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

GCE AS

B410U20-1

O20-B410U20-1

TUESDAY, 13 OCTOBER 2020 – 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.**	**13**	
	8.	**19**	
	9.	**11**	
	10.	**13**	
	11.	**14**	
	Total	**80**	

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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.10***(a)*(i).

If you run out of space, use the continuation page(s) at the back of the booklet, taking care to number the question(s) correctly.

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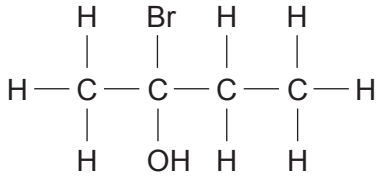
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SECTION A

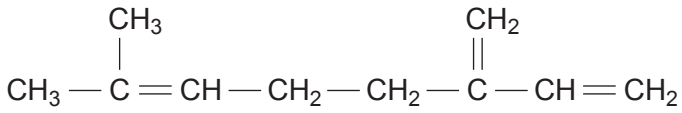
Answer **all** *questions in the spaces provided.*

1. Name the compound whose formula is shown below. [1]



2-bromobutan-2-ol

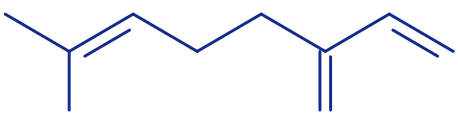
2. Myrcene is a significant component of the essential oils of many plants. It has the structure shown below.



(a) State the **empirical** formula of myrcene. [1]

C_5H_8

(b) Draw the **skeletal** formula of myrcene. [1]



(c) Describe a test to show that myrcene contains C=C double bonds. [2]

Add bromine water: the colour changes from orange to colourless.

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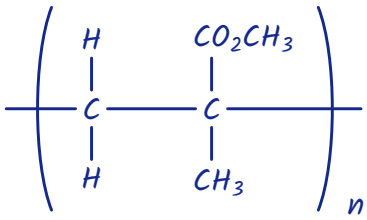
3. Name an element that contaminates many hydrocarbon fuels and that burns to form an oxide that contributes to acid rain. [1]

sulfur

4. The polymer PMMA which is used in aeroplane windows and skylights is formed from the monomer methyl methacrylate.

$CH_2{=}C(CH_3)CO_2CH_3$

Draw the repeat unit of this polymer. [1]



5. Complete the equation for the reaction between propanoic acid and sodium carbonate. [1]

$2C_2H_5COOH + Na_2CO_3 \longrightarrow 2C_2H_5COONa + H_2O + CO_2$

6. Collagen has the formula $C_{57}H_{91}N_{19}O_{16}$. Analysis of a sample showed that it contained 0.0204 mol of carbon.

Calculate the simplest ratio of carbon atoms to nitrogen atoms in the formula and use this to calculate the mass of nitrogen present in the sample. [2]

C : N = 57 : 19 = 3 : 1

n(N) = 0.0204 ÷ 3 = 0.00680 mol

mass of N = 0.00680 × 14.0 = 0.0952 g

Mass of nitrogen = 0.0952 g

10

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SECTION B

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

7. *(a)* Biogas refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Its main component is methane.

Suggest why burning biogas is considered to be more environmentally friendly than burning natural gas. [2]

When biogas burns there is no net change in atmospheric CO_2 levels, because the CO_2 released is equivalent to the CO_2 absorbed (by photosynthesis) during the growth of the bio-resource that produced it.

Natural gas is a fossil fuel, so burning it adds extra CO_2 to the atmosphere.

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(b) Ethanol is widely used as a biofuel in some countries.

(i) Write the equation to represent the standard molar enthalpy change of formation of ethanol. [2]

$2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$

(ii) The equation for its combustion is given below.

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

I. A student calculated the enthalpy change for this reaction as –1031 kJ mol^{-1} using the average bond enthalpy values given in the table.

