Cambridge Assessment International Education

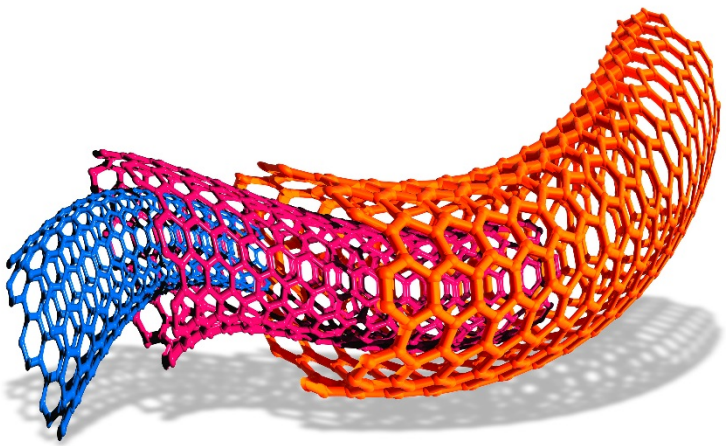
Teaching Pack

Graphing the rate of reaction between hydrochloric acid and calcium carbonate

Cambridge O Level

Chemistry 5070

This *Teaching Pack* can also be used with the following syllabuses:
- Cambridge IGCSE Chemistry **0620**
- Cambridge IGCSE (9–1) Chemistry **0971**
- Cambridge IGCSE Physical Science **0652**
- Cambridge IGCSE Combined Science **0653**
- Cambridge IGCSE Co-ordinated Sciences (Double Award) **0654**
- Cambridge IGCSE (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge O Level Combined Science **5129**



Version 1

Cambridge Pathway

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Icons used in this pack:

Briefing lesson

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Graphing the rate of reaction between hydrochloric acid and calcium carbonate

This *Teaching Pack* focuses on graphing a rate of reaction experiment.

In this experiment you will investigate how the rate of reaction of hydrochloric acid with marble chips varies with the concentration of the acid. The results will be visualised and discussed using graphs.

This experiment has links to the following syllabus content (see syllabus for detail):

- 7.2 Rate (speed) of reaction

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- Make and record measurements and estimates
- Interpret and evaluate experimental observations and data
- Demonstrate knowledge of how to safely use techniques, apparatus and materials (including following a sequence of instructions)
- Evaluate methods and suggest possible improvements

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 2.1 Measurement
- 8.1 The characteristic properties of acids and bases

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about rates of reaction at Advanced level.

Briefing lesson: Drawing better graphs

Resources	• Worksheet A and answer sheet • A piece of A4 graph paper • the apparatus mentioned in question 1 if available. (sizes other than those mentioned, may also be used).
Learning objectives	By the end of the lesson: • ***all*** learners should be able to identify some of the mistakes in the graph and be able to replot it correctly with assistance. • ***most*** learners should be able to identify the majority of the mistakes in the graph and be able to replot it correctly. • ***some*** learners will be able to identify all the mistakes in the graph and replot it correctly without assistance.

Timings	Activity
5 min 5 min	**Starter/Introduction** Working in pairs, learners write down one fast and one slow chemical reaction. They should write out a full balanced equation using books/internet to research if necessary. Create two headings of 'fast reactions' and 'slow reactions' on the board and elicit and discuss examples from learners.
45 min	**Main lesson** Learners should be given Worksheet A. They will also need a sheet of graph paper for question 4. This activity consists of questions preparing learners for being able to cope with the main activity of this pack. Points to note and discuss with your learners: **Question 1:** if you have these pieces of equipment, display an example of each at the front of the classroom. If not, refer learners to suitable images. **Question 2:** learners may need assistance with balancing the equation. **Question 3:** Many learners find plotting graphs correctly quite challenging so you may need to spend time explaining each mistake. **Question 4:** On a piece of graph paper, learners replot the graph using the same data as in question 3 and finally compare it to the answer sheet which should be displayed and discussed. Remind learners to use a sharp pencil for plotting graphs and not to draw a thick obscuring trendline.

Timings	Activity
	**Plenary** Explain to the learners that they are going to perform (or watch) an experiment based on question 2 of Worksheet A. Ask learners to discuss safety measures in this experiment. (Acid is corrosive, syringe is made of fragile glass.)

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Practical video – teacher • Worksheets B and C • A sheet of A4 graph paper • Practical equipment and outlines in the notes
Learning objectives	By the end of the lesson: • ***all*** learners should be able to take readings from the experiment and use the data obtained to plot graphs with teacher support. • ***most*** learners should be able to take readings from the experiment, use the data obtained to plot graphs and draw basic conclusions from them. • ***some*** learners will be able to take readings from the experiment, use the data obtained to plot graphs and fully evaluate the experiment.

Timings	Activity
5 min	**Starter/Introduction** Explain to learners that in this experiment lots of data is going to be collected in data tables and plotted graphically. Discuss with learners why it is necessary to go to the trouble of taking organised tabulated experimental data and plotting it on graphs. You may wish to discuss how graphs help us visualise data better and see trends more easily. This is especially true for this experiment, when several sets of data will be plotted on the same sheet of graph paper for direct comparison. You may also wish to show learners some examples of different types of graph shapes, e.g. straight line graphs with various gradients, bell shaped curves, exponential, etc. This aim of this is just to remind learners that various graph shapes arise depending on the data obtained from experiments.
50 min	**Main lesson** In this experiment learners will investigate the rate of reaction of marble chips (calcium carbonate) with 3 different concentrations of dilute hydrochloric acid. Please note: suggested concentrations are 2.0, 1.0 and 0.4 mol dm^{-3}, but the exact concentrations your learners use will be dependent on your trial runs beforehand. Learners should be reminded to write these concentrations into the spaces provided in their results tables on Sheet C. For each trial run of the experiment, the rate of production of carbon dioxide gas will be monitored using a gas syringe and graphs will be plotted to compare the rates using these 3 concentrations of acid.

Timings	Activity
	Safety Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate. Provide learners with the method sheet (Worksheet B), a sheet to record their results (Worksheet C) and a sheet of A4 graph paper. **Extension:** For more able learners, you could ask them to devise their own results recording tables, instead of handing them Worksheet C. Divide learners into groups of 3 for this experiment. Each member of the group will rotate roles as Learner A, B and C, so that by the end of three trials of the experiment, each learner has added the reactants (A), operated the stopwatch (B) and taken readings from the gas syringe (C). Learner A: adds the acid to the marble chips, secures the bung and records results in the results table Learner B: operates the stopwatch Learner C: takes reading from the gas syringe Learners follow the instructions on Worksheet B carefully and perform the three trials of the experiment. Ensure that after the experiment is finished, each learner in the group obtains a copy of the completed results table. Then, each learner in the group plots the 3 trials of the experiment on a single piece of A4 graph paper. Remind learners to pay close attention to the skills learnt in the briefing lesson in order to produce good quality graphs. Ensure that learners also pay close attention to what they learned/revised in the Briefing lesson regarding the correct plotting of graphs. Remind them to use a sharp pencil for plotting and not to draw a thick obscuring trendline. The accurate plotting of graphs is a time-consuming procedure and should not be rushed. Please allow learners extra time to complete this task or set it as a homework assignment if necessary.
	**Plenary** Volunteers hold up example graphs from their groups, so that they can be compared and briefly discussed. Learners will hopefully arrive at the conclusion that as the concentration of hydrochloric acid increases the rate of the reaction increases.

