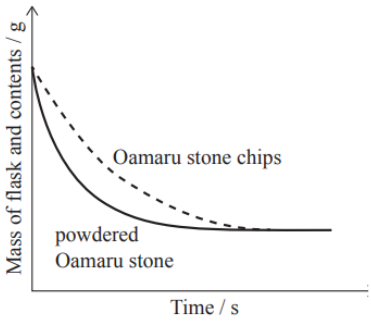
COLLATED QUESTIONS – REACTION RATES

2020:2

Oamaru stone is used as a building material in New Zealand. It is a mixture of calcium carbonate and some unreactive chemicals. 5 g samples of Oamaru stone were each reacted with the same volume of hydrochloric acid.

calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide

One sample was powdered Oamaru stone, the other was chips of Oamaru stone. The same concentration of hydrochloric acid was used for each sample. The total mass of each flask was measured until the mass remained constant, and the results plotted on a graph.



(a) Use collision theory to explain why the rate of reaction at the start of the two reactions is different.

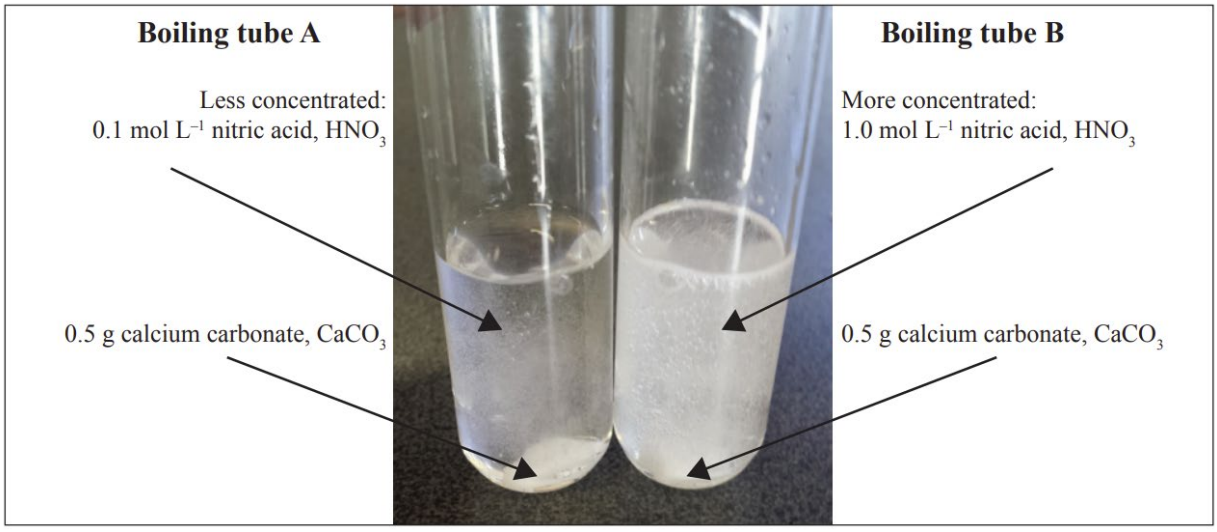
(b) Explain why the final masses of the two flasks were the same.

2020:3

Sulfuric acid is reacted with black copper oxide, CuO, to make blue copper sulfate, $CuSO_4$, solution.

(c) Use collision theory to explain why the reaction happens quicker when warm sulfuric acid is used, rather than cold sulfuric acid.

Two boiling tubes both contain 10 mL of nitric acid, HNO_3. Boiling tube A contains a 0.1 mol L^{-1} solution of nitric acid and boiling tube B contains a more concentrated 1.0 mol L^{-1} solution of nitric acid. A piece of marble chip (calcium carbonate, $CaCO_3$) with a mass of 0.5 g is added to each boiling tube and the reaction is observed and photographed. The temperature of the acid in both boiling tubes is 20°C



(a) Write the word equation AND the balanced symbol equation for the reaction between the nitric acid and calcium carbonate.

(b) Explain the effect of using a higher concentration of nitric acid on the rate of this reaction, compared to using a lower concentration of acid. Your answer should refer to particle collisions.

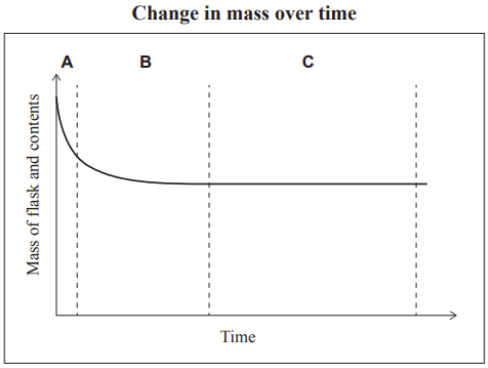
(c) In a second investigation, two different boiling tubes each contain 10 mL of the same concentration 1 mol L^{-1} nitric acid, HNO_3. The nitric acid in boiling tube A is at 20°C and the nitric acid in boiling tube B is at 40°C. A piece of marble chip (calcium carbonate, $CaCO_3$) with a mass of 0.5 g is added to each boiling tube, and the reaction is observed.
Explain the effect of increasing the temperature of the nitric acid from 20°C to 40°C on the rate of reaction. Your answer should refer to particle collisions.

2018:3

Some magnesium carbonate powder is added to dilute nitric acid in an open conical flask. The flask is on an electronic balance, as shown in the illustration.

(a) Write the word equation AND the balanced symbol equation for the reaction between the nitric acid and magnesium carbonate.