Calculate the average bond enthalpy for the C — O bond. [3]

Bond	Average bond enthalpy / kJ mol^{-1}
C — C	348
C — H	412
O — H	463
O = O	496
C = O	743

bonds broken: $5(C-H) + (C-C) + (C-O) + (O-H) + 3(O=O)$

$= 2060 + 348 + (C-O) + 463 + 1488 = (C-O) + 4359$

bonds formed: $4(C=O) + 6(O-H) = 2972 + 2778 = 5750$

ΔH = bonds broken − bonds formed

$-1031 = (C-O) + 4359 - 5750$

$(C-O) = -1031 - 4359 + 5750 = 360$

Average bond enthalpy of C — O = 360 kJ mol^{-1}

II. The literature value for the enthalpy change of this reaction is –1370 kJ mol^{-1}.

State why the values are different. [1]

Average bond enthalpies were used in the calculation, rather than the actual bond enthalpies in these molecules.

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(c) Ethanol is the main alcohol present in alcoholic drinks. When driving in England, the legal limit for alcohol in the blood is 80 mg per 100 cm^3 of blood.

Calculate the concentration of ethanol in blood at this level in mol dm^{-3}. [2]

80 mg per 100 cm^3 = 0.80 g dm^{-3}

$M_r(C_2H_5OH)$ = 46.0

concentration = 0.80 ÷ 46.0 = 0.0174 mol dm^{-3}

Concentration = ... 0.0174 ..... mol dm^{-3}

(d) A fluorocarbon has a relative molecular mass which is twice that of its empirical formula. 9.56 g of this compound contains 6.73 g of fluorine.

Find its molecular formula. [3]

mass of carbon = 9.56 − 6.73 = 2.83 g

C : F = 2.83 ÷ 12.0 : 6.73 ÷ 19.0 = 0.236 : 0.354

mole ratio = 1 : 1.5 = 2 : 3, so empirical formula C_2F_3

M_r is twice that of C_2F_3, so molecular formula = C_4F_6

Molecular formula ..... C_4F_6 .....

13

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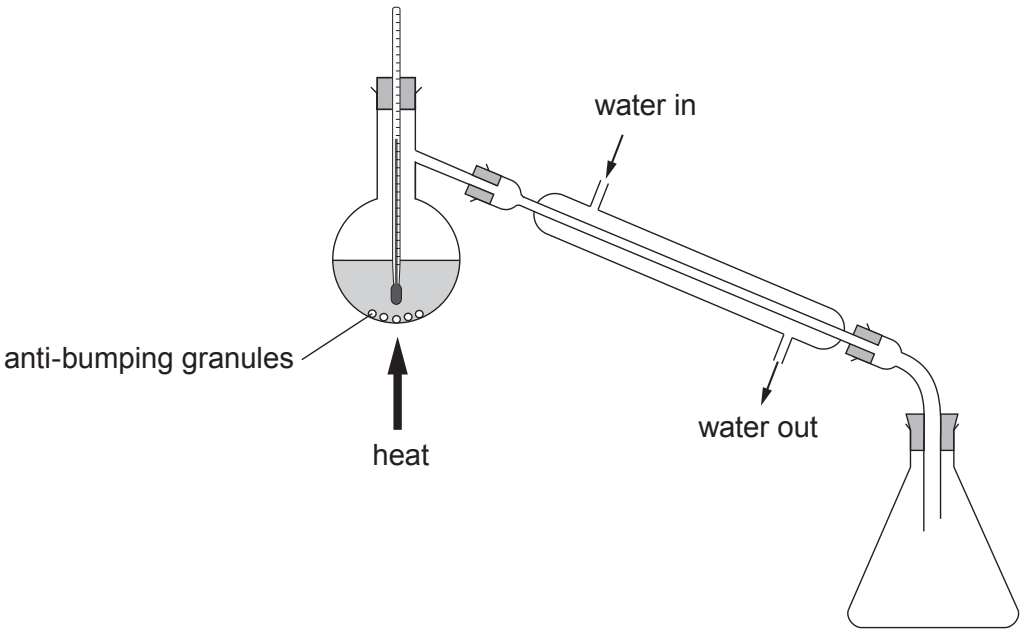
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8. *(a)* A student wanted to form a halogenoalkane from an alcohol. He added hydrochloric acid to the alcohol and a mixture of organic and inorganic products formed. The halogenoalkane is the only substance in the mixture that does not dissolve in the inorganic aqueous solution.