Timings	Activity
	Explain to learners that the results and conclusions to this experiment will be further discussed in the debriefing lesson to follow.

Teacher notes

Watch the video entitled 'Graphing the rate of reaction between hydrochloric acid and calcium carbonate' (teacher version) and read these notes.

Each group of three learners will require:

- marble chips (calcium carbonate pieces)
- hydrochloric acid of three concentrations (suggested: 2.0 mol dm^{-3}, 1.0 mol dm^{-3}, 0.4 mol dm^{-3}).

NOTE THAT THESE ARE SUGGESTED CONCENTRATIONS ONLY. SINCE THE SIZE OF MARBLE CHIPS MAY VARY CONSIDERABLY, IT IS IMPORTANT TO TRIAL THE EXPERIMENT BEFORE GIVING IT TO YOUR LEARNERS

- a top pan balance (1 d.p is sufficient)
- a 100 cm^3 gas syringe (equipped with a piece of string attached to the body and barrel)
- a 100 cm^3 conical flask
- a 50 cm^3 measuring cylinder
- a plastic pipette
- a bung fitted with an 'L' shaped deliver tube (with a short length of rubber tubing attached to which also fits the gas syringe)
- 2 clamp stands
- a digital stop-clock
- a tare boat

Safety

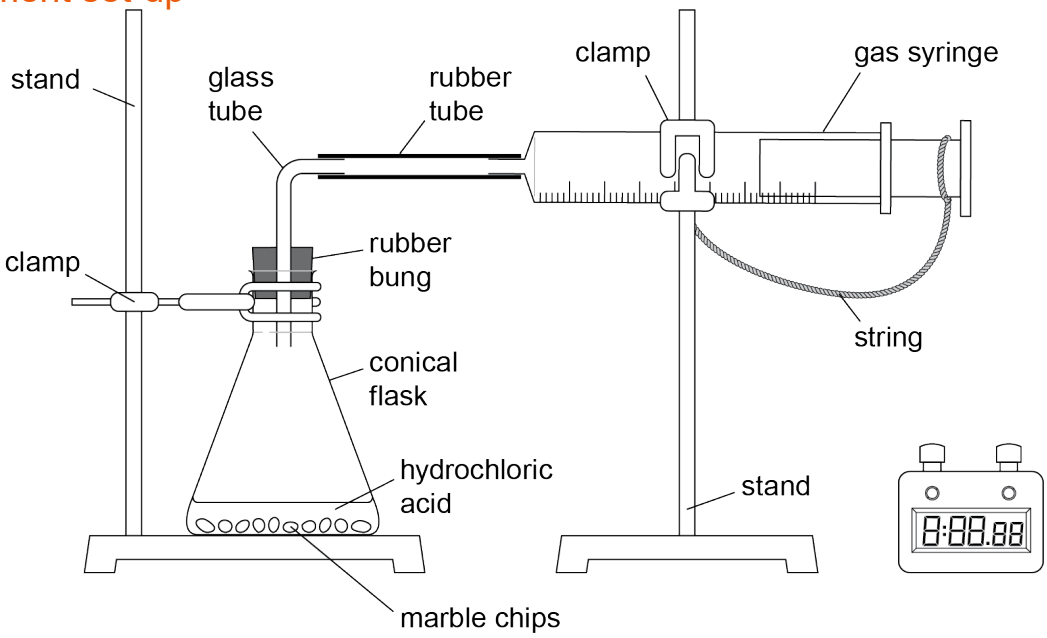
The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
Calcium carbonate chips (marble chips)	Low hazard	
Moderately concentrated hydrochloric acid (if less than 6.8M but more than 2.7M)	 GHS07 (moderate hazard **MH**) WARNING. It may irritate the eyes, and respiratory system.	**In the eye:** Flood the eye with gently-running tap water for 10 minutes. See a doctor. **Swallowed:** Do no more than wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor. **Spilt on the skin or clothing:** Remove contaminated clothing. Then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate.

Substance	Hazard	First aid
		Rinse with plenty of water. Wipe up small amounts with a damp cloth and rinse it well.
Dilute hydrochloric acid (if less than 2.7M)	 GHS07 (*moderate hazard* **MH**) [below a concentration of 2.7 mol/dm^3]	**In the eye:** Flood the eye with gently-running tap water for 10 min. See a doctor. **Vapour breathed in:** Remove to fresh air. Call a doctor if breathing is difficult. **Swallowed:** Do no more than wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor. **Spilt on the skin or clothing:** Remove contaminated clothing, then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** For release of gas, consider the need to evacuate the lab and open all windows. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate. Rinse with plenty of water. Wipe up small amounts with a damp cloth and rinse it well.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them Worksheet B.

Before you begin

Plan how you will group your learners during the experiment session. This experiment is best performed with 3 learners as detailed in the experiment sheet.

Think about:

- the number of groups of 3 learners you will need
- the amount of equipment/chemicals required.

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Step	Notes
Check that learners have set up the equipment properly and are ready to start the experiment.	Ensure that the barrel of the gas syringe moves freely and that the string is correctly secured.
Check that learners have Worksheets B, C and a sheet of A4 graph paper.	
Warn learners about safety during the experiment.	i. Be careful of the fragile gas syringe and if for any reason the volume of gas looks like it may exceed the volume of the syringe, the bung can be lifted out of the flask. ii. Ensure that they are wearing goggles and their lab coats are buttoned up.
Weigh 0.5g of marble chips on a top pan balance and place in the reaction vessel.	Marble chips come in different sizes and shapes. Do not worry about this now but it may provide an interesting discussion point during the evaluation of the experiment.
Measure out 50cm^3 of 2.0 mol dm^{-3} hydrochloric acid into a measuring cylinder. Make up to volume using a plastic pipette.	Great accuracy is not needed in this step since the limiting reagent is calcium carbonate in this reaction. But it is good practice to use a measuring cylinder correctly. If time allows you may wish to challenge your learners to perform calculations to find out which reagent is in excess and which is limiting in these reactions.
When learners are fully organised in their specific roles for the first trial of the experiment, the acid is added to the reaction	

Step	Notes
flask, the bung twisted and secured. Simultaneously, the stopwatch is started.	
After 30s the first data is entered into the results table.	You may of course change the time interval to be recorded in the data table. It is always wise to do a trial reaction before you do the experiment with learners. The average size of the marble chips may be different to the those used in the experiment video, which may have a significant effect on the rate of reaction. Again, this is a valid point for discussion with learners during evaluation of this experiment.
Learners continue taking readings every 30s until the reaction ceases.	Since calcium carbonate is the limiting reagent in this reaction, it should be completely used up and the barrel of the syringe should become fully extended. Once again you may wish to provide some or all of the learners with the opportunity to show that 0.5g $CaCO_3$ when reacting with excess acid produces enough carbon dioxide gas to do produce greater than 100 cm^3 gas.
Learners swap roles and repeat the whole procedure using the other acid concentrations.	Swapping roles give all learners the opportunity to read the gas syringe and perform all the other tasks in the experiment. Note that since marble chips vary in size from company to company and batch to batch the concentrations suggested in this experiment 2.0, 1.0 and 0.4 mol dm^{-3} are only suggestions. It is important to trial the experiment first before doing it with your learners.