The total mass of the flask and its contents is measured over time and recorded on the graph below.



(b) (i) Why does the mass of the flask and its contents decrease during the reaction?

(ii) Explain what is happening in sections A, B, and C of the graph. Link your answer to rates of reaction and particle collisions.

(c) Explain how increasing the temperature will make the reaction between magnesium carbonate and nitric acid faster. Link your answer to rates of reaction and particle collisions.

2017:1

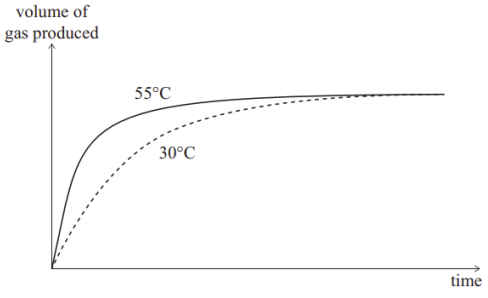
A sample of powdered sodium hydrogen carbonate ($NaHCO_3$) was added to sulfuric acid (H_2SO_4) in a flask, and fizzing was observed. Two experiments were carried out with the acid at different temperatures, using the same amount of powdered sodium hydrogen carbonate and the same concentration and volume of sulfuric acid:

Experiment	Temperature of acid, °C
1	30
2	55

(a) What caused the fizzing?

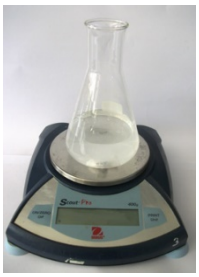
(b) Why was the fizzing fastest immediately after the sodium hydrogen carbonate had been added? Your answer should refer to particle collisions.

(c) The rate of reaction for each experiment was found by measuring the volume of gas produced over time, as shown in the graph.
What is the effect of increasing temperature on the rate of reaction? Your answer should refer to particle collisions and explain why both lines finish at the same point.



(d) Write a word equation AND a balanced symbol equation for the reaction between sodium hydrogen carbonate ($NaHCO_3$) and sulfuric acid (H_2SO_4).

2016:2



A sample of calcium carbonate is added to dilute hydrochloric acid in an open conical flask. The total mass of the flask and contents is measured over time. Three experiments are carried out at 25°C using the same mass of calcium carbonate, and the same volume of acid:

	Calcium carbonate pieces	pH of acid
Experiment 1	Chips	1
Experiment 2	Powdered	1
Experiment 3	Powdered	5

(a) For each of the experiments reacting calcium carbonate and dilute acid together, the mass of the flask and its contents decreases over time. Describe why this happens.

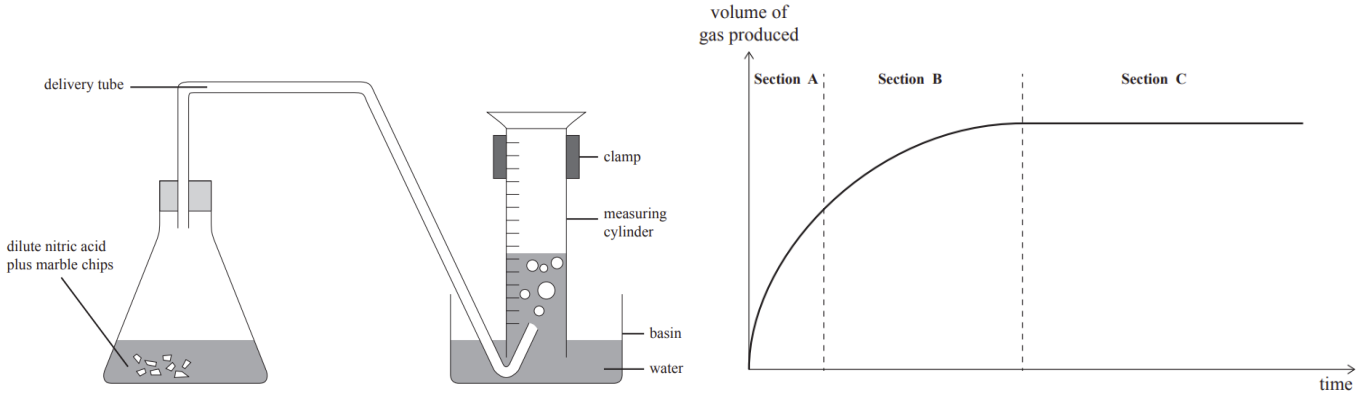
(b) (i) Identify the factor affecting the reaction rate being investigated in Experiments 1 and 2.

(ii) Explain how this factor affects the rate of reaction in the two flasks, with reference to particle collisions. Explain any observations, including changes in mass, over the course of Experiments 1 and 2 until the reactions are finished.

(c) Compare and contrast the rate of reaction of Experiments 2 and 3, with reference to particle collisions and the concentration of hydrogen ions in the solution.

2015:1

Marble chips (calcium carbonate) were added to nitric acid in a conical flask. The temperature of the acid was 50°C. The flask was connected to an inverted measuring cylinder in a basin of water to measure the volume of gas produced, as shown in the diagram below. The graph below shows the volume of gas produced against time.



(a) Explain what is happening in terms of particle collisions and rate of reaction in each section of the graph.

(b) The reaction was carried out again but this time at 20°C. The mass and size of the marble chips, and the concentration and volume of nitric acid used were kept the same.

(i) Draw a line on the graph that represents the reaction at 20°C.