(i) Suggest how the student could separate the halogenoalkane from the other compounds. [1]

Use a separating funnel: the halogenoalkane forms a separate layer, so run off and keep this layer.

(ii) The student wants to purify the halogenoalkane by distillation. He sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.



I. Anti-bumping granules were placed in the flask.

Suggest why these granules prevent bumping. [1]

They provide a surface for small bubbles to form, preventing large bubbles forming suddenly.

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II. State **two** changes that must be made to the apparatus for safe and effective use. Give your reason in each case. [4]

The bulb of the thermometer should be level with (opposite) the opening to the condenser, so that the temperature of the vapour that is distilling is measured.

The water should go in at the bottom of the condenser and out at the top, so that the condenser stays full of water (no air-lock), giving better cooling.

(b) Another student wanted to make 1-chloropentane.

She started with pentan-1-ol and obtained 1.62 g of 1-chloropentane. The percentage yield of 1-chloropentane was 67 %.

A fellow student told her that since 67 % is about two-thirds, she must have started with about 2.43 g of pentan-1-ol.

Is the student correct? Justify your answer. [3]

$M_r(C_5H_{11}Cl) = 106.6$, $M_r(C_5H_{11}OH) = 88.0$

moles of 1-chloropentane formed = $1.62 \div 106.6 = 0.0152$ mol

moles of pentan-1-ol used = $0.0152 \times 100 \div 67 = 0.0227$ mol

mass of pentan-1-ol used = $0.0227 \times 88.0 = 2.00$ g

The student is incorrect: she started with 2.00 g, as the two compounds have different M_r values.

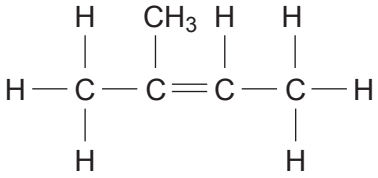
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(c) Halogenoalkanes can also be formed from alkenes.

The alkene 2-methylbut-2-ene reacts with hydrogen bromide to form a mixture of 2-bromo-2-methylbutane and 2-bromo-3-methylbutane.



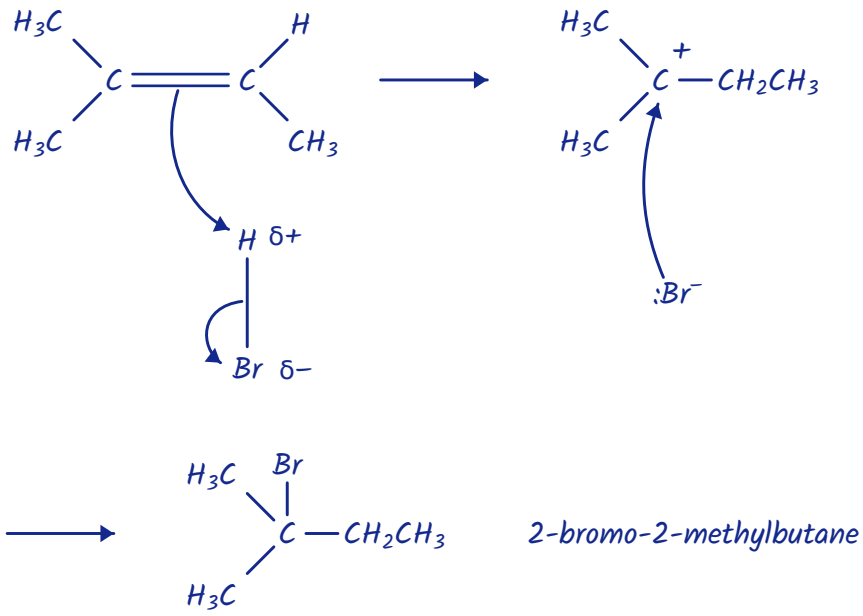
(i) Classify the reaction mechanism. [1]

electrophilic addition

(ii) Explain why 2-bromo-2-methylbutane is the major product of this reaction. [2]