Clean-up

After the experiment learners should:

- clean all glassware but be very careful handling the fragile gas syringe
- tidy up their workspace
- ensure any spillages have been mopped up
- return all equipment and any unused chemicals to you

The contents of the reaction vessel can be decanted carefully into the sink.

Lab lesson: Option 2 – virtual experiment

Resources	• Experiment video • Worksheet D (data sheet) • A4 graph paper
Learning objectives	By the end of the lesson: • ***all*** learners should be able to plot the graphs with assistance and interpret the general pattern shown by them. • ***most*** learners should be able to plot the graphs with very little assistance and correctly interpret them. • ***some*** learners will be able to plot the graphs independently and correctly interpret them.

Timings	Activity
10 min	**Starter/Introduction** Explain to learners that in a rate experiment of this kind, a large amount of data is collected in data tables and then plotted graphically. Discuss with learners why it is necessary to take organised tabulated experimental data and plot it on graphs. You may wish to inform learners that graphs help us visualise the data better, and see trends more easily. This is especially true for this experiment when several sets of data will be plotted on one piece of graph paper for direct comparison. You may also wish to show learners some examples of different types of graph shapes. Ex. straight line graphs with various gradients, bell shaped curve, exponential, etc. The aim of this is just to remind learners that various graph shapes arise depending on the data obtained from experiments.
45 min	**Main lesson** Show the virtual experiment video once through to learners. Explain that the focus of this lesson is the accurate plotting of graphs to show how the rate of reaction varies with the concentration of the hydrochloric acid used. The video only shows data for one example concentration of acid (2.0 mol dm^{-3}) [at 04:06]. Pause the video at this data table again. However, learners are going to use data from 3 experiments using 3.0, 1.0 and 0.2 mol dm^{-3} hydrochloric acid respectively. Handout Worksheet D which contains 3 tables of data. Learners can work in pairs, though each learner should plot each graph individually. Also, handout a sheet of A4 graph paper.

Timings	Activity
	Ensure that learners pay close attention to what they learned/revised in the Briefing lesson regarding the correct plotting of graphs. Also remind them to use a sharp pencil for plotting and not to draw a thick obscuring trendline.
	**Plenary** Volunteers hold up example graphs so that they can be compared and briefly discussed. Hopefully, all learners will arrive at the conclusion that as the concentration of hydrochloric acid increases the rate of the reaction increases. Explain to learners that the results and conclusions to this experiment will be further discussed in the debriefing lesson to follow.

Debriefing lesson: Interpreting graphs

Resources	• Worksheet E • Worksheet E and corresponding answer sheet • Worksheet F
Learning objectives	By the end of the lesson: • ***all*** learners should interpret and sketch the graphs with support. • ***most*** learners should be able to interpret and sketch the graphs correctly with guidance. They will also be able to perform the rate calculation with some support. • ***some*** learners will be able to interpret and sketch the graphs correctly. They will also be able to perform the rate calculation independently.

Timings	Activity
5 min	**Starter/Introduction** In the previous parts of this Teaching Pack the way in which the rate of reaction varies with concentration was studied. Ask learners to make a list of other factors that might change the rate of reaction in this experiment. • Temperature • A catalyst • Surface area Briefly discuss that experiments could be performed changing these variables, data collected, and graphs plotted to see how the rate varies.
50 min	**Main lesson** The focus of this lesson is to practice and extend learners fluency in reading, interpreting and manipulating graphs. Handout Worksheet E to learners, who can work individually or in their original experiment groups for this activity. In question 2, the learner is required to sketch a line on a graph. Ensure that they do this in pencil as a thin line. Later in the same question, the learner must interpret the graph, reading volumes and times from it. Encourage learners to use rulers to mark on dotted lines to help them make the reading accurately. Question 3 requires learners not to plot, but to sketch a graph. This should be done in pencil in case mistakes are made.

Timings	Activity
	In the final question, learners calculate the instantaneous rate of the reaction from a tangent. They may not be familiar with this procedure and may need some guidance. Units should not be forgotten.
	**Plenary** Handout the answer Worksheet E – answers, so that learners can check their answers. It would be worth projecting this sheet on screen if possible, so that the method of obtaining the correct answers can be visualised together.

Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson:*		
A: Drawing better graphs	**20**	**33**
For use in *Lab lesson: Option 1:*		
B: Experimental Procedure	**23**	
C: Results	**24**	
For use in *Lab lesson: Option 2:*		
D: Results tables	**26**	
For use in the *Debriefing lesson:*		
E: Interpreting graphs	**27**	**35**

Worksheet A: Drawing better graphs

Answer the following questions to help you understand, perform and evaluate the main experiment in this skills pack.

1. A volume of gas will be measured in the experiment. Circle which piece(s) of apparatus could not be used for this purpose with reason(s).

   $50cm^3$ gas syringe $50cm^3$ beaker $100cm^3$ measuring cylinder

   $25cm^3$ pipette $50cm^3$ burette

2. Hydrochloric Acid + calcium carbonate ⟹ calcium chloride + water + carbon dioxide

   For the reaction above:

   i. Write out the balanced equation, including state symbols

   ii. Indicate which substance could be measured using gas collection apparatus.

   iii. Make a list of the variables which you could change in this reaction, which might affect the rate of reaction.

