5.3 Rates of chemical reactions

Explosions are combustion reactions that occur in a fraction of a second. In contrast, the corrosion reaction that rusts a shipwreck may take years. Being able to control how fast chemical reactions occur is of great use in industry, medicine, at home and in science laboratories. Scientists can slow down unwanted reactions and speed up useful reactions for our benefit.

Fast and slow chemical reactions

The speed at which a chemical reaction proceeds is known as the **rate of reaction**. Some chemical reactions that proceed quickly are explosions and combustion reactions (Figure 5.3.1), when vinegar is mixed with bicarbonate of soda and the burning of gas in a Bunsen burner. These reactions are said to have a fast rate of reaction. Chemical reactions that proceed slowly are said to have a slow rate of reaction. Rusting, ripening and the fermentation of wine (Figure 5.3.2) are examples.

Figure 5.3.1 Welders use the rapid combustion of acetylene to produce the extremely hot flame required to weld and cut metals.

Figure 5.3.2 The slow chemical reactions that ferment wine and give it its flavour mean that it can take years before the wine is ready to drink.

Controlling the rate of chemical reactions

The rate of almost every reaction can be increased or decreased. For example, when you run a race and then breathe deeply, your heart pumps faster to speed up the rate of respiration. In contrast, the rate of respiration slows down when you're calm and relaxed. Scientists examine how each chemical reaction works to determine the best method for controlling its rate of reaction.

Factors that affect the rate of reaction are:

- temperature
- concentration of the reactants
- surface area (if the reactants are in lumps or fine powder)
- agitation (mixing and stirring)
- catalysts (chemical helpers).

By changing these variables, scientists can control how fast or slow a chemical reaction proceeds.

Temperature

Increasing the temperature will normally increase the rate of a chemical reaction. This occurs for two reasons.

First, increasing the temperature increases the speed of the particles in liquids and gases. As a result, particles collide more frequently, so more chemical reactions occur in a shorter amount of time.

Second, increasing the temperature gives the particles more energy. So, when the molecules collide, chemical bonds are more likely to break and the atoms in the reactants can rearrange more easily to form products.

1 p169

There are many reasons for using heat to increase the rate of a reaction. When you bake a batch of biscuits, you place it in the oven to increase the rate of chemical reactions that convert your dough into biscuits. However, you can't increase the temperature too much or the rate of reaction will be so fast that the biscuits will burn before they are cooked all the way through. This is what has happened in Figure 5.3.3.

Figure 5.3.3 Biscuits must be baked at the right temperature. If the temperature is too high, the reaction is so fast that they burn before they are cooked inside.

Sometimes you may want to decrease the rate of reaction by lowering the temperature. When you place a carton of milk in the fridge, it slows the rate of the chemical reaction that turns milk sour. Similarly, fruit farmers will transport their produce in refrigerated trucks to stop the fruit ripening before it gets to market.

SciFile

Putting life on hold

Through the process of in-vitro fertilisation (IVF), human egg cells can be fertilised and frozen for later use. Freezing the eggs stops the chemical reactions that cause the embryo to develop. Today, one in 33 births in Australia is the result of IVF. That's almost one in every classroom.

Figure 5.3.4 Frozen human eggs

Concentration

The term **concentration** refers to the amount of reactants present in a particular volume of liquid or gas during the reaction. For example, if you put 20 teaspoons of sugar in a litre of water, then the concentration of sugar is high. The solution is concentrated. However, if you put 1 teaspoon of sugar in a litre of water, then the concentration of sugar is low. The solution is dilute. Concentrated and dilute solutions are shown in Figure 5.3.5.

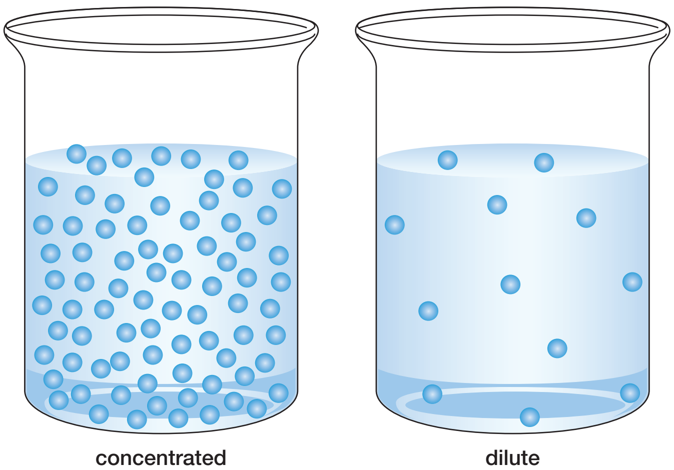

Figure 5.3.5 A concentrated solution has a large number of sugar molecules in the beaker of water. A dilute solution has very few sugar molecules in the same volume.

Increasing the concentration of the reactants will increase the rate of reaction. This is because the particles are more likely to collide and react when they are highly concentrated. Collisions between particles are necessary to allow the bonds to break and new bonds to form.