2-bromo-2-methylbutane is formed from a tertiary carbocation, whereas 2-bromo-3-methylbutane is formed from a secondary carbocation. The tertiary carbocation is more stable than the secondary carbocation, so more 2-bromo-2-methylbutane forms.

(iii) Draw the mechanism for the formation of 2-bromo-2-methylbutane. [3]



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(d) When 2-bromobutane is heated with potassium hydroxide dissolved in ethanol, two structural isomers are formed.

(i) State the meaning of the term *structural isomers*. [1]

Compounds with the same molecular formula but different structural formulae.

(ii) Draw the structure of both isomers. [2]

$H_2C{=}CH{-}CH_2{-}CH_3$ but-1-ene

$H_3C{-}CH{=}CH{-}CH_3$ but-2-ene

(iii) Circle the isomer which exhibits *E-Z* isomerism. Explain your choice. [1]

But-2-ene: it has two different groups attached to both carbon atoms of the C=C double bond (CH_3 and H on each).

19

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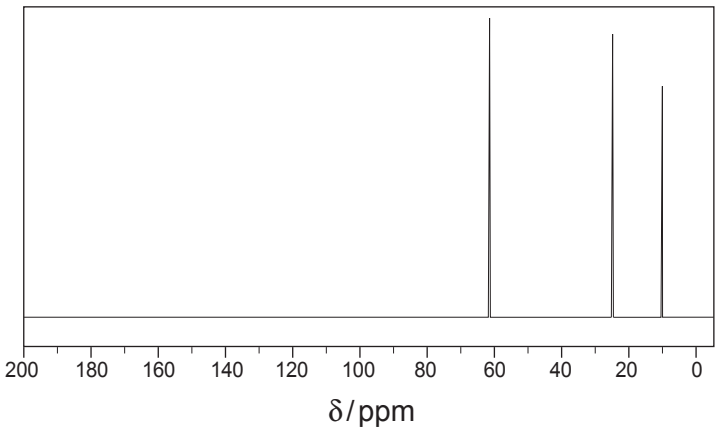
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9. *(a)* Compound **X** is an alcohol. When compound **X** is warmed with acidified potassium dichromate(VI) there is a colour change.

In the mass spectrum of compound **X**

- the molecular ion peak is at m/z 74
- the peak with the greatest relative intensity is at m/z 43 and is due to a secondary carbocation

Compound **X** has the following ^{13}C NMR spectrum.



Explain what can be deduced from each piece of information and identify the structure of compound **X**. [7]

It reacts with acidified dichromate(VI) (orange to green), so it is a primary or secondary alcohol: it cannot be a tertiary alcohol.

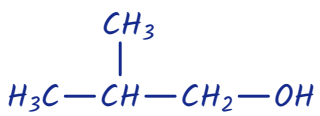
Molecular ion peak at m/z 74, so M_r = 74. The alkyl chain must have M_r 74 − 17 = 57 (C_4H_9), so the molecular formula is $C_4H_{10}O$.

Peak at m/z 43 is $C_3H_7^+$; as it is a secondary carbocation it is $(CH_3)_2CH^+$, so the chain is branched (loss of CH_2OH, m/z 31).

^{13}C NMR shows only three peaks, so there are only three carbon environments: the two CH_3 carbons are equivalent, plus CH and CH_2OH (at about 69 ppm).

So X is 2-methylpropan-1-ol, $(CH_3)_2CHCH_2OH$.

