Surname	StemUp Model Solution	Centre Number	Candidate Number
Other Names			2

GCE AS – NEW

B410U20-1

S17-B410U20-1

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

FRIDAY, 9 JUNE 2017 – AFTERNOON

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 6.**	**10**	
Section B	**7.**	**17**	
	8.	**15**	
	9.	**13**	
	10.	**14**	
	11.	**11**	
	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.9***(b)*.

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.

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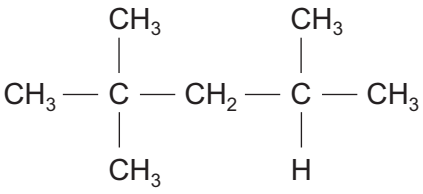
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SECTION A

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

1. Reforming and cracking are two important reactions in the petrochemical industry.

(a) The following compound is produced by reforming.



Give the systematic name for this compound. [1]

2,2,4-trimethylpentane

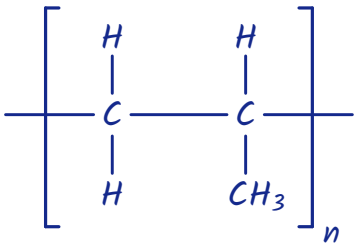
(b) An example of a cracking reaction is decane being broken down.

When decane is cracked propene and one other product is formed. Write an equation for this reaction. [1]

$C_{10}H_{22} \rightarrow C_3H_6 + C_7H_{16}$

2. Propene is used to make the important polymer polypropene.

Draw the repeating unit in polypropene. [1]



3. Describe the difference in structure between a primary and a secondary alcohol. [1]

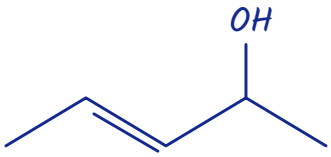
In a primary alcohol the C bearing the OH group is bonded to one C atom (and 2 H); in a secondary alcohol it is bonded to two C atoms (and 1 H).

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4. *(a)* Draw the **skeletal** formula of pent-2-en-4-ol. [1]



(b) State what you would observe when acidified potassium manganate(VII) is added to pent-2-en-4-ol. [1]

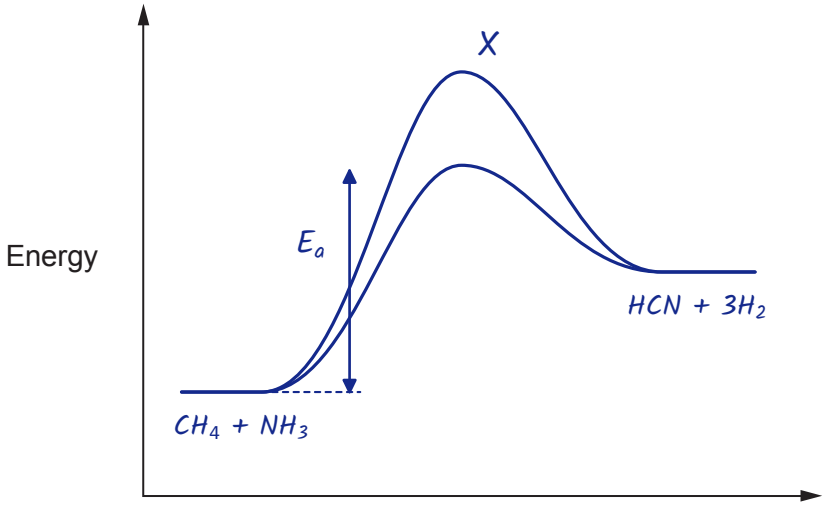
The colour changes from purple to colourless.

5. Hydrogen cyanide can be made by heating methane with ammonia in the presence of a platinum catalyst.

$$CH_4(g) + NH_3(g) \rightleftharpoons HCN(g) + 3H_2(g) \qquad \Delta H = 247 \text{ kJ mol}^{-1}$$

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(a) On the axes below, sketch the energy profile for this reaction. Label the activation energy of the forward reaction. [1]



(b) On the same axes, sketch the energy profile for the **uncatalysed** reaction. Label this profile **X**. [1]

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6. Give a chemical test which could be used to show the presence of a carboxylic acid group, —COOH. Your answer should include all reagents and observations. [2]

Add sodium carbonate (or sodium hydrogencarbonate) solution.