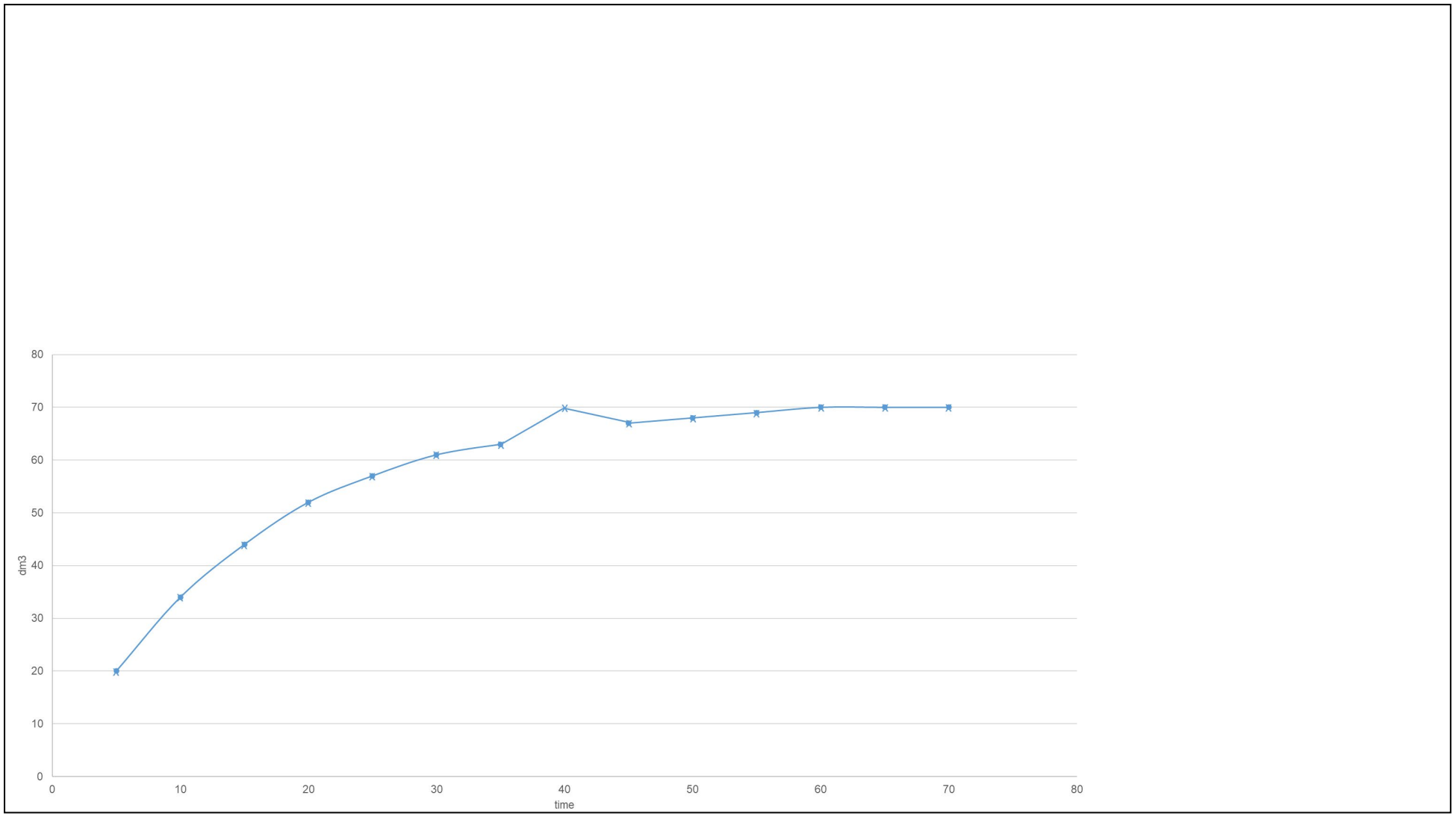
Worksheet A: Drawing better graphs, *continued*

3. A graph was plotted from the data below to show the rate of reaction between zinc powder and dilute nitric acid (see next page).

   Indicate on the graph all the mistakes that you can find. (There are seven.)

Time (s)	Volume of hydrogen collected (cm^3)
0	0
5	20
10	34
15	44
20	52
25	57
30	61
35	63
40	70
45	67
50	68
55	69
60	70
65	70
70	70

Worksheet A: Drawing better graphs, *continued*



4. Use the blank sheet of graph paper supplied and draw the graph correctly this time.

Worksheet B: Experimental procedure

Learner instructions

SAFETY: Make sure that you are wearing goggles and have buttoned up your lab coat ready to start the experiment.

Before you start:

i. Make sure you know which task you will perform for the first trial of the experiment. You will then rotate roles with other members of your group, so that after 3 trials, you will have assumed each learner role A-C:
   - Learner A: adds the acid to the marble chips in the flask and secures the bung. They also record results in the results table.
   - Learner B: operates the stopwatch.
   - Learner C: takes readings from the gas syringe.

ii. Make sure that you have a copy of Worksheet C, to enter your results and a piece of A4 graph paper.

Experimental procedure:

1. Collect all the necessary equipment and set it up as you have seen in the video.
2. Check that the barrel of the gas syringe can move freely.
3. Ask your teacher to check your set-up it before proceeding any further.
4. Weigh 0.5g of marble chips using a top pan balance and add to the reaction flask.
5. Measure out 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid* into a 50 cm^3 measuring cylinder. Use a plastic pipette to make up to volume.
6. Add 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid solution to the reaction flask and start the stopwatch immediately.
7. Record the results in the results table.
8. Repeat steps 1-6 for the other two acid concentrations*. Continue taking readings every 30s until the reaction is complete and/or the barrel of the gas syringe is full.
9. Plot graphs for each set of results on the same graph paper for comparison purposes.

*the exact acid concentrations to be used in this experiment will be determined by your teacher beforehand

Worksheet C: Results

Record your results for each concentration of acid below. Do not forget to write in the concentrations of acid used in each experiment. A suggested time interval is to record the results every 30 seconds. This may need to be changed depending on for example, the size of the marble chips used. This should be discussed with your teacher before proceeding.

Results using …….. mol dm^{-3} hydrochloric acid

Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)
0					

Results using …… mol dm^{-3} hydrochloric acid

Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)
0					

Worksheet C: Results, *continued*

Results using ….. mol dm^{-3} hydrochloric acid

Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)
0					

Worksheet D: Results tables

The exact concentrations of hydrochloric acid used in the experiment is determined by the size of the marble chips used in the experiment. In these series of experiments, the data supplied below was obtained using 3.0, 1.0 and 0.5 mol dm^{-3} hydrochloric acid respectively.

Results using 3.0 mol dm^{-3} hydrochloric acid

Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)
0	0	240	71	480	90
30	12	270	77	510	90
60	23	300	81	540	90
90	33	330	85	570	90
120	41	360	88	600	90
150	49	390	89	630	90
180	62	420	90	660	90
210	65	450	90	690	90

Results using 1.0 mol dm^{-3} hydrochloric acid

Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)
0	0	240	67	480	87
30	9	270	62	510	88
60	18	300	67	540	89
90	27	330	68	570	89
120	35	360	76	600	90
150	41	390	80	630	90
180	47	420	83	660	90
210	52	450	85	690	90