Increasing the concentration of reactants is a very common way of increasing the rate of reaction. You concentrate the reactants whenever you turn up the gas knob on a heater or stove like in Figure 5.3.6, add more wood to a fire, add more sugar to a breadmaker or drink 20 mL instead of 10 mL of antacid to relieve heartburn.

2 p170

Figure 5.3.6 When you increase the flow of gas on a gas stove, you increase the concentration of reactants to produce a bigger flame and more heat.

It is also common to reduce the concentration of reactants in order to slow the rate of some reactions. When you place food in a zip-lock bag or air-tight container, you are limiting the concentration of oxygen and therefore limiting how quickly the food can go stale. A similar principle is used to protect some iron structures from rusting. Iron is often coated with paint to limit the amount of oxygen that can react with the surface to form iron(II) oxide (rust).

Agitation

Stirring reactants can also increase the rate of reaction. Stirring is known scientifically as **agitation**. Agitation ensures that the reactants are kept in contact, by removing build-up of products around the reactants. For example, if a solid piece of calcium carbonate is dropped into the bottom of a beaker of sulfuric acid, it will react with the acid to produce calcium sulfate, water and carbon dioxide gas. The word equation for this reaction is:

calcium carbonate + sulfuric acid → calcium sulfate + water + carbon dioxide

and the formula equation is:

$$CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4(aq) + H_2O(l) + CO_2(g)$$

Although the carbon dioxide bubbles off as a gas, the other products—calcium sulfate and water—build up around the calcium carbonate as shown in Figure 5.3.7. The products surround the calcium carbonate, which means less sulfuric acid contacts the calcium carbonate to react. Agitating the reaction flushes the products away from the calcium carbonate, and allows the sulfuric acid to attack the surface of the calcium carbonate. Magnetic stirrers (Figure 5.3.8) are used in the laboratory to constantly agitate reactions and ensure the maximum rate of reaction.

3 p171

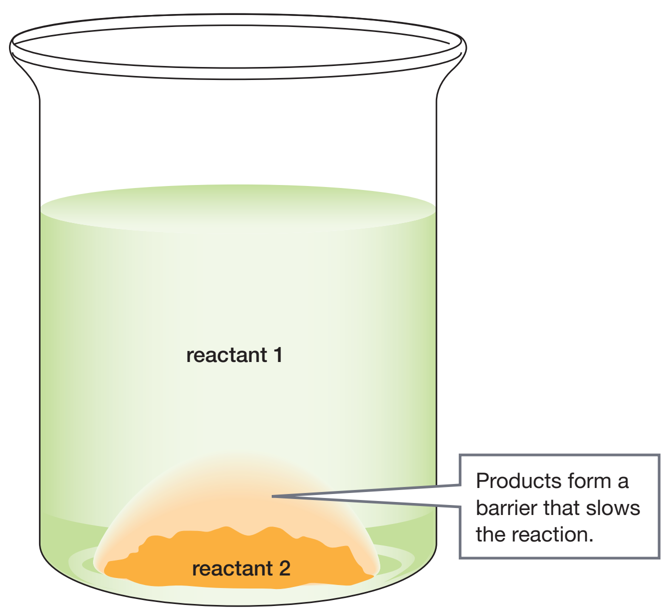

Figure 5.3.7 When a solid reacts with a liquid, the products build up around the solid, slowing down the rate of reaction. Agitation removes the build-up of products to maximise the rate of reaction.

Figure 5.3.8 In the laboratory, scientists use magnetic stirrers to constantly agitate and ensure maximum rate of reaction.

Surface area of reactants

The rate of reaction between calcium carbonate and sulfuric acid can be increased further if the calcium carbonate is crushed into a powder rather than used as one solid piece. If the calcium carbonate is placed in the acid as a single, solid lump, the sulfuric acid can only react with the outside of the lump, as shown in Figure 5.3.9. However, if the lump is broken down into smaller pieces, then particles originally on the inside of the lump are now exposed and can react with the acid. This means more particles are reacting at the same time, so the reaction is faster. Dividing up solid reactants into smaller pieces creates a much larger surface in contact between the reactants.

Having a large surface area is important in the delivery of medicines in the form of capsules. The capsules contain powdered medicines so that when the capsule breaks apart in your stomach, the powdered medicines can be absorbed into your bloodstream more quickly.

