2-methylbutan-2-ol (a tertiary alcohol) is not oxidised: there is no change, the solution stays orange.

(f) Another student wanted to make pure 2-chloro-2-methylbutane from 2-methylbutan-2-ol in a multi-step process. One of the steps used was distillation.

(i) An incomplete diagram of the distillation apparatus is shown below.



Complete the diagram by drawing a thermometer and clearly labelled arrows to show the flow of water into and out of the condenser. [2]

© WJEC CBAC Ltd.

Examiner only

(ii) The student predicted that since this was a multi-step process the overall yield would be less than 70 %.

In the process, 5.00 cm^3 of 2-methylbutan-2-ol were used and 4.05 cm^3 of 2-chloro-2-methylbutane were made.

Is the student correct? Use the following information to justify your answer. [3]

Compound	Density / g cm^{-3}
2-methylbutan-2-ol	0.805
2-chloro-2-methylbutane	0.866

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

mass of alcohol = 5.00 × 0.805 = 4.025 g

moles of alcohol = 4.025 ÷ 88.1 = 0.0457 mol

$M_r(C_5H_{11}Cl)$ = 106.5, theoretical mass = 0.0457 × 106.5 = 4.87 g

actual mass of chloroalkane = 4.05 × 0.866 = 3.51 g

percentage yield = (3.51 ÷ 4.87) × 100 = 72 %

The yield is 72 %, which is more than 70 %, so the student is not correct.

21

© WJEC CBAC Ltd.

stemup.co.uk

BLANK PAGE

© WJEC CBAC Ltd.

stemup.co.uk

10. Hydrogen peroxide reacts with iodide ions in acid solution to produce iodine. The equation for the reaction is as follows.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2H_2O(l)$$

A student is asked to investigate the effect of changing the concentration of hydrogen peroxide on the rate of reaction by a "clock method".

She is told to carry out the following method.

- Measure 10.0 cm^3 of sulfuric acid, 10.0 cm^3 of sodium thiosulfate, 15.0 cm^3 of potassium iodide and 1.0 cm^3 of starch solution into a conical flask.
- Measure 5.0 cm^3 of hydrogen peroxide and 9.0 cm^3 of water into a boiling tube.
- Add the peroxide solution to the other reagents in the flask and start a stopwatch at the same time.
- Record the time taken, to the nearest second, for a blue-black colour to form in the reaction mixture.
- Repeat the procedure five times, with each run differing only in the peroxide concentration in the mixture, ensuring that the reaction times are neither too short nor too long.

She obtains the following results.

Experiment	Volume H_2O_2 / cm^3	Volume H_2O / cm^3	Time / s	$\frac{1}{\text{Time}}$ / s^{-1}
1	5.0	9.0	28	0.0357
2	6.0	8.0		
3	7.0	7.0	17	0.0589
4	4.0	10.0	36	0.0278
5	3.0	11.0	54	0.0185
6	2.0	12.0	102	0.0098

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(a) The student says that it would be better to make up a single batch containing the acid, thiosulfate, iodide and starch solutions in the correct proportions before starting and use 36.0 cm^3 of this in each experiment. Is she correct? Justify your answer. [1]

Yes, she is correct: all the mixtures would then be identical in composition, and it is more efficient and quicker than measuring four solutions each time.

(b) State **two** changes which could be made in order to improve the results in this experiment. Explain your reason in each case. [4]

Keep the temperature constant by using a thermostatic water bath, because all rates of reaction are temperature dependent.

Repeat each experiment and calculate the mean of the concordant results, which makes the mean value more accurate and identifies anomalies.

(c) Give a reason why the peroxide is measured into a boiling tube first and not added directly to the flask from a burette. [1]

So that all the peroxide can be added quickly at once, since the reaction starts as soon as peroxide is added.