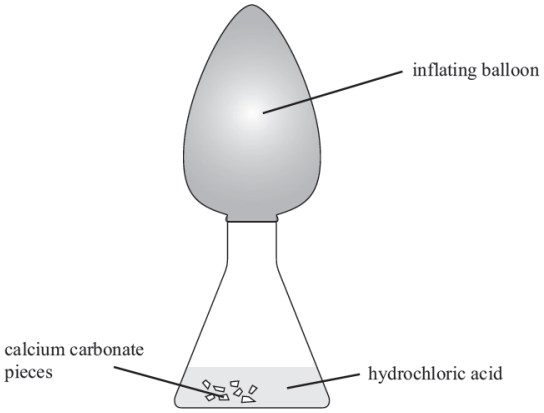
(ii) Explain why you drew this line where you did, and explain if this means that the rate of reaction is slower, the same, or faster. In your answer you should

- discuss why you drew your line with the slope that you did, and why you stopped the line at the point that you did
- explain the effect of temperature on reaction rate, in terms of particle collisions.

(c) Write a word equation AND a balanced symbol equation for the reaction between nitric acid and calcium carbonate.

2014:2 BALLOONS

(a) Calcium carbonate pieces are placed in a flask and hydrochloric acid is added. Immediately a balloon is placed over the top of the flask. The balloon then starts to inflate.



(i) Explain why the balloon inflates.

In a second experiment, the same mass of calcium carbonate in a powdered form is used.

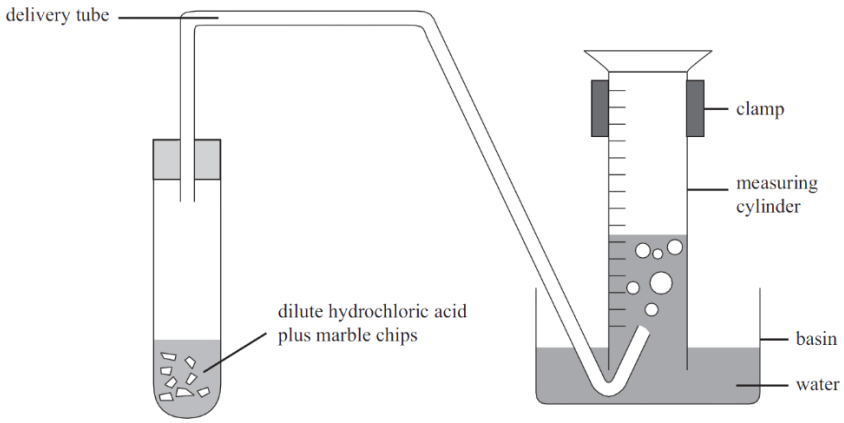
(ii) Explain why the balloon inflates faster when powdered calcium carbonate is used.

(b) Using the same chemical substances (calcium carbonate and hydrochloric acid), discuss a different way to make the balloon inflate faster. In your answer you should refer to rates of reaction and particle collisions.

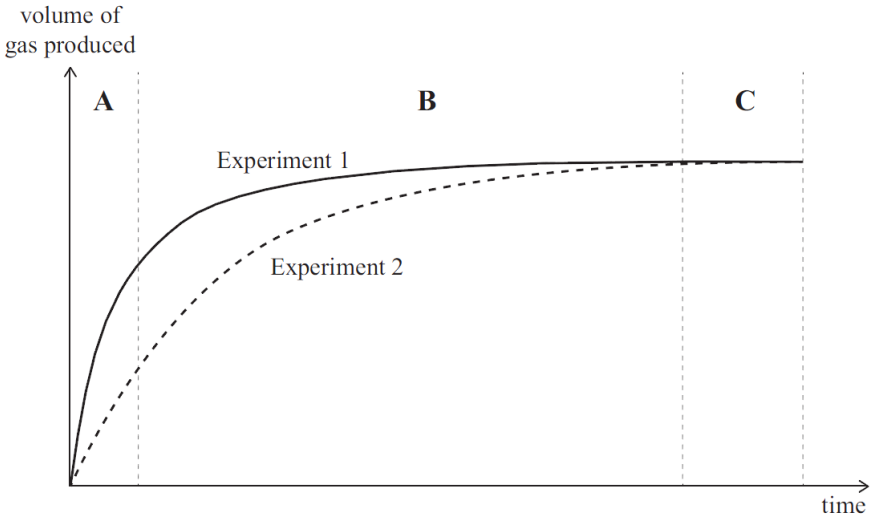
2013:3 REACTION RATES

The table below shows the size of marble chips (calcium carbonate) used in a chemical investigation into factors affecting rate of reaction.

Experiment	Size of marble chips (calcium carbonate)
Experiment 1	small marble chips
Experiment 2	large marble chips



The graph below shows the results for the volume of gas produced over a period of time.



(a) State what factor affecting the rate of reaction is being investigated in this experiment.

(b) Explain what is happening in Experiment 1 in sections A, B, and C of the graph in terms of reaction rate. In your answer you should refer to particle collisions.