Bubbles (effervescence) are seen; the gas, CO_2, turns limewater milky.

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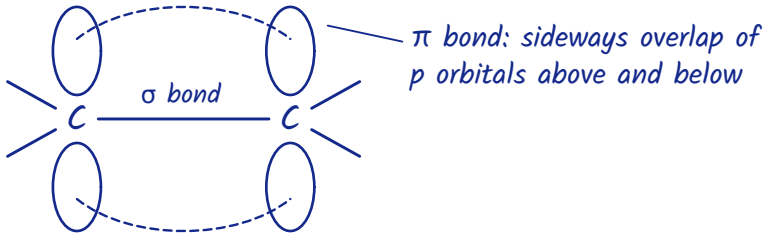
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SECTION B

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

7. *(a)* Describe the nature of the bonding in simple alkenes and explain how this governs their chemical behaviour. [4]

A diagram may be used as part of your answer.



Each C=C contains a σ bond and a π bond between the two C atoms; C to H bonds are σ bonds.

The π bond forms by sideways overlap of p orbitals, giving a region of high electron density above and below the C to C axis. The π bond is weaker than the σ bond.

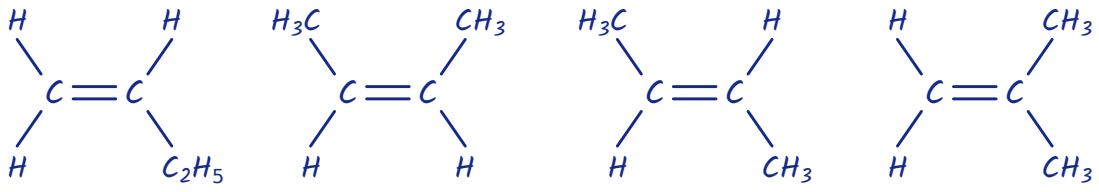
So alkenes are attacked by electrophiles and react by electrophilic addition.

(b) State the type(s) of isomerism that exists in simple alkenes and draw the structures of **all** the isomeric forms of C_4H_8 that are alkenes. [3]

Type(s) of isomerism

structural (chain/position) and geometric (E-Z / cis-trans)

Structures



but-1-ene

Z-but-2-ene

E-but-2-ene

2-methylpropene

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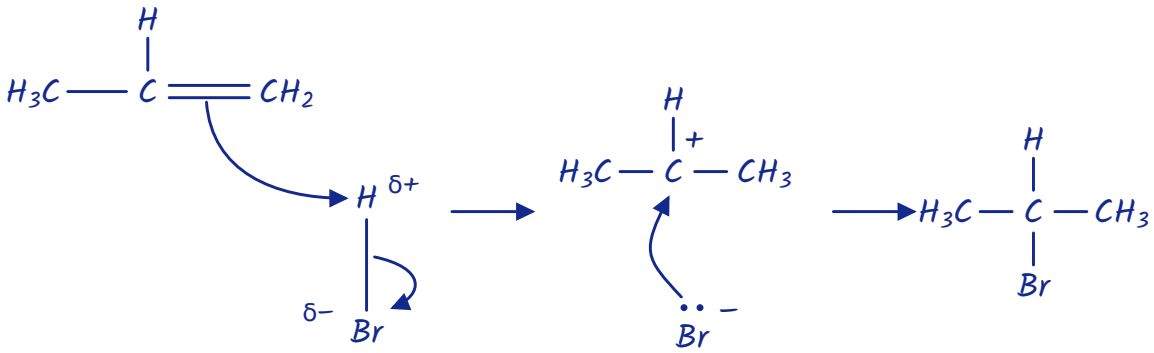
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(c) Propene reacts with hydrogen bromide to give 2-bromopropane as the major product.

(i) Draw the mechanism for this reaction. [3]



(ii) State briefly why 2-bromopropane is the main product of this reaction. [1]

The secondary carbocation (intermediate) is more stable than the primary carbocation.

(d) 1-Bromopropane is used in the synthesis of many organic compounds.