Structure of compound **X**



2-methylpropan-1-ol

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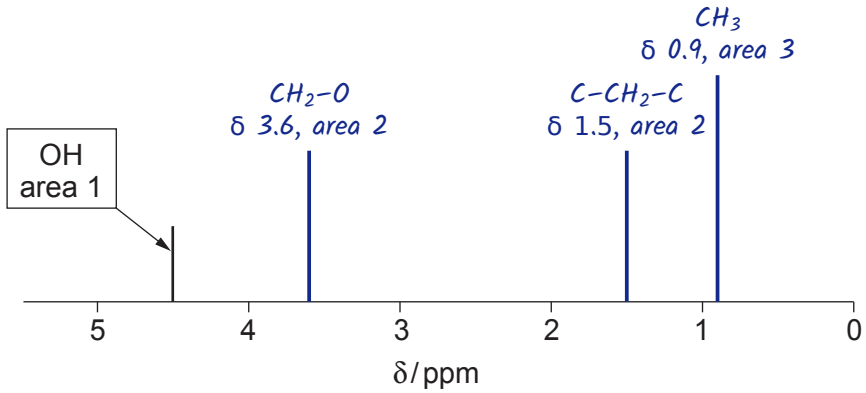
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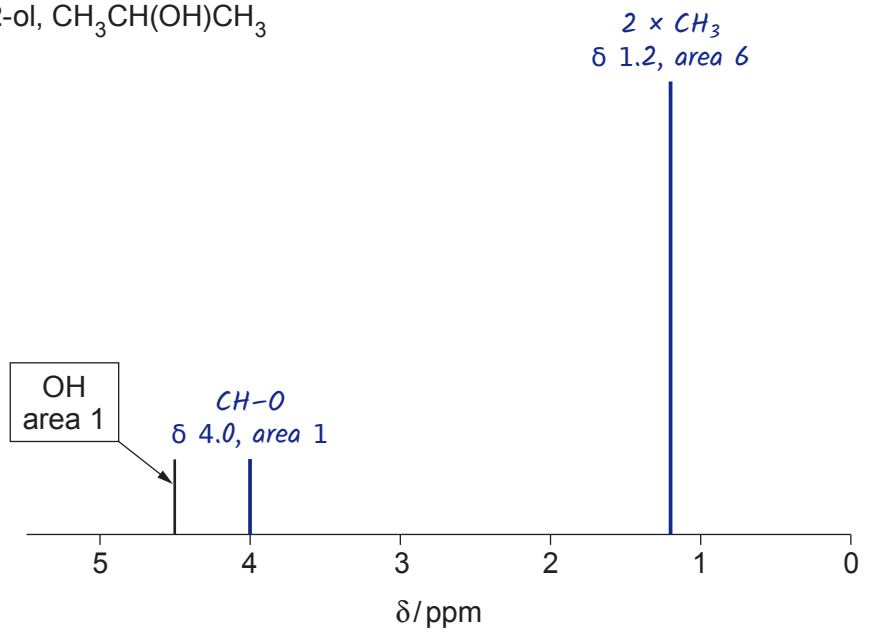
(b) Complete the sketches of the **low resolution** ^{1}H NMR spectra for propan-1-ol and propan-2-ol.

Identify which protons are responsible for each peak giving the approximate chemical shift (ppm) and the relative area of each peak. [4]

Propan-1-ol, $CH_3CH_2CH_2OH$



Propan-2-ol, $CH_3CH(OH)CH_3$



11

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10. *(a)* (i) Describe how you would carry out an experiment to determine the enthalpy change of the reaction between magnesium oxide and hydrochloric acid.