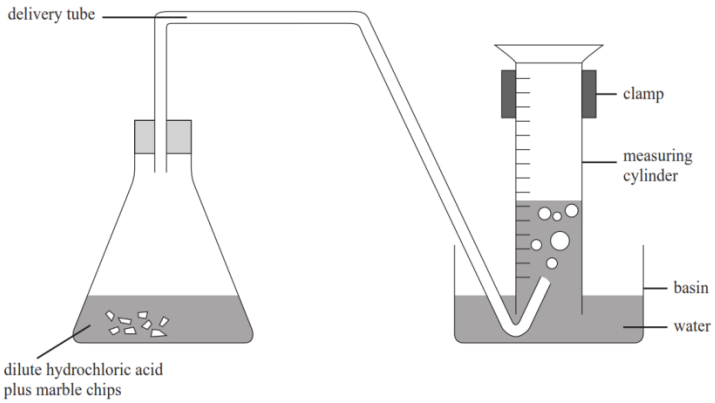
(c) Explain why Experiment 1 was faster than Experiment 2.
In your answer you should:

- explain how the size of the marble chips affects the number of particle collisions.

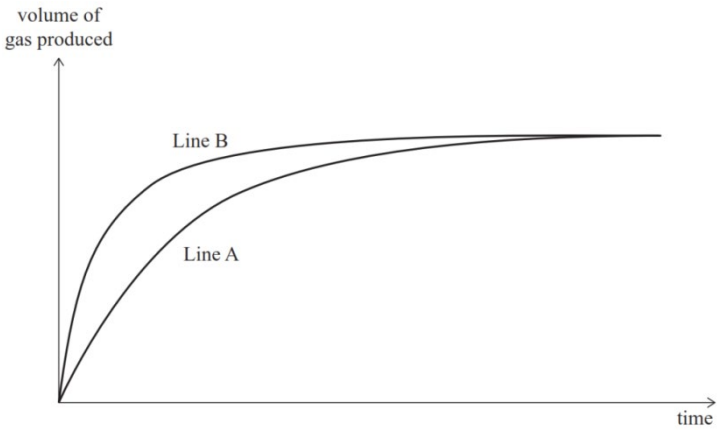
2012:4 REACTION RATES

The following experiment was carried out at 20°C and then repeated at 40°C.

Marble chips (calcium carbonate) were added to hydrochloric acid in a conical flask. The mass and size of marble chips, and the concentration and volume of hydrochloric acid used, were the same for both experiments. The flask was connected to an inverted measuring cylinder in a basin of water, as shown in the diagram below.



The volume of gas produced at the two different temperatures was measured for a few minutes and the results were used to sketch the graph shown below.



State which line on the graph represents the reaction at 40°C and explain how you worked this out.
In your answer you should:

- identify which line represents the reaction at 40°C
- explain why the line you have identified is the reaction at 40°C

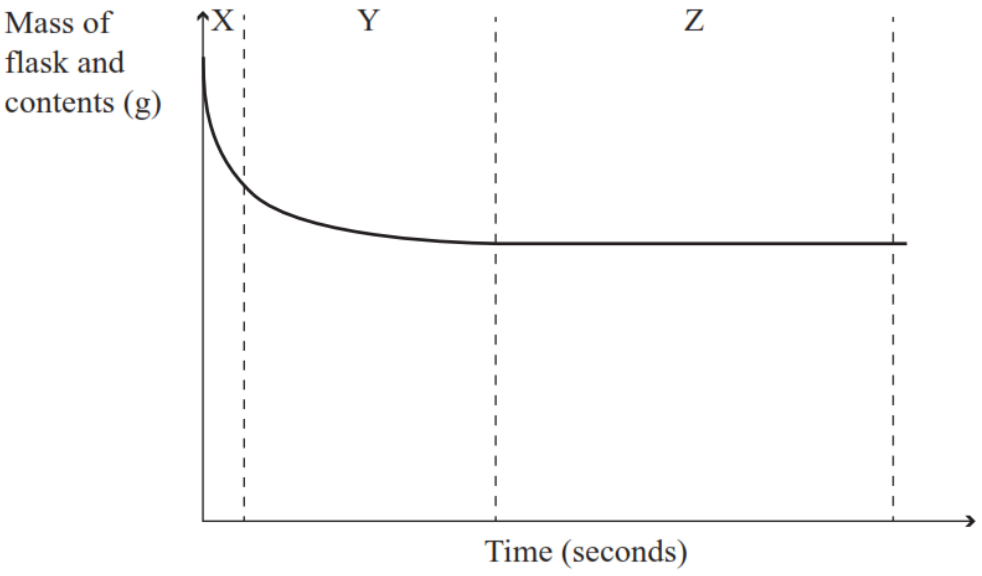
- explain why both lines end up horizontal.

2011:2 RATES OF REACTION

Calcium carbonate (marble chips) and hydrochloric acid react together in a conical flask.
The word equation for this reaction is:

calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide gas

(a) Describe an observation you would make when this reaction occurs.
The mass of the flask and contents is measured on a scale over time and recorded on the graph shown below.



(b) Explain why the mass decreases with time.
In your answer you should:

- consider all the products being formed
- explain what is happening, in terms of particles AND the rate of reaction, in **each** section of the graph.