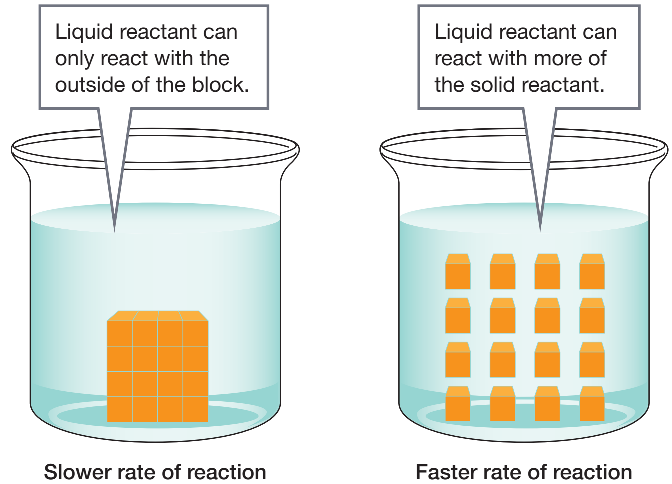

Figure 5.3.9 If the solid reactant is divided into smaller pieces, more of the solid is exposed to the liquid reactant and the rate of reaction is increased.

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5.6

Catalysts

Catalysts are chemicals that speed up reactions but are not consumed (used up) during the reaction. They can be considered 'chemical helpers' that help the reactants to form the products. Catalysts can do this in two ways:

- They reduce the amount of energy that is required to convert the reactants into products
- They make it easier for reactant molecules to collide and form products.

For example, a catalytic converter in a car exhaust system uses platinum metal as a catalyst to help convert the poisonous gas carbon monoxide (CO) into the less toxic carbon dioxide (CO_2). Normally, carbon monoxide and oxygen would not react fast enough to form carbon dioxide (Figure 5.3.10).

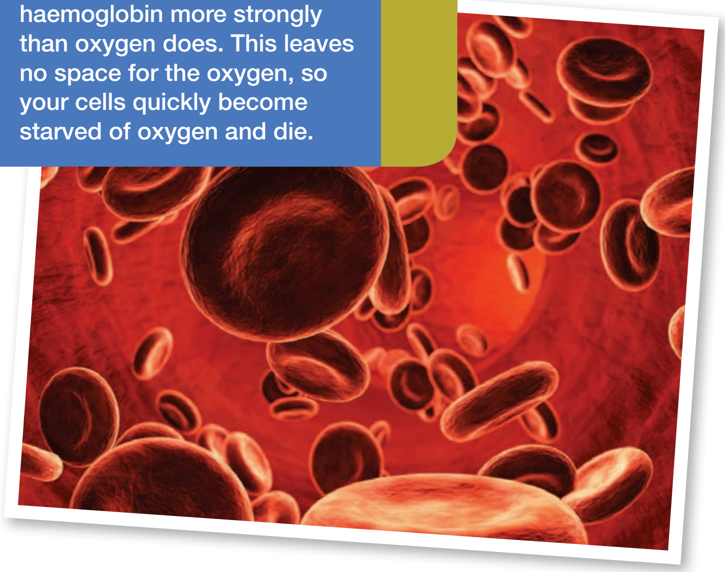
Figure 5.3.10 Catalytic converters in car exhaust systems prevent toxic chemicals from being released into the environment.

However, in a catalytic converter the carbon monoxide and oxygen molecules both stick to the platinum catalyst and move around on its surface. When they finally collide, the platinum helps the reactant molecules to rearrange and form carbon dioxide, which then leaves the surface of the platinum and is flushed out via the exhaust. Catalytic converters also remove some dangerous nitrogen oxides.

SciFile

Carbon monoxide poisoning

Carbon monoxide is a colourless, odourless gas that is produced when petrol is burnt in a limited supply of oxygen. Haemoglobin is the molecule in red blood cells that transports oxygen around your body. However, carbon monoxide binds to haemoglobin more strongly than oxygen does. This leaves no space for the oxygen, so your cells quickly become starved of oxygen and die.



Enzymes

Enzymes are biological catalysts. Enzymes are natural molecules that hold reactant molecules together until they rearrange to form products. Many enzymes are at work in your body right now. One of the first processes of digestion uses an enzyme called amylase, which is found in your saliva (Figure 5.3.11). Similar enzymes are secreted by your pancreas and small intestine. Amylase is responsible for breaking down the starches in complex carbohydrates, such as in breads and potatoes, into simple sugars for easy absorption into the body.

5.7

Figure 5.3.11 Saliva uses the enzyme amylase to break down starches into simple sugars.

INQUIRY science 4 fun

Jellied enzymes

How do the enzymes in pineapple affect jelly?

Yes

Collect this …

- jelly powder
- water
- fresh pineapple
- apple
- banana
- 4 small containers to set the jelly
- kettle
- refrigerator

Do this …

1. Cut up the fruit into small pieces, about 1–2 cm cubes.
2. Dissolve the jelly in hot water according to the instructions on the packet.
3. Divide the jelly mix evenly between the four small containers.
4. Allow the jelly to cool in the fridge for a few hours, but not set. Place the pineapple in one container of jelly, the apple in the second and the banana in the third. Don't put any fruit in the fourth.
5. Place the containers in the refrigerator and wait for them to set.

Record this …

Describe what you observed.
Explain why you think this happened.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Enzymes for fuels and pharmaceuticals

Figure 5.3.12 The enzymes in yeast cells like this one may hold the key to producing renewable biofuels.