Your answer should include details of the apparatus to be used, the measurements to be taken and the way in which you would use your results to determine the enthalpy change. [6 QER]

Measure 50.0 cm^3 of hydrochloric acid (in excess) using a measuring cylinder or burette and transfer it to a polystyrene cup (in a beaker for support, with a lid). Record the temperature of the acid with a thermometer every minute for 3 minutes until it is constant; this is the initial temperature. Weigh a known mass of magnesium oxide (about 1 g) accurately on a balance, add it to the acid at the 4th minute and stir well. Record the temperature at regular timed intervals (every 30 s) for about 10 more minutes while the mixture reaches a maximum and then cools. Plot a graph of temperature against time. Draw a line of best fit through the cooling points and extrapolate it back to the time the solid was added, and find ΔT from the graph at that time (this corrects for heat loss). Calculate $q = mc\Delta T$, with $m = 50.0$ g (mass of solution) and $c = 4.18$ J g^{-1} K^{-1}. Calculate n = mass of MgO ÷ 40.3, then $\Delta H = -q \div n$ (in kJ mol^{-1}, negative as the reaction is exothermic).

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(ii) A student carried out this experiment and calculated the enthalpy change of reaction to be –115 kJ mol^{-1}.

He used 0.900 g of magnesium oxide and 50.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid.

Show that the acid is in excess and hence calculate the maximum temperature rise the student recorded. [4]

$n(MgO) = 0.900 \div 40.3 = 0.0223$ mol

$n(HCl) = 2.00 \times 0.0500 = 0.100$ mol

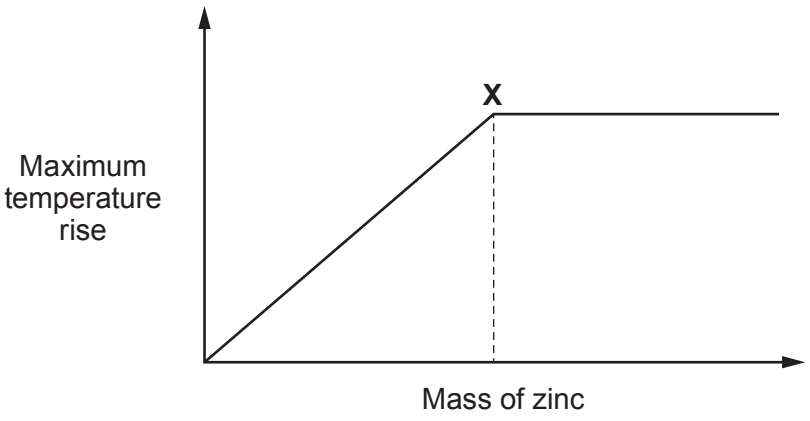
MgO + 2HCl: HCl needed = 0.0446 mol < 0.100 mol, so acid in excess

$q = 115\,000 \times 0.0223 = 2564.5$ J

$\Delta T = 2564.5 \div (4.18 \times 50.0) = 12.3$ °C

Maximum temperature rise = 12.3 °C

(b) The graph below shows the maximum temperature rise as different masses of zinc react with separate samples of 50.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid.



$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

Calculate the mass of zinc at the position labelled **X**. [3]

$n(HCl) = 0.0500 \times 0.100 = 5.00 \times 10^{-3}$ mol

$n(Zn) = 5.00 \times 10^{-3} \div 2 = 2.50 \times 10^{-3}$ mol

mass of $Zn = 2.50 \times 10^{-3} \times 65.4 = 0.164$ g

Mass of zinc = 0.164 g

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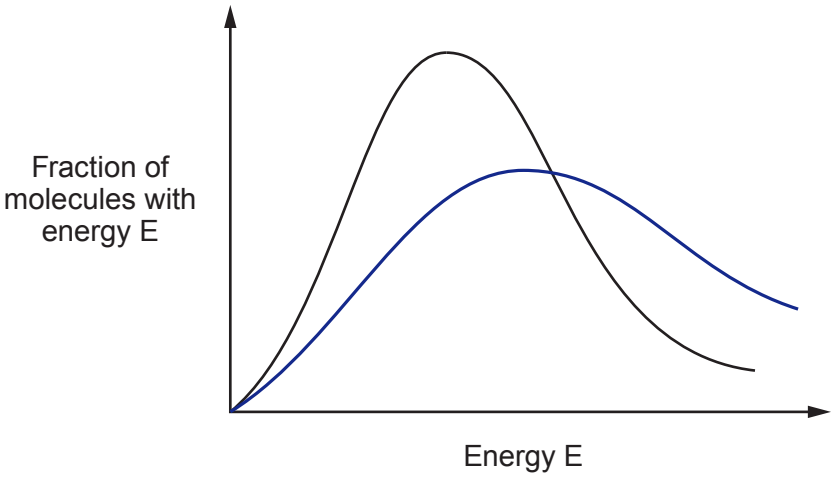
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11. *(a)* The decomposition of gaseous hydrogen iodide, HI, is represented by the following equation.