The mass decreases with time because……

In section X:
In section Y:
In section Z:

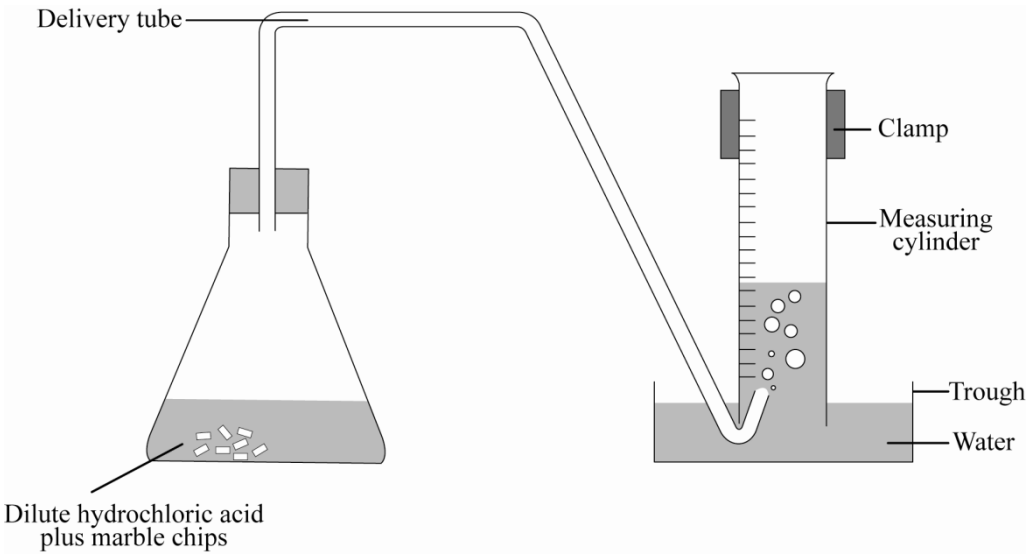
(c) When more concentrated hydrochloric acid is used, the reaction is faster.
Explain the difference in the rate of reaction. In your answer you should refer to:

- particles
- collisions
- reaction rate

2011:4 QUESTION FOUR: RATES OF REACTION (SAMPLE)

Marble chips (calcium carbonate) are added to dilute hydrochloric acid in a conical flask. The flask is connected to an inverted measuring cylinder in a trough of water, as shown in the diagram below.

The volume of gas produced is measured over a few minutes, and the results used to sketch a graph.



(a) The slope of the graph is steep at the beginning and then levels off over time.
Explain what is happening, in terms of particles, during the reaction.

(b) Complete the word and symbol equations below to show the reaction in the experiment.
Word equation:

Balanced symbol equation:

$HCl + CaCO_3 \rightarrow$

(c) The experiment is repeated but this time the same mass of marble chips is crushed into a powder before it is added to the flask.
Discuss the effect on the reaction rate of using powdered marble with hydrochloric acid compared with using marble chips. In your answer, you should:

- compare the rates of reaction
- explain the differences in the reaction rate by discussing how crushing the marble chips affects the number of particle collisions.

COLLATED QUESTIONS – REACTION RATES
ANSWERS

2019:1

(a) Nitric acid + calcium carbonate → calcium nitrate + water + carbon dioxide
$2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

(b) When more concentrated acid is used, there are more acid particles / H^+ ions / nitric acid particles in (the same volume of) the acid. Because of this, there are more particles available to collide with the calcium carbonate particles. Because there are more to collide, more successful collisions occur per second or per unit time, and the rate of reaction is faster.

(c) As the temperature of the nitric acid increases, the particles move faster and have more (kinetic) energy. There are more collisions per second between the acid and the carbonate particles due to higher speed, and more of these collisions have enough energy to cause a reaction. Therefore, increasing the temperature will cause more successful collisions per second, and the reaction will occur faster.

2018:3

(a) Magnesium carbonate + nitric acid → magnesium nitrate + water + carbon dioxide
$MgCO_3 + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2O + CO_2$

(b) (i) One of the products is carbon dioxide gas. The gas escapes, and so the mass of the flask and its contents decreases.

(ii) When reactant particles collide successfully, they form product particles. As the reaction progresses, the number of reactant particles decreases, the frequency of successful collisions decreases, leading to a slower rate of reaction.
Section A: There are more reactant particles, so more collisions per second. More product particles are being formed, including more gas, so more gas escapes and the mass decreases quickly. Section B: There are fewer reactant particles, so fewer successful collisions per second and so less product is being made, so the mass decreases less quickly. Section C: The reaction has stopped as one of the reactants has been used up, so there are no more collisions between reacting particles.

(c) As the temperature of the nitric acid increases, the particles move faster and have more (kinetic) energy. There are more collisions per second between the acid and the carbonate particles due to higher speed, and more of these collisions have enough energy to cause a reaction. Therefore, increasing the temperature will cause more successful collisions per second, and the reaction will occur faster.

2017:1

(a) A gas / carbon dioxide released.

(b) The concentration of reactants is highest at the start of the reaction, i.e. greatest number of reactant particles per unit volume at the start. As a result, there is a higher frequency of successful / effective collisions at the start and therefore a faster rate of reaction than later as reactants run out.

(c) As the temperature increases from 30°C to 55°C, the reactant particles gain kinetic energy, i.e. the average kinetic energy of particles increases. This causes the particles to move more quickly, and therefore increases the frequency of collisions. In addition, more of the collisions are effective / successful because the particles have more energy / force. This leads to a faster rate of reaction. Since the same amounts of each reactant are used at both temperatures, the total volume of gas produced is the same for each temperature, and therefore both lines finish at the same point.

(d) Sodium hydrogen carbonate + sulfuric acid → sodium sulfate + water + carbon dioxide
$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$

2016:2

(a) The mass of the flask and its contents decreases over time because one of the products is carbon dioxide gas. Since the reaction takes place in an open conical flask, the mass of the CO_2 gas is lost to the surroundings.

(b) (i) Surface area.