Results using 0.2 mol dm^{-3} hydrochloric acid

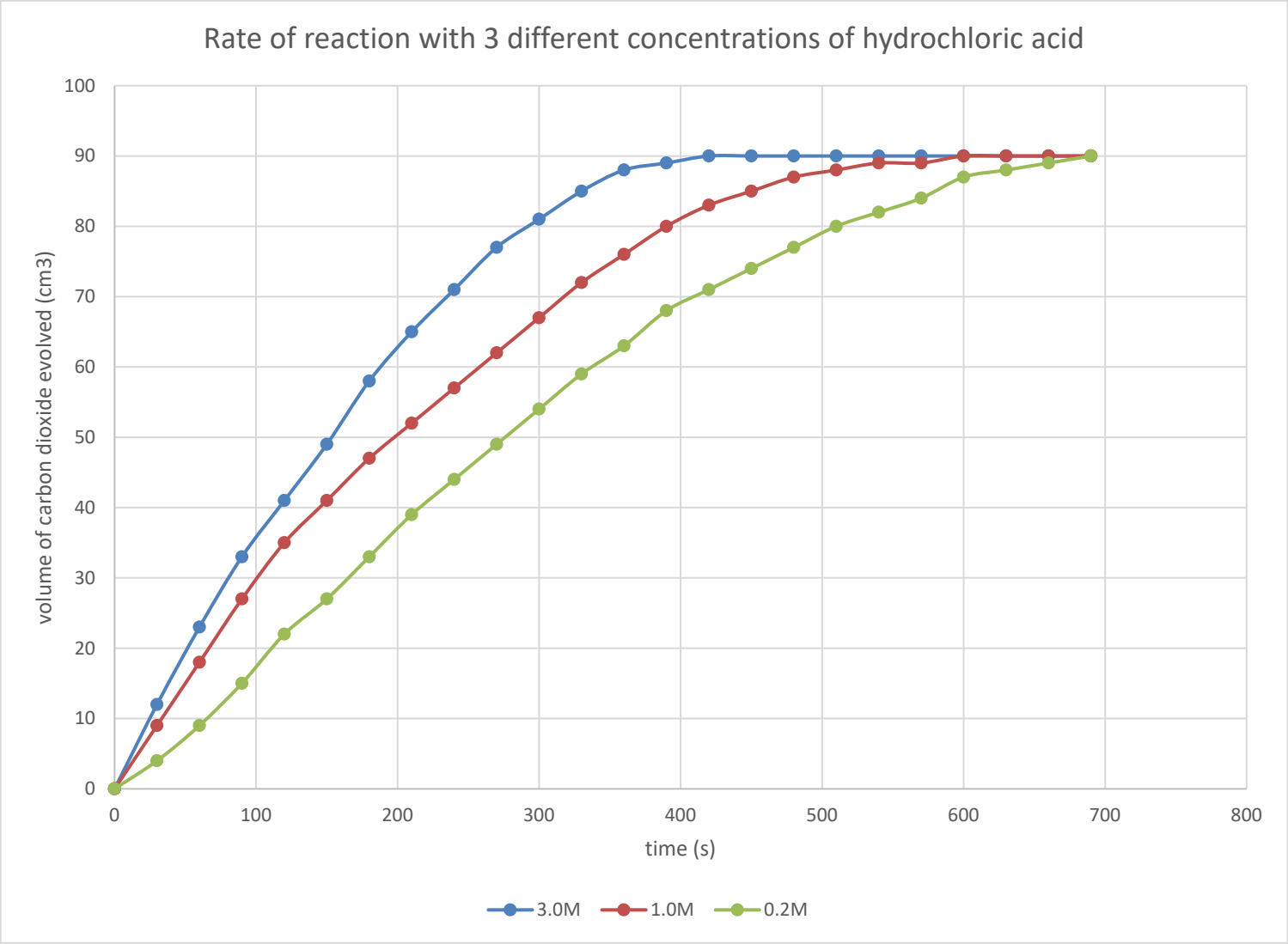
Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)	Time (s)	Volume (cm^3)
0	0	240	39	480	77
30	4	270	49	510	80
60	9	300	54	540	82
90	15	330	59	570	84
120	22	360	63	600	87
150	27	390	68	630	88
180	33	420	71	660	89
210	39	450	74	690	90

Worksheet E: Interpreting graphs

1. In terms of the collision theory, explain why increasing the concentration of hydrochloric acid, increases the rate of reaction with marble chips.

Worksheet E: Interpreting graphs, *continued*

2. Using the graph answer the following questions.



Worksheet E: Interpreting graphs, *continued*

i. Why are the graphs for this reaction not a straight line passing through the origin (0,0)?

ii. Sketch on your graph, the line you might expect to obtain using 5.0 mol dm^{-3} hydrochloric acid.

iii.

a. What are the volumes of carbon dioxide produced at t =200s for each of the three trials?

For the 3.0 mol dm^{-3} acid experiment:

For the 1.0 mol dm^{-3} acid experiment:

For the 0.2 mol dm^{-3} acid experiment:

b. What do you conclude from the values obtained in iii.a. above?

Worksheet E: Interpreting graphs, *continued*

iv.

a. How long does it take for each trial to produce 30cm^3 carbon dioxide gas?

For the 3.0 mol dm-3 acid experiment:

For the 1.0 mol dm-3 acid experiment:

For the 0.2 mol dm-3 acid experiment:

b. What do you conclude from the values obtained in iv.a. above?

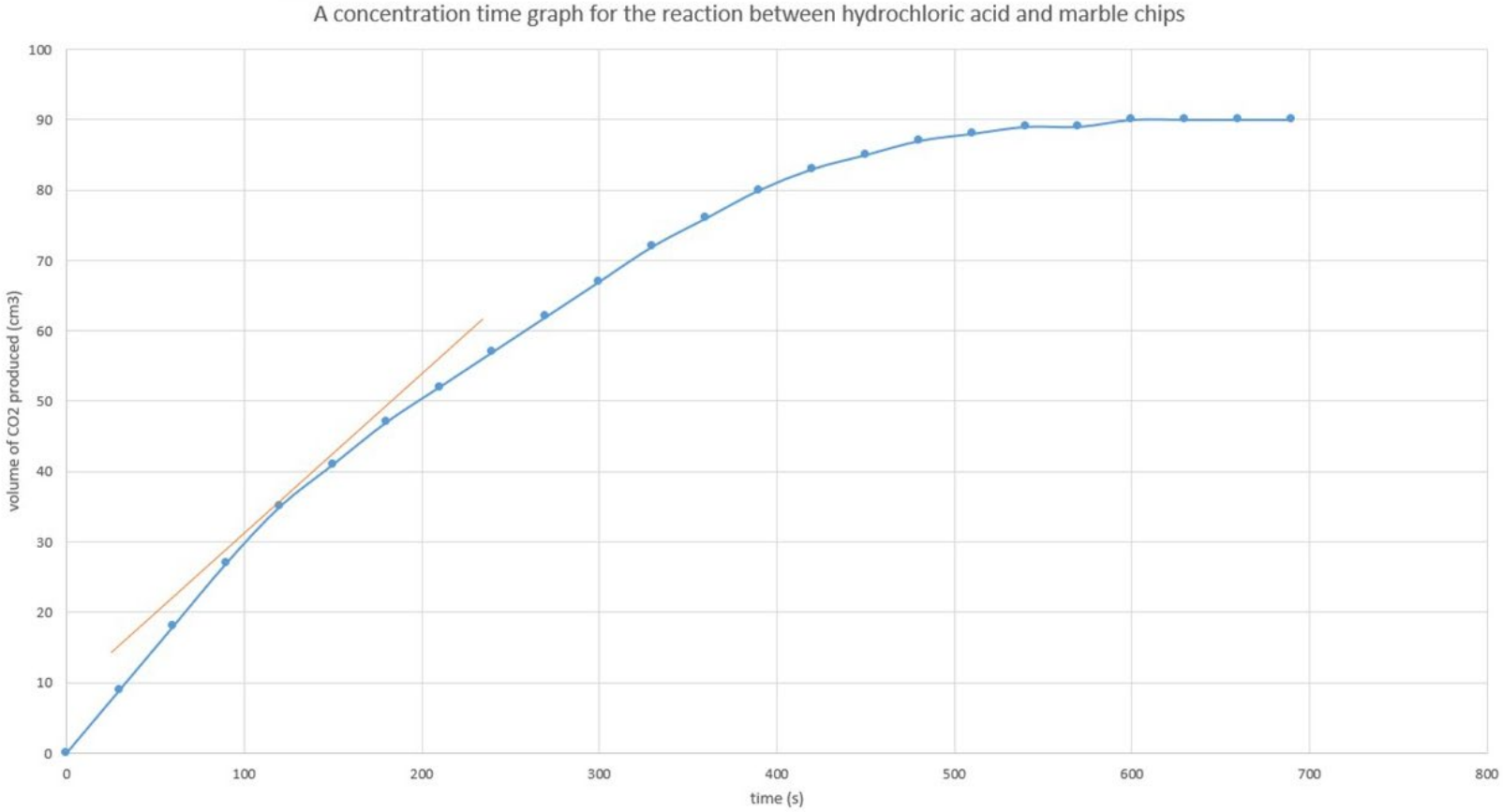
Worksheet E: Interpreting graphs, *continued*

3. Imagine that you performed an experiment, in which you used three different sizes of marble chips (small, medium and large). The total mass of marble chips was the same for all 3 trials. The concentration of hydrochloric acid solution was held constant (2.0 mol dm^{-3}).