(i) Classify the type of reaction mechanism taking place when propan-1-ol is formed from 1-bromopropane. [1]

Nucleophilic substitution

(ii) Give the reagent(s) and conditions necessary to convert 1-bromopropane to propene. [1]

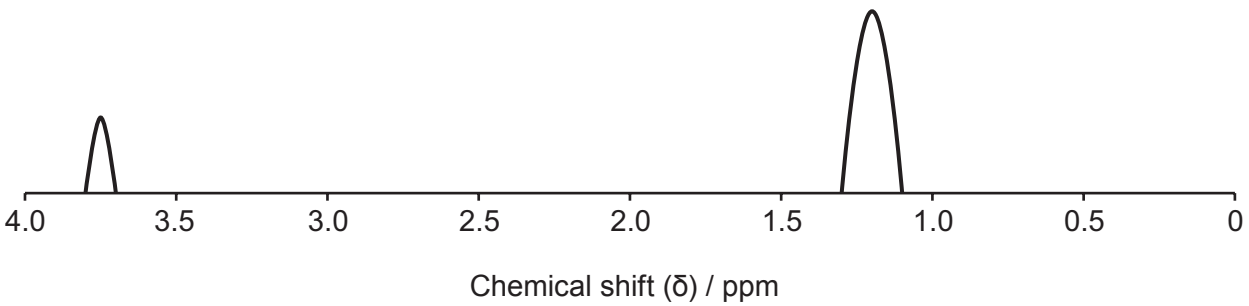
Alcoholic (ethanolic) potassium hydroxide, heat (under reflux).

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(e) A student was given a sample of bromopropane but was not told which isomer it was. The low resolution ^{1}H NMR spectrum of the sample is shown below.



Deduce which isomer the student was given and hence the relative areas under each peak. Give your reasoning. [2]

2-bromopropane, $CH_3CHBrCH_3$: there are only two peaks, so only two different proton environments (1-bromopropane would have three).

Relative areas: 6 : 1 (the 6 equivalent CH_3 protons at about 1.2 ppm, the 1 CH proton at about 3.7 ppm).

(f) Some halogenoalkanes can be classified as chlorofluorocarbons (CFCs). One common CFC is trichlorofluoromethane, CCl_3F. In the stratosphere CCl_3F breaks down to give chlorine radicals which destroy the ozone layer.

(i) Explain what is meant by a *radical*. [1]

A species (atom or group of atoms) with an unpaired electron.

(ii) Give a reason why chlorine radicals form but fluorine radicals do not. [1]

The C to F bond is stronger than the C to Cl bond, so only the C to Cl bond breaks in UV light.

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8. *(a)* A student was asked to prepare ethanoic acid from ethanol using the following method.

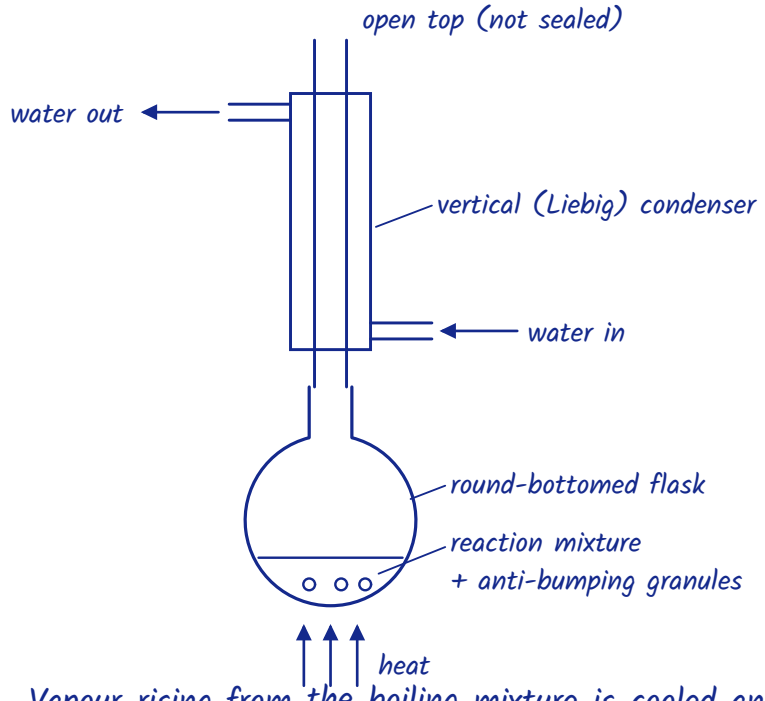
- Pour 10 cm^3 of dilute sulfuric acid into a round-bottomed flask.
  Add 5 g of a suitable reagent and 2-3 anti-bumping granules.
- Swirl the flask gently until all the reagent has dissolved.
- Add 2 cm^3 of concentrated sulfuric acid and cool the flask under running water.
- Set up the apparatus for heating under reflux. Add 12.0 cm^3 of ethanol, drop by drop, to the solution in the round-bottomed flask.
- When all of the ethanol has been added, boil gently under reflux for 20 minutes, not allowing any vapour to escape.
- Distil the mixture in the flask and collect the aqueous solution of ethanoic acid formed.