(ii) The mass of the flask and its contents will decrease faster with the powder (experiment 2) compared to the chunks (experiment 1), and the gas production will be faster. This is because the powder has a larger surface area than the large chips, so more particles of calcium carbonate are exposed for the acid to react with / collide with, and therefore experiment 2 has a higher frequency of successful collisions, and subsequently a faster rate of reaction. Both reactions will get to the same mass, as both have the same amount of reactants and therefore release the same amount of CO_2, but at different rates.

(c) An acid with a pH of 1 has a higher $[H^+]$ than an acid with a pH of 5. Since experiment 2 has more H^+ ions per unit volume / a higher concentration of H^+ ions, it will have a higher frequency of successful collisions (more successful collisions per second) and subsequently a higher / faster rate of reaction.

2015:1

(a) As the reactant particles collide, they form product particles. As the reaction proceeds, there are fewer and fewer reactant particles left to collide, and so the rate of reaction becomes slower. At the start (section A) of the reaction, more product particles are being formed. This is because at the start of the reaction there are many particles present; therefore there will be many collisions, and the more collisions (per unit time), the faster the rate of reaction, and the more gas produced. In section B, there are now fewer (less) reactants, and so there are fewer collisions per second (unit time); therefore a slower rate of reaction and so less product is formed. In section C, the reaction has stopped, as one of the reactants (marble chips or nitric acid) has run out, so there are no particles left to react.

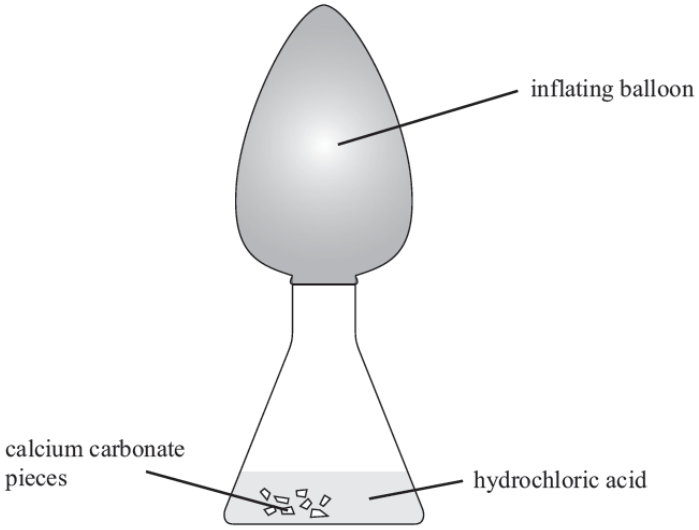
(b) A line is drawn with a less steep gradient but levelling out at the same volume of gas produced. The reaction is slower at the lower temperature, because the particles have less kinetic energy, and therefore are moving slower. When they are moving slower, there will be less frequent collisions, and less of these collisions will be effective, as the particles will collide with less energy. The line drawn represents this slower reaction, as it is less steep at the start. Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, i.e. one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with.

(c) nitric acid + calcium carbonate → calcium nitrate + carbon dioxide + water

$2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

2014: 2 BALLOONS

(b) Calcium carbonate pieces are placed in a flask and hydrochloric acid is added. Immediately a balloon is placed over the top of the flask. The balloon then starts to inflate.



(i) Explain why the balloon inflates.

When a metal carbonate reacts with an acid, carbon dioxide gas is released. This gas causes the balloon to inflate.

In a second experiment, the same mass of calcium carbonate in a powdered form is used.

(ii) Explain why the balloon inflates faster when powdered calcium carbonate is used.

It is faster when powder is used, because the surface area of the powder is greater. Because there is more surface area, there is more surface (exposed calcium carbonate particles) with which the HCl particles can collide. Because more collisions occur more frequently, the rate is faster, and CO_2 will be generated more quickly.

(b) Using the same chemical substances (calcium carbonate and hydrochloric acid), discuss a different way to make the balloon inflate faster. In your answer you should refer to rates of reaction and particle collisions.

One way of making the reaction occur faster is to increase the concentration of the acid used. When this happens there are more HCl particles in the same volume of acid, and therefore there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO_2 is produced more rapidly, and the balloon inflates faster.

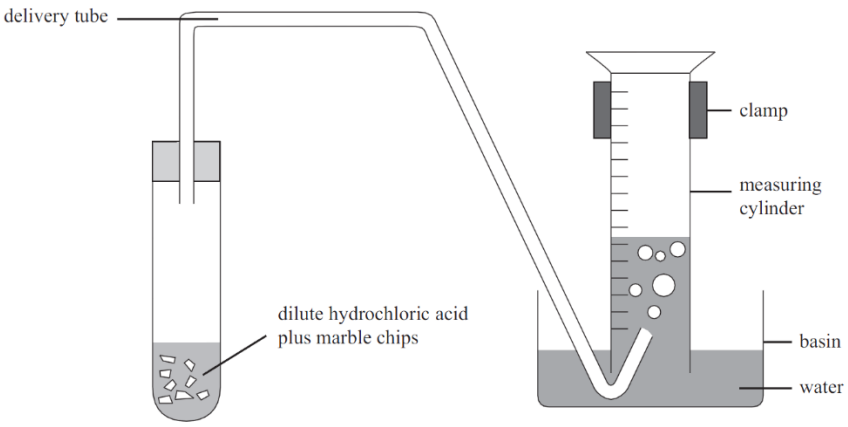
OR

The other way is to increase the temperature of the acid. When this happens, the HCl particles move faster; because they are moving faster, there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO_2 is produced more rapidly, and the balloon inflates faster.