   Draw **sketch** graphs below for the results you might obtain. Ensure that you label the axes appropriately and label each sketch graph according to the three sizes of marble chips used. You may colour code each sketch for clarity if you wish.

Worksheet E: Interpreting graphs, *continued*

4. The graph below shows the rate experiment as in question 2, but this time, for only one concentration of hydrochloric acid. A tangent to the line has been drawn at 120s. Calculate the rate of reaction at 120s.



Worksheet A: Answers

Answer the following questions to help you understand, perform and evaluate the main experiment in this skills pack.

1. A volume of gas will be measured in the experiment. Circle which piece(s) of apparatus could not be used for this purpose with reason(s).

$50cm^3$ gas syringe	(50cm³ beaker)	$100cm^3$ measuring cylinder
(25cm³ pipette)	$50cm^3$ burette	

$50cm^3$ beaker: even though a beaker may have graduations, they are approximations only and cannot be used for quantitative work. In addition, an inverted beaker could not be used in the same was as an inverted measuring cylinder. This is because it is very wide and small changes in the volume of a gas could not be measured.

$25cm^3$ pipette: this cannot be used since a pipette can only measure one volume, in this case $25cm^3$. It only has one graduation mark on it.

2. Hydrochloric Acid + calcium carbonate ⟹ calcium chloride + water + carbon dioxide

   For the reaction above:

   i. Write out the balanced equation, including state symbols

   $2HCl_{(aq)} + CaCO_{3(s)} \Longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

   ii. Indicate which substance could be measured using gas collection apparatus.

   The volume of carbon dioxide gas could be measured during the progress of this reaction.

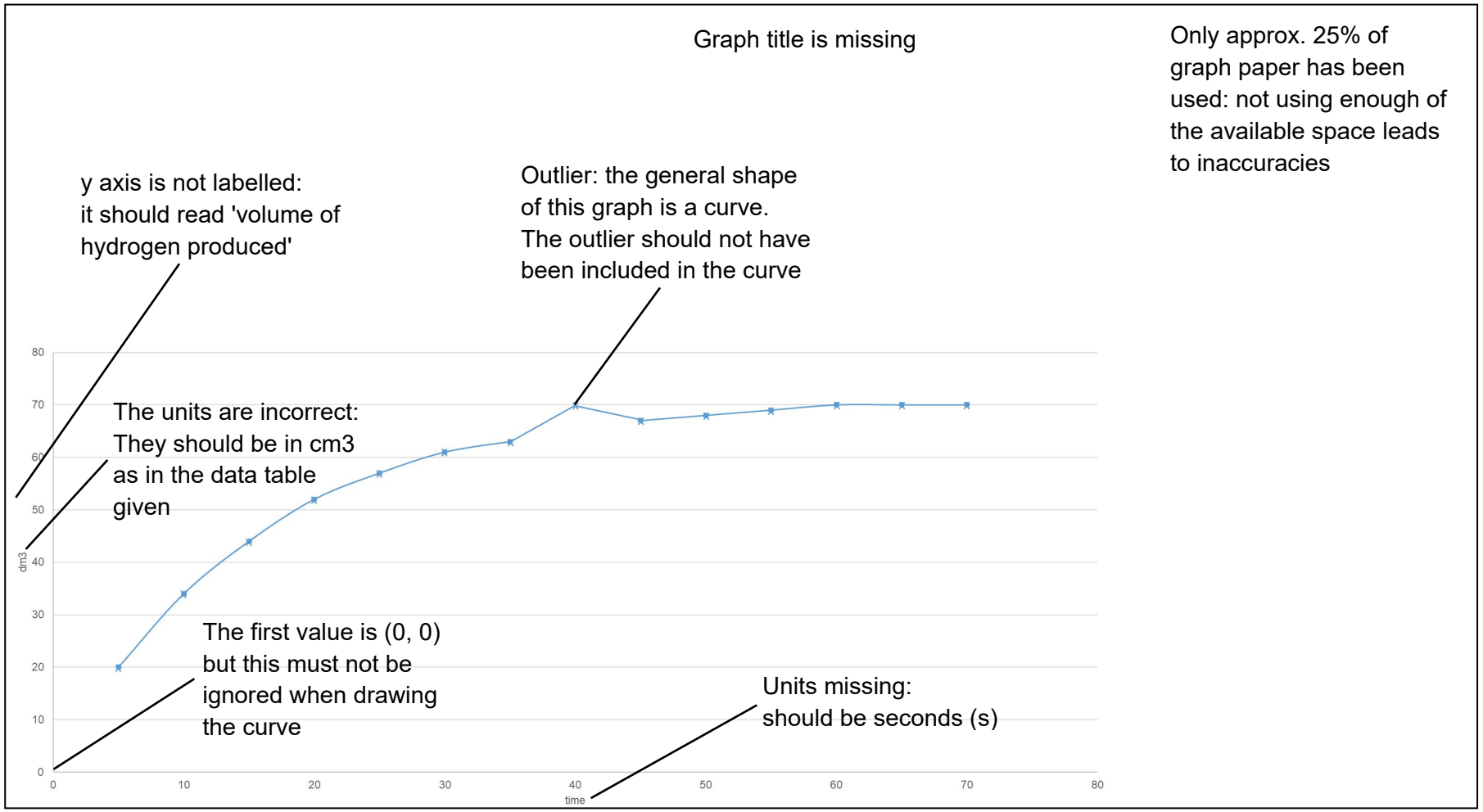
   iii. Make a list of the variables which you could change in this reaction, which might affect the rate of reaction.

   Variables include: concentration of the acid, the size of the particles of calcium carbonate (surface area), temperature, use of a catalyst

Worksheet A: Answers, *continued*

4. A graph was plotted from the data below to show the rate of reaction between zinc powder and dilute nitric acid (see next page).

   Indicate on the graph all the mistakes that you can find. (There are seven).