Enzymes are natural catalysts that control biological processes such as digestion, respiration and photosynthesis. Scientists are constantly finding new ways to apply enzymes in industrial processes, such as the production of renewable, environmentally friendly fuels and the development of new pharmaceutical drugs.

Biofuels

As the world's fossil fuel resources start to run out, scientists around the world are looking for alternative fuels and resources. Biofuels are a new type of fuel that promises to be a renewable resource. The biofuel can be manufactured by fermenting the sugars in crops such as sugar cane, potato and corn. The fermentation process uses enzymes in microorganisms such as yeast to convert the sugars into ethanol according to the reaction:

glucose + enzyme → ethanol + carbon dioxide

$C_6H_{12}O_6$ + zymase → $2C_2H_6O$ + $2CO_2$

Figure 5.3.13 This is one of a new generation of vehicles that use biofuels.

Ethanol is found in alcoholic drinks, but also makes up to 25% of the petrol used in cars around the world.

Pharmaceuticals

The field of medicine has also benefited greatly from scientists' deeper understanding of enzymes. One of the most revolutionary discoveries has been the synthesis of penicillin, which is the world's most widely used antibiotic and has saved countless lives.

The process for producing penicillin involves the use of two different enzymes to combine three different biochemicals into the wonder drug. These enzymes occur naturally in the *Penicillium* fungi, in which the drug was first discovered by Scottish scientist Alexander Fleming in 1928. However, it was Australian scientist Howard Florey (Figure 5.3.14) and his colleagues Ernest Chain and Norman Heatley who discovered how to produce large quantities of the drug in the laboratory. Their discoveries earned Florey, Fleming and Chain a Nobel Prize in 1945.

Figure 5.3.14 In 1945, Howard Florey won Australia's second ever Nobel Prize for his work on the mass production of penicillin.

5.3 Unit review

Remembering

1 **List** three examples each of fast and slow reactions.

2 **State** the five ways that the rate of reaction can be controlled.

3 **State** the name given to chemicals that speed up a chemical reaction but are not used up during the chemical reaction.

Understanding

4 **Define** the term *rate of reaction*.

5 **Explain** why you need to choose the right temperature when baking a cake.

6 Scientists use magnetic stirrers to maximise the rate of reaction. **Explain** how continually stirring the reaction helps to make it go faster.

7 **Explain** how a catalyst increases the rate of reaction.

8 **Explain** why particles must collide before they can react.

Applying

9 a **Identify** two examples of reactions at home that you speed up.

b **Identify** two examples of reactions at home that you slow down.

c For each case, **describe** what you do to change the rate.

10 To remove a stain faster, Jenny applies more stain remover. **Identify** which of the methods of increasing the rate of reaction Jenny is using.

11 The advice on headache tablet boxes is that adults can take two, but a child should only take one. **Identify** a factor affecting reaction rate that is relevant to this advice.

Analysing

12 **Distinguish** between the terms *chemical change* and *chemical reaction*.

13 **Discuss** two other examples where the word *rate* is used in everyday life. Assess what this word means in each context.

14 **Compare** the similarities in how increasing agitation and increasing the surface area of reactants increase the rate of a reaction.

Evaluating

15 **Propose** the effect of the following changes on a wood fire heater. **Justify** your predictions.

a The wood is chopped into smaller pieces.

b The vent is closed so that less air can get in.

16 Athletes use altitude training to increase their numbers of red blood cells and hence the concentration of oxygen in their bloodstream. **Propose** how this might help them during a race.

Creating

17 **Construct** a labelled diagram showing how the concentration of hydrochloric acid increases the rate that it reacts with a block of calcium carbonate.

Inquiring

1 Research metabolism to answer the following questions.

a What is metabolism and what is meant by your *metabolic rate*?

b How can you change your metabolic rate?

c How does metabolic rate change as you get older?

2 Investigate metabolism in ectothermic (cold-blooded) and endothermic (warm-blooded) animals and how the rate of metabolism is controlled in each case.

3 Research the role of enzymes in digestion. Write a paragraph about their role in digestion and the types of enzymes that exist.

4 Design an experiment to investigate the effect of temperature on the rate of reaction between calcium carbonate and hydrochloric acid.

5.3 Practical activities

1 Rate of reaction: The effect of temperature

Purpose

To determine how temperature affects the light intensity of light sticks.

Materials

- 2 light sticks
- 2 beakers
- iced water
- hot water

Procedure

1. Start the light sticks glowing and darken the room as much as possible.
2. Place one light stick in a beaker of iced water and one in a beaker of hot tap water as shown in Figure 5.3.15.