(i) Name the type of reaction taking place, giving a suitable reagent. [2]

Oxidation.

Reagent: acidified potassium dichromate(VI), $K_2Cr_2O_7$ / H_2SO_4

(ii) Draw a labelled diagram of the apparatus you would use for heating under reflux. Explain how this apparatus prevents the escape of vapour. [4]



Vapour rising from the boiling mixture is cooled and condensed in the vertical condenser and the liquid drips back (returns) into the flask.

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(iii) Give **two** reasons why the escape of vapour should be prevented. [2]

Volatile reactant (ethanol) or product would be lost, so the yield would be reduced.

Complete oxidation to the acid could not occur (the intermediate ethanal would escape); also the vapour is flammable (and acidic).

(iv) Ethanol has a density of 0.79 g cm^{-3} at room temperature. Calculate the number of moles of ethanol in 12.0 cm^3. [2]

mass = 12.0 × 0.79 = 9.48 g; $M_r(C_2H_5OH)$ = 46.0

n = 9.48 ÷ 46.0 = 0.206 mol

n = 0.206 mol

(v) In another experiment, the same reaction mixture was only gently heated and the product distilled off as it was formed. Explain why ethanoic acid is not produced in this instance. [2]

Ethanal (an aldehyde) is formed, as it distils off as soon as it forms.

So only partial oxidation occurs: ethanal is not oxidised further to the acid.

(b) In another preparation of ethanoic acid from ethanol, 10.2 g of pure ethanoic acid were obtained. The percentage yield of ethanoic acid was 65 %.

Calculate the mass of ethanol used in the preparation. [3]

n(ethanoic acid) = 10.2 ÷ 60.0 = 0.170 mol

n(ethanol) = 0.170 × 100 ÷ 65 = 0.262 mol (1 : 1)

mass of ethanol = 0.262 × 46.0 = 12.0 g

Mass = 12.0 g

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9. *(a)* A compound contains carbon, hydrogen and oxygen only. It is a sweet-smelling compound and has a molar mass of 88.1 g mol^{-1}. It contains 54.5 % carbon and 9.10 % hydrogen by mass.

(i) Calculate both the empirical and molecular formulae of the compound. [3]

C : H : O = 54.5/12.0 : 9.10/1.01 : 36.4/16.0

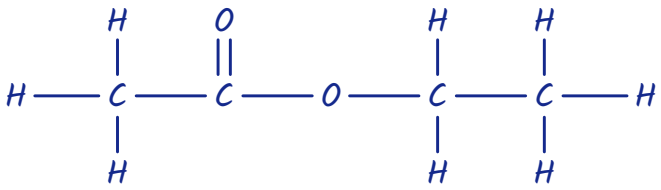
= 4.54 : 9.01 : 2.28

÷ 2.28: 2.00 : 3.96 : 1 so C_2H_4O (M_r = 44.0)

88.1 ÷ 44.0 = 2, so molecular formula = $C_4H_8O_2$

Empirical formula C_2H_4O Molecular formula $C_4H_8O_2$

(ii) Draw a displayed formula for the compound and give its systematic name. [2]



Name ethyl ethanoate

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(b) Ethanol is normally produced worldwide by hydration of ethene obtained from crude oil.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46 \text{ kJ mol}^{-1}$$

This reaction is typically carried out using a catalyst of phosphoric acid at 300 °C and 70 atm.

However, an increasing amount of ethanol is being made by the fermentation of glucose. Fermentation is catalysed by enzymes from yeast at a temperature of 40 °C under atmospheric pressure.

$$C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

State which process you think that a company should use.

Justify your answer using both your knowledge and the information given. [6 QER]

I think a company should use fermentation, although each process has advantages.

Renewability: ethene comes from crude oil, which is non-renewable and will run out, whereas glucose comes from plants (sugar cane) which are renewable.