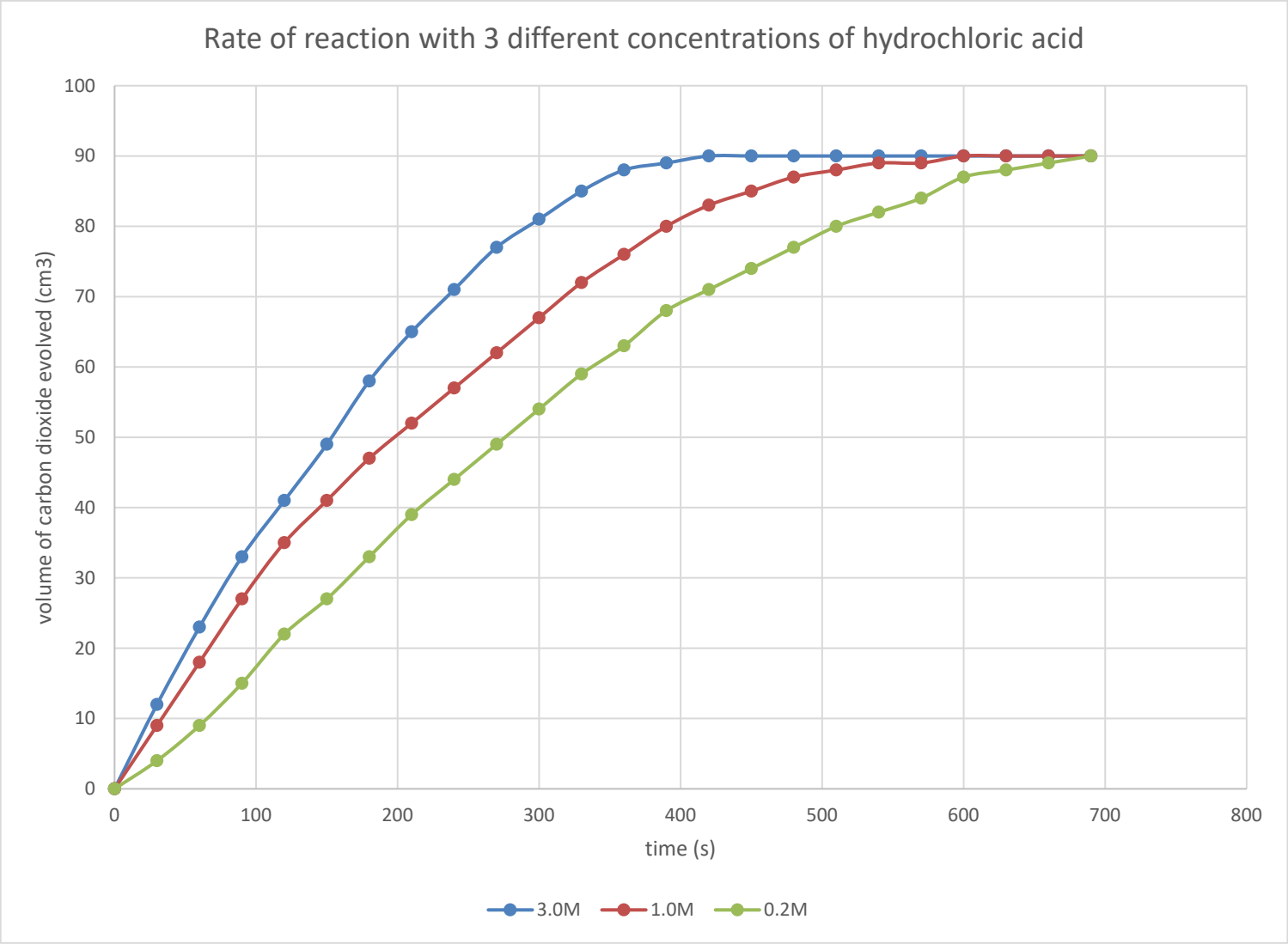
Worksheet E: Answers

1. In terms of the collision theory, explain why increasing the concentration of hydrochloric acid, increases the rate of reaction with marble chips.

A higher concentration of hydrochloric acid means that there are more hydrochloric acid particles available for reaction with the marble chips. Therefore, the collision rate of the acid particles with the marble chips will be greater.

Worksheet E: Answers, *continued*

2. Using the graph answer the following questions.



Worksheet E: Answers, *continued*

i. Why are the graphs for this reaction not a straight line passing through the origin (0,0)?

They are not straight lines because the rate of reaction decreases as the reaction proceeds. This is because there are less reacting particles causing the rate to slow down.

ii. Sketch on your graph, the line you might expect to obtain using 5.0 mol dm^{-3} hydrochloric acid.
The line should start at (0,0), rise more steeply and to the left of the other 3 trials of the experiment. The line will plateau more quickly finishing at 90cm^3. [see graph]

iii.

a. What are the volumes of carbon dioxide produced at t =200s for each of the three trials?

For the 3.0 mol dm^{-3} acid experiment: *62cm^3*

For the 1.0 mol dm^{-3} acid experiment: *50cm^3*

For the 0.2 mol dm^{-3} acid experiment: *36cm^3*

b. What do you conclude from the values obtained in iii.a. above?

These values show that with greater concentrations of hydrochloric acid, larger volumes of carbon dioxide gas are produced more quickly, indicating a greater rate of reaction.

Worksheet E: Answers, *continued*

iv.

a. How long does it take for each trial to produce 30cm^3 carbon dioxide gas?

For the 3.0 mol dm-3 acid experiment: 70s

For the 1.0 mol dm-3 acid experiment: 100s

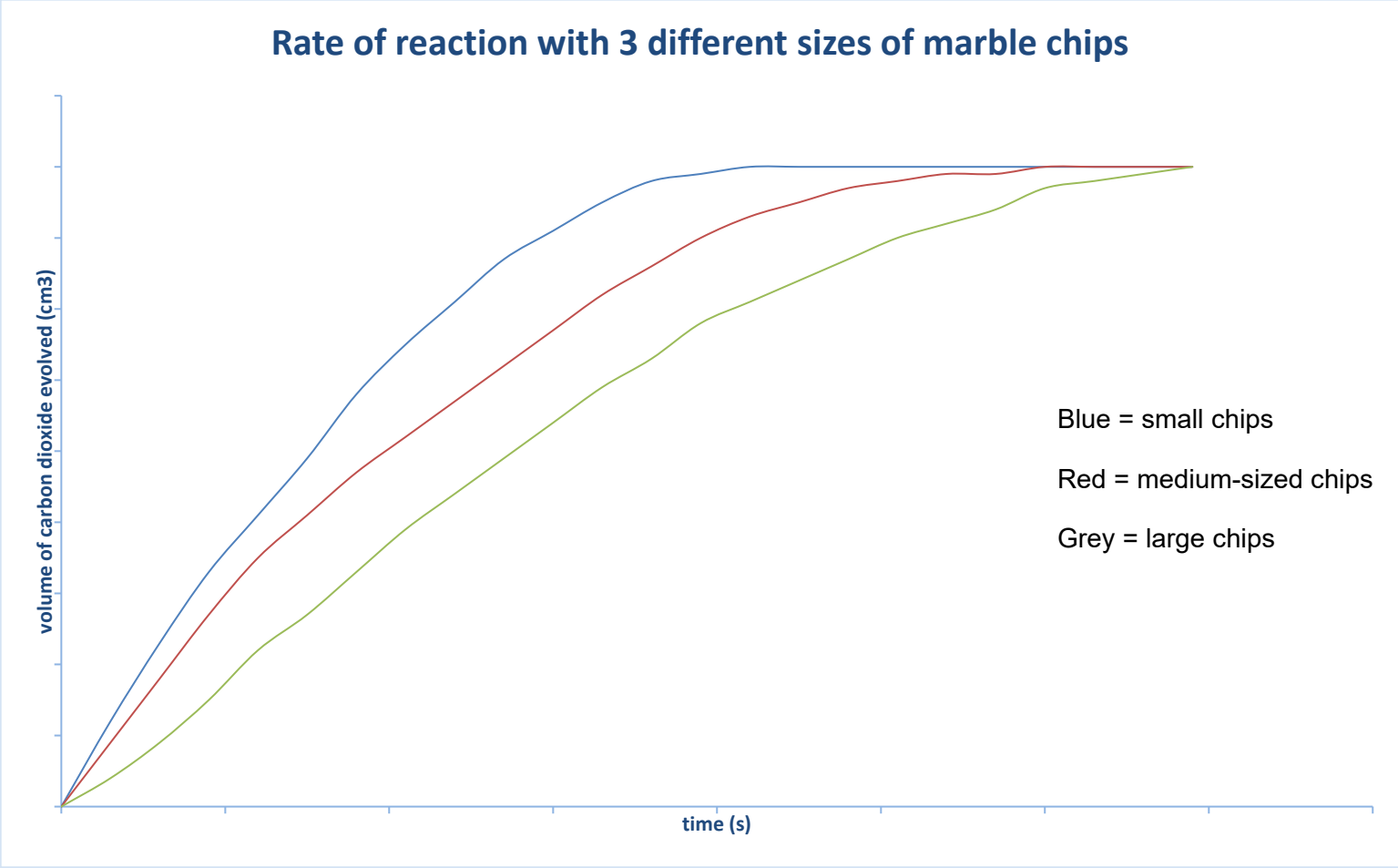
For the 0.2 mol dm-3 acid experiment: 170s