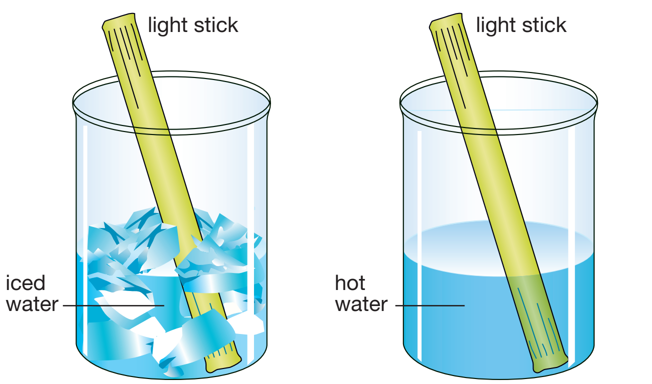


Figure 5.3.15

Results

Record your observations

Discussion

1. **State** what evidence there is that a chemical reaction is taking place inside the light sticks.
2. **State** what changing the temperature has done to the rate of reaction. **Justify** your answer based on your observations.
3. Light sticks work by a chemical reaction between hydrogen peroxide and a chemical called an ester. A product of this reaction then causes a dye to emit light. **Explain** how temperature may be affecting the reaction.

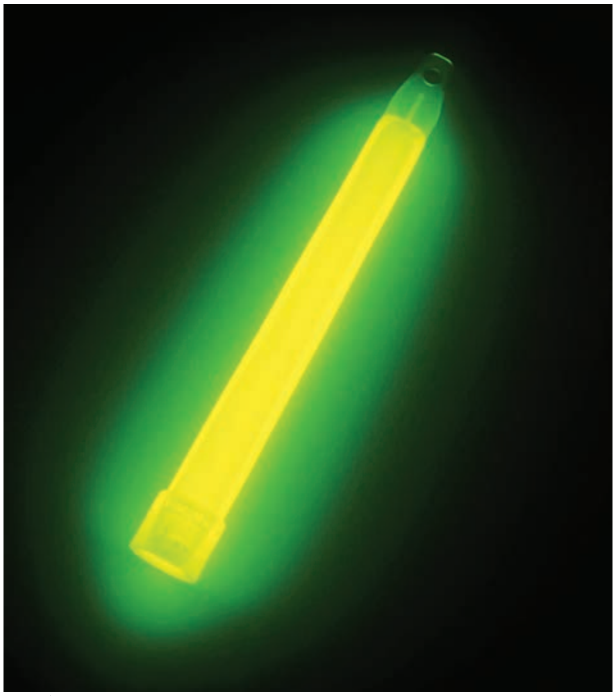


Figure 5.3.16 A light stick glowing

5.3 Practical activities

2 Rate of reaction: The effect of concentration

Purpose

To examine how the concentration of hydrochloric acid affects the rate at which it reacts with marble chips.

Materials

- marble chips
- 20 mL of 0.5 M hydrochloric acid in a small beaker
- 20 mL of 2 M hydrochloric acid in a small beaker
- 3 large test-tubes
- rubber stopper with flexible delivery tube
- large deep tray
- retort stand with test-tube clamp
- timer
- ruler
- water

SAFETY

Wear safety glasses at all times.

Procedure

1 Place a few marble chips in two of the large test-tubes. Make sure the amount of marble chips is the same in each test-tube.

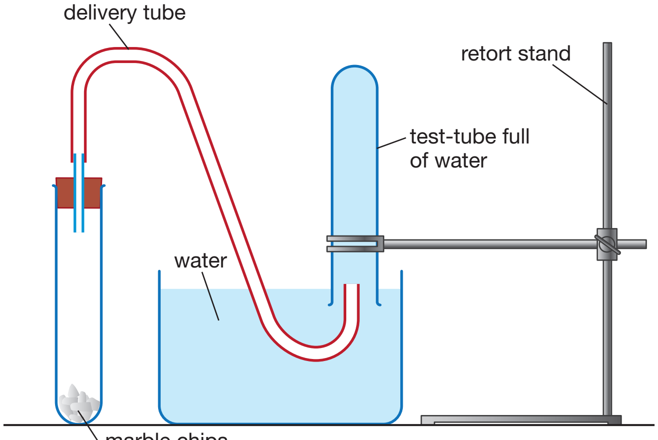


Figure 5.3.17

2 Set up the rest of the apparatus as shown in Figure 5.3.17. Fill the tray with water, fill the large test-tube with water and place it horizontally in the tray then invert the test-tube. Make sure the mouth of the test-tube remains submerged and then clamp the test-tube as shown.

3 Carefully pour 20 mL of 0.5 M hydrochloric acid into one of the test-tubes containing marble chips then immediately connect it to the rubber stopper and hose.

4 Start the timer and let the reaction run for 5 minutes.

5 Record how much water was displaced in the inverted test-tube in the table in the results section.

6 Set up the apparatus again so that the inverted test-tube is filled with water.

7 Repeat steps 3–5 using 2 M hydrochloric acid.

Results

Copy and complete the following table.

Acid	Displaced water (cm)
0.5 M hydrochloric acid	
2 M hydrochloric acid	

Discussion

1 Marble chips are a form of calcium carbonate. When they react with hydrochloric acid, they produce calcium chloride, carbon dioxide and water. **Construct** word and formula equations for this reaction.