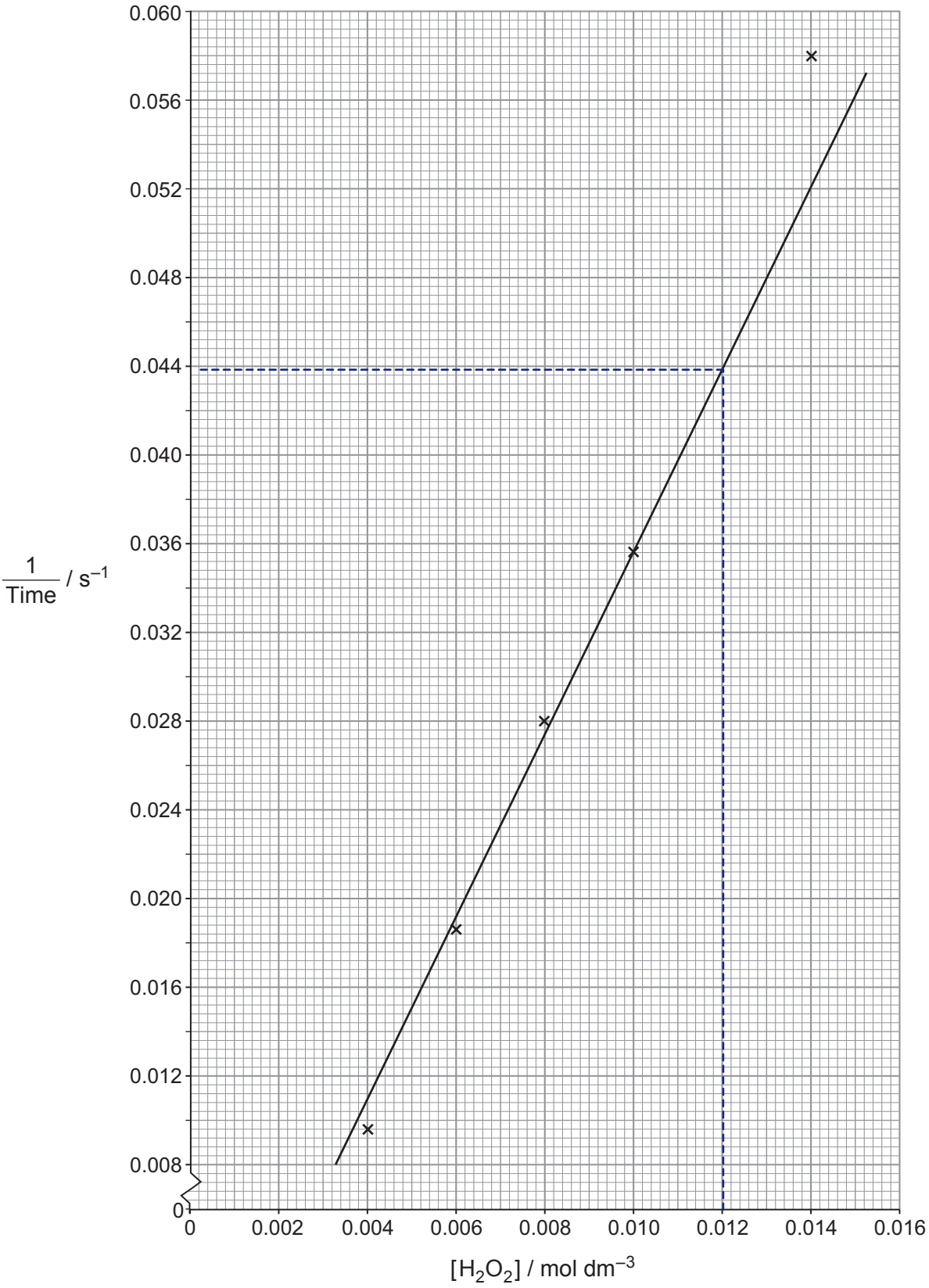
(d) Suggest a reason why the student did not carry out the procedure using 8.0 cm^3 of hydrogen peroxide and 6.0 cm^3 of water. [1]

The reaction time would be too short, so the percentage error in timing would be too high.

© WJEC CBAC Ltd.

stemup.co.uk

(e) She plotted a graph of rate against concentration of peroxide. This is shown below.



© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(i) State how the rate depends on the concentration of peroxide. [1]

Rate is directly proportional to the concentration of peroxide (first order).

(ii) Use the graph to find the time taken for the colour change to occur when she used 6.0 cm^3 of hydrogen peroxide and 8.0 cm^3 of water. [2]

6.0 cm^3 gives $[H_2O_2]$ = 0.012 mol dm^{-3} (5.0 cm^3 gives 0.010)

from graph, 1/time = 0.044 s^{-1}

time = 1 ÷ 0.044 = 22.7 s

Time = 23 s

(f) Suggest another method, not using sodium thiosulfate, by which the rate of this oxidation reaction could be measured. [2]

Monitor the intensity of the colour of the iodine formed over time, using a colorimeter.

(g) Explain, using simple collision theory, why the rate of this reaction changes as the concentration of hydrogen peroxide changes. [2]

As concentration increases there are more molecules in the same volume, so there are more collisions per second.

So there is a greater chance of collisions with energy greater than the activation energy, giving more successful collisions.

14

END OF PAPER

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

For continuation only.

© WJEC CBAC Ltd.

stemup.co.uk

BLANK PAGE

© WJEC CBAC Ltd.

stemup.co.uk