Energy: hydration needs 300 °C and 70 atm, which costs a lot of energy (and fossil fuel); fermentation runs at 40 °C and atmospheric pressure, so the energy demand is lower.

Environment: the CO_2 given off in fermentation is taken in by plants as they grow, so the process is (nearly) carbon neutral.

Availability: oil-producing countries may prefer hydration of ethene, while warm countries can grow sugar crops for fermentation.

Atom economy: hydration has 100% atom economy (one product), and it is fast and continuous giving pure ethanol; fermentation has a lower atom economy (CO_2 is wasted), is a slow batch process and needs distillation.

On balance fermentation is more sustainable, so the company should use it.

(c) Ethanol can form ethene by a dehydration reaction.

Name a suitable reagent for this reaction and state how you would expect the infrared absorption spectrum of ethanol to differ from that of ethene. [2]

Reagent: concentrated sulfuric acid (or aluminium oxide).

Ethanol absorbs at 3200 to 3550 cm^{-1} (O to H) and 1000 to 1300 cm^{-1} (C to O) but not at 1620 to 1670 cm^{-1} (C=C), as ethene does.

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10. *(a)* A student was asked to calculate the enthalpy change, $\Delta_r H$, for the reaction of magnesium oxide and carbon dioxide to form magnesium carbonate.

Since this is difficult to measure directly he decided to determine the enthalpy changes for the reactions of magnesium oxide and magnesium carbonate with excess dilute hydrochloric acid in two similar, separate experiments and apply Hess's law to his results.

(i) The first experiment was to find the molar enthalpy change, ΔH_1, for the reaction

$$MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$$

ΔH_1 was calculated to be –115 kJ mol^{-1}.

Give **one** assumption made when finding the value of ΔH_1 from experimental results. [1]

No heat is lost to the surroundings (the solution has the same specific heat capacity as water and a density of 1.00 g cm^{-3}).

(ii) The second experiment was to find the molar enthalpy change, ΔH_2, for the reaction

$$MgCO_3(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$$

The following values were recorded during the experiment:

Mass of magnesium carbonate	3.50 g
Volume of hydrochloric acid	50.0 cm^3
Initial temperature of hydrochloric acid	22.0 °C
Final temperature of solution	30.8 °C

I. Calculate the molar enthalpy change for this reaction, ΔH_2, in kJ mol^{-1}. Give your answer to an appropriate number of significant figures. [4]

$\Delta T = 30.8 - 22.0 = 8.8$ °C; $m = 50.0$ g

$q = mc\Delta T = 50.0 \times 4.18 \times 8.8 = 1839$ J

$n(MgCO_3) = 3.50 \div 84.3 = 0.0415$ mol

$\Delta H_2 = -mc\Delta T \div n = -1839 \div 0.0415$

$= -44318$ J mol^{-1} $= -44.3$ kJ mol^{-1} (3 sig figs)

ΔH_2 = −44.3 kJ mol^{-1}

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II. State and explain the effect, if any, on the calculated enthalpy change, ΔH_2, if the experiment were repeated with the same mass of damp magnesium carbonate. [2]

The enthalpy change would be less negative (less exothermic).

Some of the 3.50 g is water, so less $MgCO_3$ reacts and the temperature rise is lower.

(iii) The hydrochloric acid used in these experiments could be measured using either a volumetric pipette or a measuring cylinder. Give **one** practical advantage of using each piece of apparatus. [2]

Volumetric pipette

More accurate (more precise, lower percentage error) measurement of volume.

Measuring cylinder

Faster, easier and more convenient to use.

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

error in ΔT = 2 × 0.1 = 0.2 °C

% error = 0.2 ÷ 8.8 × 100 = 2.27

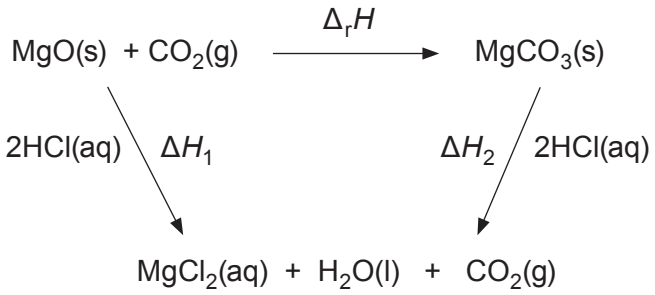
Percentage error = *2.3* %

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(v) A Hess cycle connecting $\Delta_r H$ to ΔH_1 and ΔH_2 is shown below.