2 **Compare** the rate of reactions for the 0.5 M and 2 M hydrochloric acid.

3 **Explain** your observations.

4 **Discuss** other factors that should be kept constant during this experiment to ensure that only the concentration of the acid affects the rate of reaction.

5 **Evaluate** your experiment.

3 Rate of reaction: The effect of agitation

Purpose

To see the effect of stirring on the rate at which chalk dissolves in hydrochloric acid.

Materials

- 2 × 5 mm pieces of chalk
- 2 × 250 mL beakers
- stirring rod
- 1 M hydrochloric acid
- stopwatch

Procedure

1. Fill both beakers with 50 mL of hydrochloric acid.
2. Place one piece of chalk into each beaker of acid at the same time.
3. Start the stopwatch.
4. Stir one beaker with the stirring rod continuously while leaving the other standing still.
5. Record the time that both pieces of chalk finish reacting in the table in the results section.

Results

Copy and complete the following table.

Reaction	Time for reaction to complete
Still reaction	
Agitated reaction	

Discussion

1. **State** what indicates that a chemical reaction is taking place.
2. **Discuss** anything you observed that suggested one chemical reaction was going faster than the other.
3. **Identify** which reaction was faster. **Justify** your choice.

4 Rate of reaction: The effect of surface area

Purpose

To design and conduct an experiment to determine how changing the surface area of a reactant changes the rate of reaction.

Materials

- chalk
- 1 M hydrochloric acid
- beakers
- timers
- rulers
- marking pens

Procedure

1. To design your experiment you should consider the following.
   - How will you measure the rate of reaction?
   - What one factor will you change in each of your samples?
   - What factors will you try and keep the same for each sample?
2. Assess how you will carry out your experiment, how you will collect your data and a list of equipment you will need.
3. Construct a diagram of your experimental apparatus. Show this to your teacher before you start experimenting.
4. Carry out your experiment and collect your data.
5. Assess the safety aspects of this activity

Results

Present your data in a suitable way and answer the discussion questions.

Discussion

1. **Describe** any pattern or patterns you found in the data.
2. **Summarise** the relationship between surface area and rate of reaction.
3. **Explain** the relationship between surface area and rate of reaction.

5 Chapter review

Remembering

1 **State** the law of conservation of mass.

2 **List** five different types of chemical reaction.

3 **State** the meaning of the symbols (s), (l), (g) and (aq) in a chemical equation.

4 **Name** the gas given off when calcium carbonate undergoes thermal decomposition.

5 **Recall** the two-step process for the reduction of iron ore in a blast furnace by writing the chemical equations.

6 **List** ways in which the speed of a chemical reaction can be controlled.

Understanding

7 **Define** the term *rate of reaction*.

8 **Describe** what distinguishes redox reactions from other chemical reactions.

Applying

9 **Identify** types of ionic compounds that are almost always soluble and list any exceptions.

10 **Identify** two reactions that should be slowed down and how they are slowed down.

11 **Demonstrate** the action of heat on a metal carbonate using word and formula equations.

12 **Calculate** the correct number of reactants and products to balance the following equations. Include any missing states.

a $H_2(g) + O_2(g) \rightarrow H_2O$

b $Na + Cl_2 \rightarrow NaCl(s)$

c $CaCO_3(s) \rightarrow CaO(s) + CO_2$

d $CH_4(g) + O_2 \rightarrow CO_2 + H_2O(l)$

e $HNO_3(aq) + Ca \rightarrow Ca(NO_3)_2(aq) + H_2$

Analysing

13 **Classify** each of the following reactions as decomposition, combination, combustion or precipitation.

a $Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$

b Magnesium carbonate is heated to produce magnesium oxide and carbon dioxide.

c methane + oxygen → carbon dioxide + water

d Hydrogen gas (H_2) and chlorine gas (Cl_2) are reacted together to produce hydrogen chloride (HCl).

Evaluating

14 For each of the following reactions, **deduce** the:

a word equation

b balanced formula equation, including states.

i Dilute sodium hydroxide solution is added to dilute sulfuric acid. Sodium sulfate and water are produced.

ii Clear silver nitrate solution is mixed with a clear sodium chloride solution. White silver chloride precipitates out, leaving behind a clear solution of sodium nitrate.

iii Hydrochloric acid reacts with calcium metal. A solution of calcium chloride is produced, through which rise bubbles of hydrogen.

15 Refer to Table 5.2.2 on page 152. **Assess** which of the following substances would be soluble in water.

a $BaSO_4$

b $LiNO_3$

c $CaCO_3$

d $MgCl_2$

16 Hydrogen peroxide breaks up slowly by itself to form oxygen and water. When some manganese(IV) oxide (MnO_2) is added to it, there is a sudden increase in the production of oxygen gas. However, none of the manganese(IV) oxide seems to be used up in the reaction. **Propose** why the manganese(IV) oxide has this effect.