b. What do you conclude from the values obtained in iv.a. above?

These values show that with greater concentrations of hydrochloric acid, a certain volume of carbon dioxide gas is produced more quickly, indicating a greater rate of reaction.

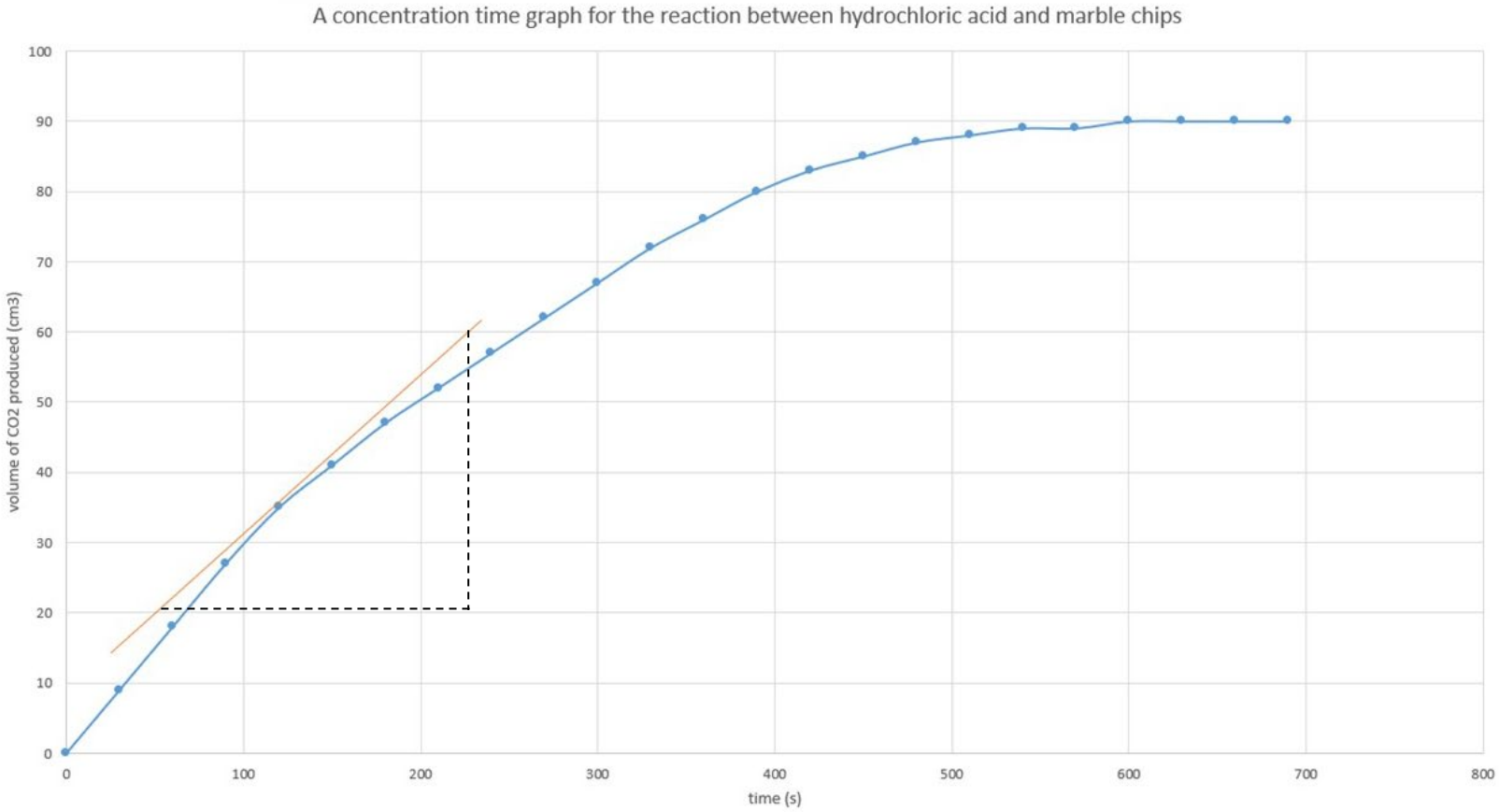
Worksheet E: Answers, *continued*

3. Imagine that you performed an experiment, in which you used three different sizes of marble chips (small, medium and large). The total mass of marble chips was the same for all 3 trials. The concentration of hydrochloric acid solution was held constant (2.0 mol dm^{-3}).
Draw **sketch** graphs below for the results you might obtain. Ensure that you label the axes appropriately and label each sketch graph according to the three sizes of marble chips used. You may colour code each sketch for clarity if you wish.



Worksheet E: Answers, *continued*

4. The graph below shows the rate experiment as in question 2, but this time, for only one concentration of hydrochloric acid. A tangent to the line has been drawn at 120s. Calculate the rate of reaction at 120s.



The rate of reaction = $\frac{\text{change in volume of carbon dioxide evolved } (cm^3)}{\text{Change in time (s)}}$

$= 40cm^3/180s = 0.22cm^3s^{-1}$

Cambridge Assessment International Education
The Triangle Building, Shaftesbury Road, Cambridge, CB2 8EA, United Kingdom
t: +44 1223 553554
e: info@cambridgeinternational.org **www.cambridgeinternational.org**