Calculate the value of $\Delta_r H$ in kJ mol^{-1}. [2]

$\Delta_r H = \Delta H_1 - \Delta H_2$

$= -115 - (-44.3)$

$= -70.7$ kJ mol^{-1}

$\Delta_r H =$ −70.7 kJ mol^{-1}

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(b) The equation for the reaction between hydrazine and nitrogen dioxide is as follows.

$$2N_2H_4(l) + 2NO_2(g) \longrightarrow 3N_2(g) + 4H_2O(l) \qquad \Delta H = -1313 \text{ kJ mol}^{-1}$$

Using this value and the standard enthalpy changes of formation, $\Delta_f H^\theta$, given in the table below, calculate the standard enthalpy change of formation of NO_2. [2]

Substance	$\Delta_f H^\theta$ / kJ mol^{-1}
$N_2H_4(l)$	50.4
$N_2(g)$	0
$H_2O(l)$	−286

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

$-1313 = 4(-286) - [2(50.4) + 2\Delta_f H(NO_2)]$

$-1313 = -1144 - [100.8 + 2\Delta_f H(NO_2)]$

$2\Delta_f H(NO_2) = 1313 - 1144 - 100.8 = 68.2$

$\Delta_f H(NO_2) = +34.1 \text{ kJ mol}^{-1}$

$\Delta_f H^\theta =$ +34.1 kJ mol^{-1}

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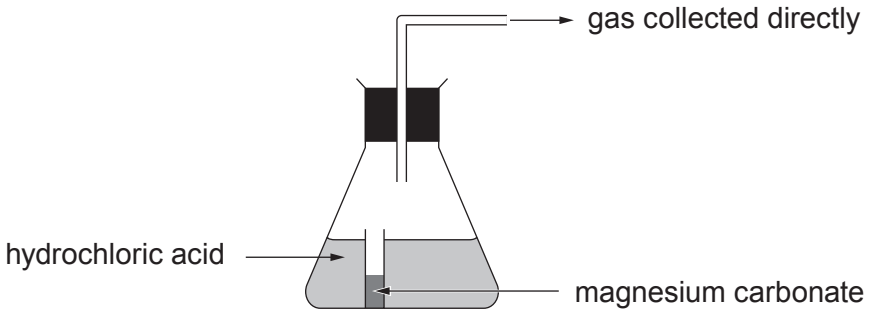
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11. Adam investigated how the initial rate of reaction between hydrochloric acid and magnesium carbonate at 20 °C is affected by the concentration of the acid. The equation for the reaction is as follows.

$$MgCO_3(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

He used 0.50 g of magnesium carbonate and 40 cm^3 of 0.20 mol dm^{-3} hydrochloric acid. He measured the volume of carbon dioxide produced at regular time intervals as the reaction proceeded. Part of the apparatus used for the experiment is shown below. The magnesium carbonate was placed in the small glass container which was tipped over to start the reaction and a stopwatch was started at the same time.



(a) Name the apparatus used to collect and measure the volume of the gas produced. [1]

Gas syringe

(b) Suggest an experimental method other than measuring the volume of gas that would allow the rate of this reaction to be studied. [2]

Measure the mass of the flask and contents on a balance (mass of CO_2 lost) at regular time intervals (over time).

(c) Elinor told Adam that in this experiment the carbonate needed to be in excess. He replied that it was. Is he correct? Justify your answer. [2]

Yes. $n(MgCO_3) = 0.50 \div 84.3 = 5.9 \times 10^{-3}$ mol; $n(HCl) = 0.040 \times 0.20 = 8.0 \times 10^{-3}$ mol.