Creating

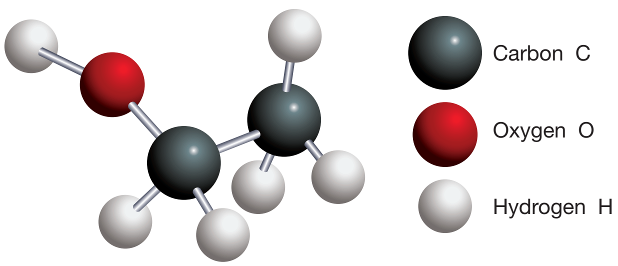
17 **Use** the following ten key terms to **construct** a mind map.

balanced equation
chemical reaction
chemical equation
combination
combustion
corrosion
decomposition
metal displacement
precipitation
redox

Thinking scientifically

Q1 Scientists use molecular formulas as short-hand notation for describing the structure of molecules. The formulas can be used to communicate which types of atom are in the molecule and how many of each type there are. For example, the chemical formula for water, H_2O, says that in every water molecule, there are two hydrogen atoms and one oxygen atom.

Shown here is a molecule of the compound ethanol. Which of the following molecular formulas best describe this molecule?



A C_2H_4O
B C_2H_5O
C C_2H_6O
D $C_2H_4O_2$

Q2 The law of conservation of mass states that during a chemical reaction, atoms cannot be created or destroyed. From this law, it follows that during a chemical reaction, the total mass of the reactants and products:

A always increases
B always decreases
C may increase or decrease
D always stays the same.

Q3 The term *solubility* is used to describe how well a compound dissolves. A compound that dissolves well is referred to as soluble, while a compound that does not dissolve is referred to as insoluble. Scientists use solubility tables like the one below to predict whether a compound will be soluble or insoluble in water.

Type of compound	Solubility	Exceptions
Nitrates NO_3^-	Soluble	None
Chlorides Cl^- Bromides Br^- Iodide I^-	Soluble	Ag^+, Hg^+, Pb^{2+}
Sulfates SO_4^{2-}	Soluble	Ca^{2+}, Ba^{2+}, Pb^{2+}, Ag^+
Carbonates CO_3^{2-}	Insoluble	Li^+, Na^+, K^+, NH_3^+
Phosphates PO_4^{3-}	Insoluble	Li^+, Na^+, K^+, NH_3^+

Use this solubility table to determine which of the following compounds is insoluble.

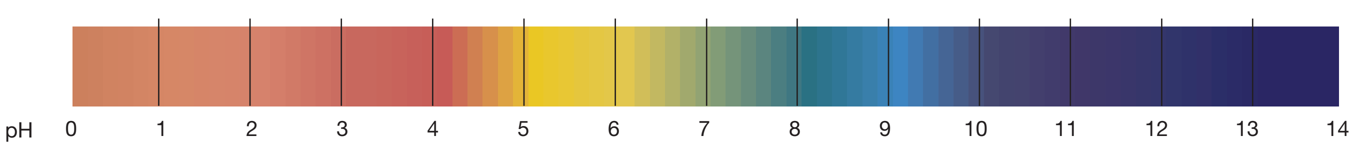
A $NaNO_3$
B $MgCl_2$
C K_2CO_3
D $PbSO_4$

Q4 Scientists use the pH scale (shown below) to measure the concentration of acids and bases. The pH scale ranges from 0 to 14. Substances with a pH less than 7 are acidic, while substances with a pH greater than 7 are basic.

The pH of a substance can be measured by an indicator. An indicator is a chemical that changes colour depending on the pH. Indicators change colour because they react with the acid or base. Universal indicator is made up of a combination of several of these chemicals so that it changes colour many times as the pH changes from 0 to 14. Below is a chart that shows the colour of universal indicator over the full pH range.

Lemon juice has pH 2.3. It is most likely to turn universal indicator:

A red-orange
B yellow
C yellow-green
D green.



Thinking scientifically

Q5 Michelle performed five experiments to see how different factors influence how quickly hydrochloric acid reacts with blackboard chalk.

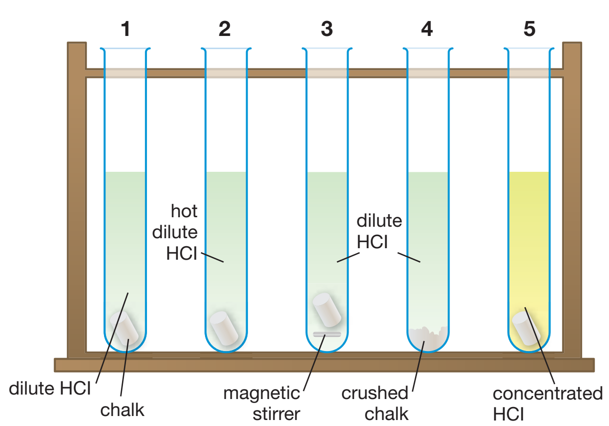
Experiment 1: 1 cm of chalk in dilute hydrochloric acid at room temperature

Experiment 2: 1 cm of chalk in dilute hydrochloric acid heated to 80°C

Experiment 3: 1 cm of chalk in dilute hydrochloric acid with a magnetic stirrer

Experiment 4: 1 cm of chalk crushed and put in dilute hydrochloric acid

Experiment 5: 1 cm of chalk in concentrated hydrochloric acid



In each case, Michelle collected and measured the volume of carbon dioxide gas (CO_2) produced in 5 minutes. Her results are tabulated below.