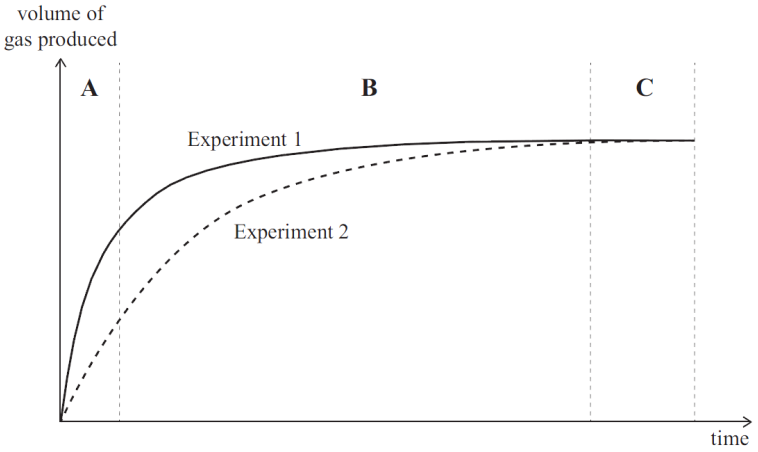
2013:3 REACTION RATES

The table below shows the size of marble chips (calcium carbonate) used in a chemical investigation into factors affecting rate of reaction.

Experiment	Size of marble chips (calcium carbonate)
Experiment 1	small marble chips
Experiment 2	large marble chips



The graph below shows the results for the volume of gas produced over a period of time.



(a) State what factor affecting the rate of reaction is being investigated in this experiment.

The factor being investigated is surface area of the calcium carbonate / marble chips.

(b) Explain what is happening in Experiment 1 in sections A, B, and C of the graph in terms of reaction rate. In your answer you should refer to particle collisions.

In section A of the graph the rate is fastest as there are more collisions between the HCl and $CaCO_3$. This is because at the start of the reaction there are more particles available for collision. In section B the rate of reaction is slowing down as the number of particles available for collision is becoming fewer as some of the HCl and $CaCO_3$ have already collided and have been used up, therefore fewer particles and therefore fewer collisions.

In part C the reaction has stopped, as all of the reactants (or one of them) have reacted, and therefore there are no particles present that can collide and react.

(c) Explain why Experiment 1 was faster than Experiment 2.

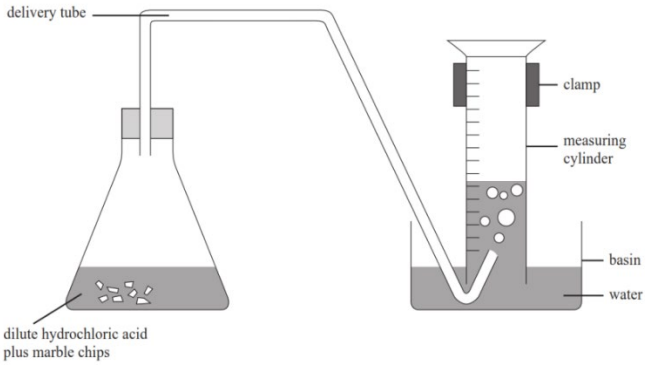
In your answer you should:

- explain how the graph shows that Experiment 1 is faster
- explain how the size of the marble chips affects the number of particle collisions.

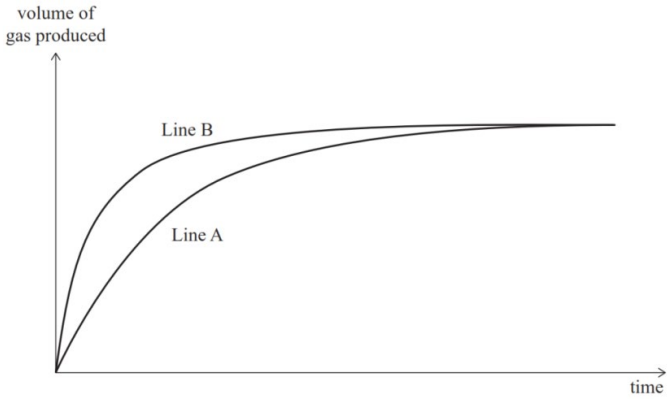
The rate of Experiment 1 is faster as the slope in section A of the graph is steeper than in Experiment 2. It is faster because when smaller chips are used, the surface area of the chips is greater. Because there is more surface area, there is more surface for the HCl particles to collide. Because there are more collisions occurring more frequently, the rate is faster.

2012:4 REACTION RATES

The following experiment was carried out at 20°C and then repeated at 40°C.
Marble chips (calcium carbonate) were added to hydrochloric acid in a conical flask. The mass and size of marble chips, and the concentration and volume of hydrochloric acid used, were the same for both experiments. The flask was connected to an inverted measuring cylinder in a basin of water, as shown in the diagram below.



The volume of gas produced at the two different temperatures was measured for a few minutes and the results were used to sketch the graph shown below.



State which line on the graph represents the reaction at 40°C and explain how you worked this out.
In your answer you should:

- identify which line represents the reaction at 40°C
- explain why the line you have identified is the reaction at 40°C
- give reasons for the different rates of reaction in terms of particles
- explain why both lines end up horizontal.