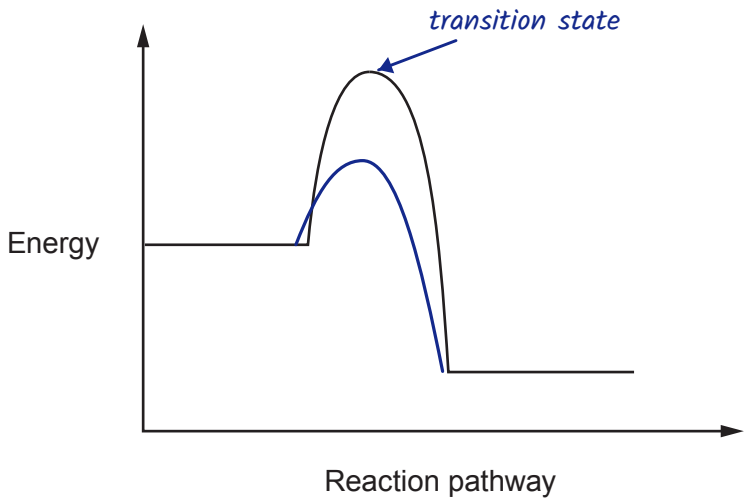
$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad \Delta H = -53\,kJ\,mol^{-1}$$

(i) Its energy distribution curve at a certain temperature is shown below.

On the same axes, draw another curve to show the distribution at a higher temperature. [1]



(ii) The energy profile for this reaction is shown below.



I. Label the position that represents the transition state of the reaction. [1]

II. **On the same axes**, draw the energy profile for the same reaction if it were catalysed. [1]

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(iii) The activation energy of the forward reaction (E_f) is 195 kJ mol^{-1}.

Calculate the activation energy of the reverse reaction (E_b). [1]