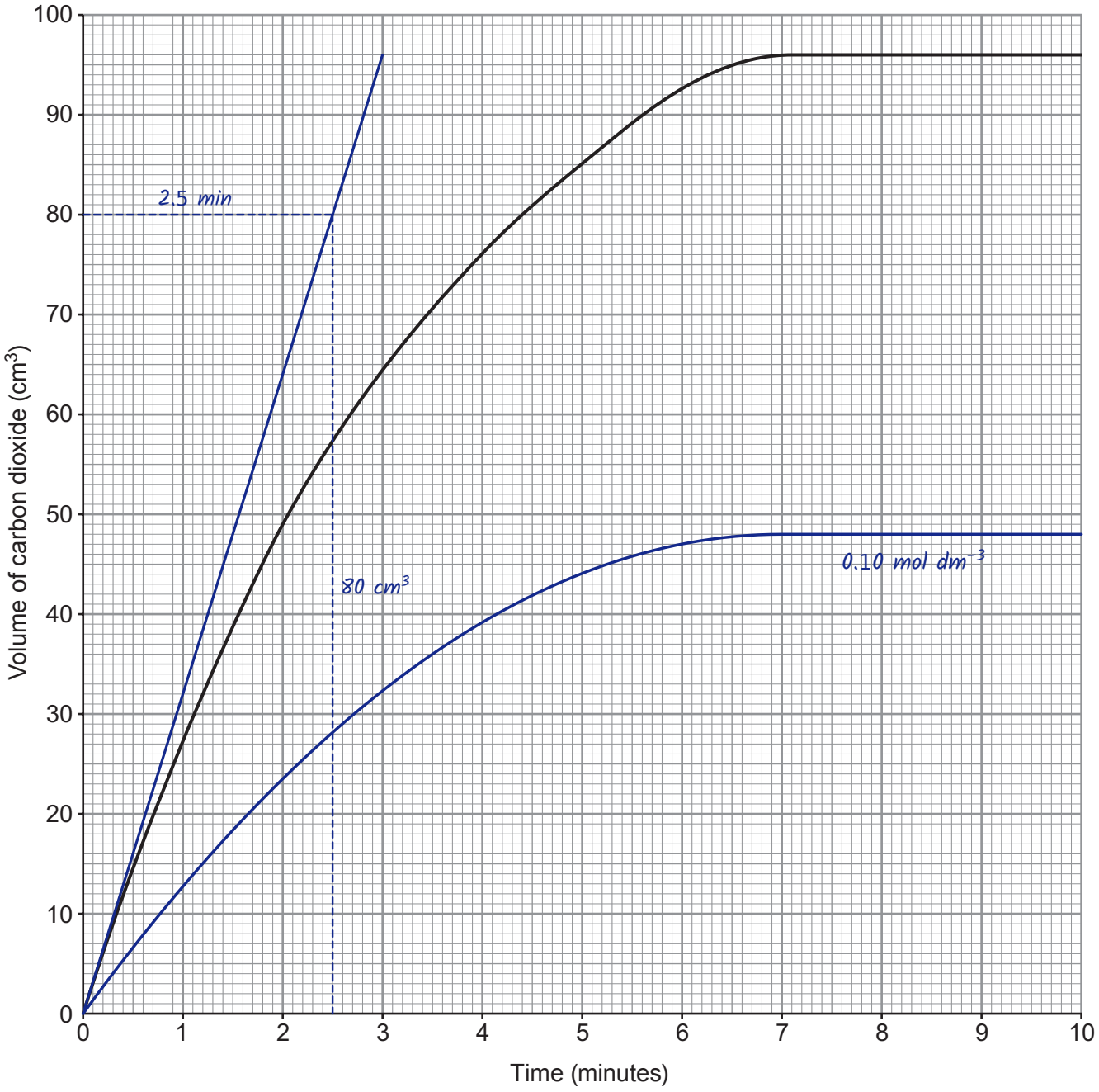
$MgCO_3$: HCl is 1 : 2, so only 4.0×10^{-3} mol $MgCO_3$ reacts: it is in excess.

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(d) Adam plotted his results as follows.



By drawing a tangent to the curve calculate the initial rate of this reaction. State the unit. [2]

gradient of tangent at t = 0: 80 ÷ 2.5 = 32

Rate = 32

Unit $cm^3\ min^{-1}$

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(e) He then repeated the experiment using 40 cm^3 of 0.10 mol dm^{-3} hydrochloric acid. Sketch on the graph in *(d)* the curve he would expect to obtain. Explain any differences in the curves. [3]

The new curve is less steep and levels off at 48 cm^3: lower concentration gives fewer successful collisions per unit time.

The volume of CO_2 halves as the moles of HCl (limiting) are halved.

(f) State **one** condition, other than temperature and pressure, which would need to be kept constant in this investigation. [1]

The surface area (particle size) of the magnesium carbonate.

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