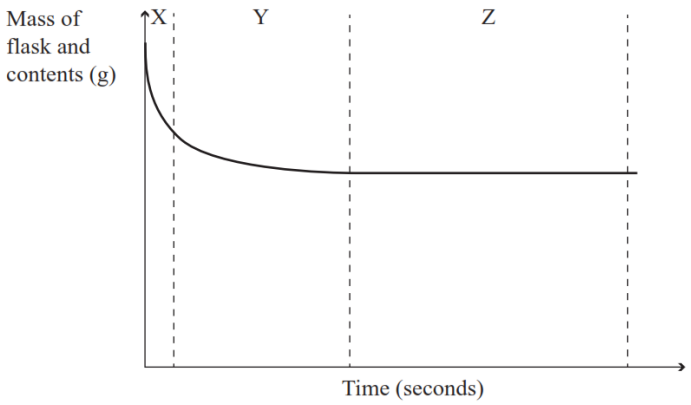
The reaction is faster at the higher temperature because the H+ ions have more kinetic energy, and therefore are moving faster. When they are moving faster, there will be more collisions, and more of these collisions will be effective, as the particles will collide with more energy.
Line B represents the faster reaction, as it is steeper at the start. This represents the reaction carried out at 40°C.
Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, i.e. one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with.

2011:2 RATES OF REACTION

Calcium carbonate (marble chips) and hydrochloric acid react together in a conical flask.
The word equation for this reaction is:

calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide gas

(a) Describe an observation you would make when this reaction occurs.
The mass of the flask and contents is measured on a scale over time and recorded on the graph shown below.



Fizzing / bubbling occurs, marble chips decrease in size.

(b) Explain why the mass decreases with time.
In your answer you should:

- consider all the products being formed
- explain what is happening, in terms of particles AND the rate of reaction, in **each** section of the graph.

The mass decreases with time because……

In section X:
In section Y:
In section Z:

The marble chips decreases as one of the products is CO_2 gas. This gas escapes and so the mass of the flask and contents is reduced.

What's happening

As the reactant particles collide, they form product particles. As the reaction proceeds, there are fewer and fewer reactant particles left to collide and so the rate of reaction becomes slower.
At the start (section X) of the reaction, more product particles are being formed, then more gas is being formed, therefore more gas escapes at first and so the mass of the flask and contents decreases more rapidly. At X, the rate of reaction is fast but decreasing with time.
In section Y there are now fewer (less) reactants and so there are fewer collisions per second (unit time) and so less product is formed, ie less gas being released, so the mass does not decrease as rapidly. At Y, the rate of reaction is slow and slowing.
In section Z the reaction has stopped, as one of the reactants (marble chips or HCl) has run out, so there are no particles left to react.

(c) When more concentrated hydrochloric acid is used, the reaction is faster.

Explain the difference in the rate of reaction. In your answer you should refer to:

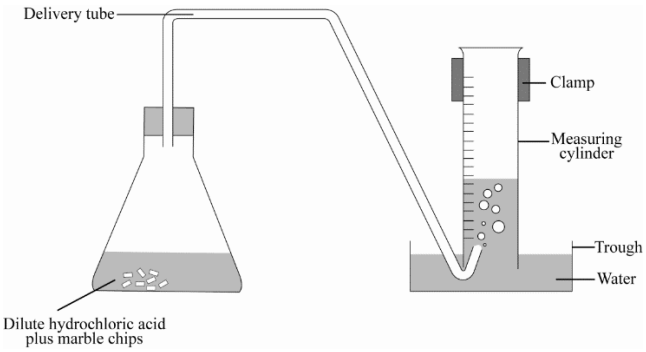
- particles
- collisions
- reaction rate

When more concentrated acid is used, there are more acid particles in the same volume of the acid. Because of this, there are more particles to collide with the calcium carbonate. Because there are more to collide, the rate of reaction is faster (as more collisions/ unit time).

2011:4 QUESTION FOUR: RATES OF REACTION (SAMPLE)

Marble chips (calcium carbonate) are added to dilute hydrochloric acid in a conical flask. The flask is connected to an inverted measuring cylinder in a trough of water, as shown in the diagram below.

The volume of gas produced is measured over a few minutes, and the results used to sketch a graph.



(d) The slope of the graph is steep at the beginning and then levels off over time.
Explain what is happening, in terms of particles, during the reaction.

Explanation of leveling of graph:
As the reactant particles collide, they are converted into product particles. Initially many gas molecules are produced, but as the reaction proceeds there are fewer and fewer reactant particles available to collide, so the volume of gas produced decreases and eventually no gas is produced.
(Most likely the supply of H+ ions in the solution will be exhausted before the marble chips disappear.)

(e) Complete the word and symbol equations below to show the reaction in the experiment.
Word equation:

Hydrochloric acid + calcium carbonate →

Hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

Balanced symbol equation:

$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

(f) The experiment is repeated but this time the same **mass** of marble chips is crushed into a **powder** before it is added to the flask.

Discuss the effect on the reaction rate of using powdered marble with hydrochloric acid compared with using marble chips. In your answer, you should:

- compare the rates of reaction
- explain the differences in the reaction rate by discussing how crushing the marble chips affects the number of particle collisions.

Comparison of rates of reaction:
The reaction rate will be faster with the powdered marble than when the chips were used. More gas will be produced each minute. The reaction itself will be completed in a shorter period of time.
Explanation of effect:
There are more reactant particles immediately available to react because the surface area of the powder is greater than that of the chip. There is greater exposure of the marble particles so there are more available for the acid particles / hydrogen ions / H^+ ions to collide with.
This means there will be more (effective) collisions per second / more frequent collisions between the acid particles and the ions in the calcium carbonate powder, leading to an increase in the rate of the reaction and the reaction will be completed sooner.