$E_b = E_f - \Delta H = 195 - (-53) = 248$

E_b = ... 248 ..... kJ mol^{-1}

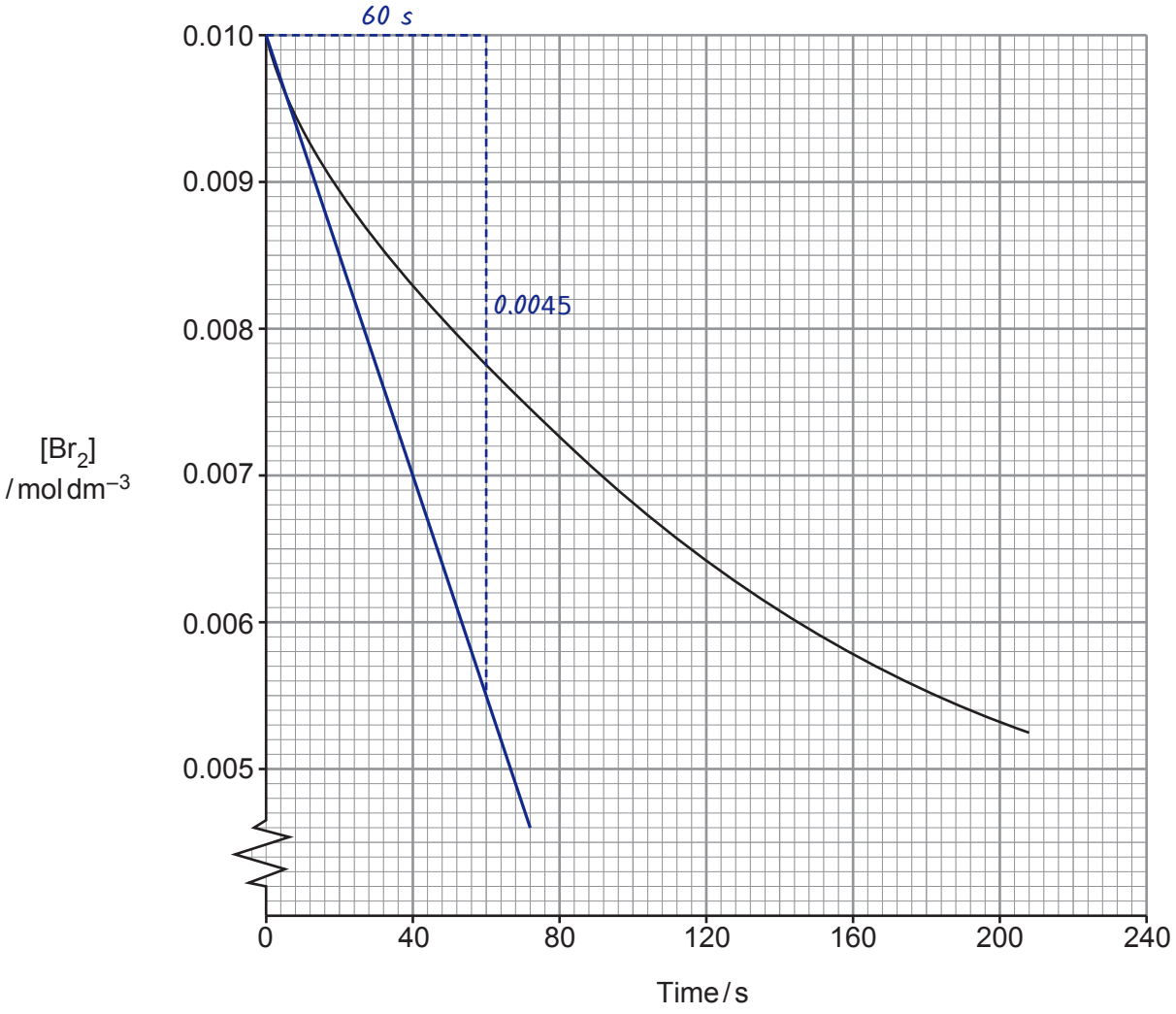
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(b) Bromine oxidises methanoic acid according to the following equation.

$$Br_2(aq) + HCOOH(aq) \longrightarrow 2H^+(aq) + 2Br^-(aq) + CO_2(g)$$

The graph below shows how the concentration of bromine changes in the initial stages of the reaction.



(i) Calculate the initial rate of the reaction from the graph and give its unit. **Show your working**. [4]

tangent drawn at t = 0 s

rate = gradient = (0.0100 − 0.0055) ÷ 60

= 0.0045 ÷ 60 = 7.5 × 10^{-5}

Initial rate = *7.5 × 10^{-5}* .....

Unit *mol dm^{-3} s^{-1}* .....

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(ii) Suggest **two** ways in which the rate of this reaction could be measured. [2]

Colorimetry: measure the change in colour (absorbance) of the bromine over time.

Measure the volume of CO_2 gas formed over time using a gas syringe.

(iii) I. State how the graph shows that the rate decreases as the reaction proceeds. [1]

As the reaction proceeds the curve gets less steep.

II. Use collision theory to explain why the rate of the reaction decreases as the reaction proceeds. [2]

The concentration of bromine and methanoic acid decreases, so there are fewer particles per unit volume.

So there are fewer successful collisions per unit time.

(iv) State why it is necessary to keep the temperature constant during this experiment. [1]

A change in temperature affects the rate of reaction, so it would not be a fair test.

14

END OF PAPER

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