Experiment	Volume of CO_2 produced (mL)
1	5
2	10
3	30
4	50
5	10

From her data, Michelle can conclude that:

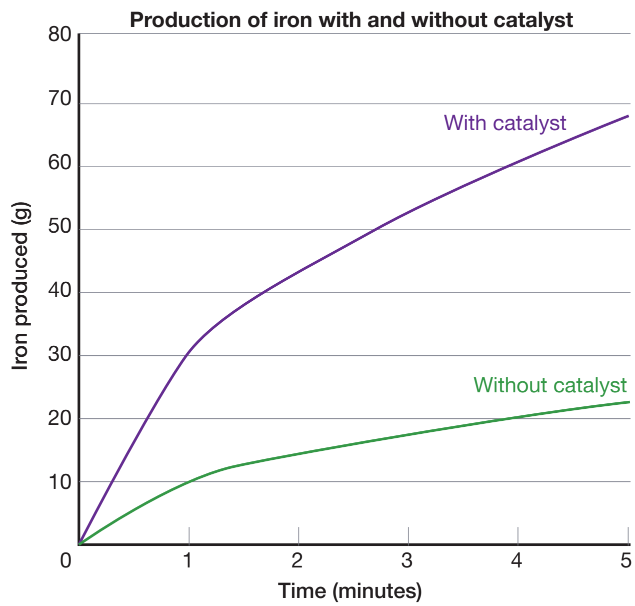
A increasing the temperature had no affect on the rate of reaction

B increasing the concentration of the acid increased the rate of reaction more than stirring the reaction

C stirring increased the rate of reaction the most

D crushing the chalk increased the rate of reaction the most.

Q6 Wasim is developing a new chemical reaction for converting iron ore into iron metal. He wants to determine how adding a catalyst changes the rate of reaction. To do this, Wasim measures the amount of iron metal produced by the chemical reaction every minute for the first 5 minutes. He has plotted the results in the graph below.



From his graph, Wasim can conclude that the catalyst:

A has no effect on the rate of reaction

B halves the rate of reaction

C doubles the rate of reaction

D triples the rate of reaction.

Glossary

Unit 5.1

Aqueous solution: a solution of a substance dissolved in water

Aqueous solution

Balanced equation: a chemical equation in which the number of each type of atom is the same on both sides of the equation

Chemical equation: a short-hand notation that scientists use to communicate what happens during a chemical reaction

Formula equation: a chemical equation where the reactants and products are identified by their chemical formulas

Law of conservation of mass: the law that states that atoms cannot be created or destroyed during a chemical reaction

Product: a substance produced by a chemical reaction

Reactant: the initial substance of a chemical reaction

Word equation: a chemical equation where the reactants and products are identified by their chemical names

Unit 5.2

Anion: a negatively charged ion

Carbon reduction: a chemical process of separation of metals from their ores using carbon

Cation: a positively charged ion

Combination reaction: a chemical reaction where two reactants combine to form one product

Combustion reaction

Combustion reaction: any chemical reaction where a substance burns in oxygen to produce heat and light

Decomposition reaction: a chemical reaction where one reactant breaks apart into two or more products

Electrolysis: a technique for reducing the ions of highly reactive metals by using an electrical current to force electrons onto the ions

Electrowinning: A process of extracting metals from solutions using electrolysis

Froth flotation: a physical process of separation of metals from their ores

Insoluble: does not dissolve

Ion: an atom that has gained or lost electrons to become electrically charged

Ionic compound: a substance made up of positive and negative ions

Oxidation: when a substance gains oxygen atoms or loses electrons

Precipitation reaction

Polyatomic: having many atoms

Precipitate: the insoluble product of a precipitation reaction

Precipitation reaction: when two clear solutions react to produce an insoluble solid

Redox: an abbreviation for oxidation and reduction pairs of reactions

Reduction: when a substance loses oxygen atoms or gains electrons

Soluble: able to dissolve

Smelting: a chemical method of extracting a metal from its ore in which the ore is heated with a reducing agent such as carbon

Unit 5.3

Agitation: stirring

Agitation

Catalyst: a chemical that helps to speed up a chemical reaction but is not used up during the reaction

Concentration: the amount of a chemical in a certain volume of water

Enzyme: a natural occurring catalyst

Rate of reaction: how fast a chemical reaction proceeds