TOPIC 12 Chemical changes

12.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

12.1.1 Why learn this?

Chemical reactions are happening everywhere around us. They occur in batteries to provide electricity, in the oven when you bake a cake, in your hair when it is bleached or coloured, and in your car when it burns fuel. They even happen inside us, where chemical reactions enable food to be turned into energy and damaging chemicals to be made harmless. It really is a changing world – chemically changing!

LEARNING SEQUENCE

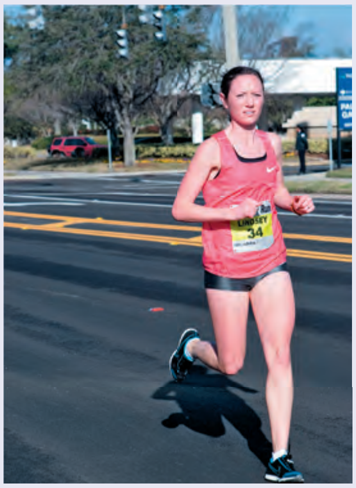
Chemical reactions can be colourful and explosive. These fireworks are the result of chemical reactions between metal salts and other compounds to produce different colours.

What is a chemical reaction?

You've probably already heard a lot about chemical reactions — at school, on television, at the movies or in books. But what is a chemical reaction, and how do you know whether a chemical reaction has taken place?

Check out the images on this page and answer the questions based on what you already know about chemical reactions.

1. The boiling liquid in the pot below is changing colour. It began as a mixture of reds, greens and blues and, after stirring, is changing into an dangerous-looking, yellow soup.
   (a) Write down your opinion about whether a chemical reaction is taking place.
   (b) Explain how you know whether a chemical reaction has taken place.
   (c) Is there a chemical reaction taking place underneath the pot? Explain your answer.
   (d) Clouds are forming above the pot. Is this evidence of another chemical reaction? Explain your answer.
2. Does a chemical reaction take place when you burn toast? What observations support your answer?
3. Does a chemical reaction take place when you toast bread without burning it? Explain your answer.
4. Is the frozen substance in this man's beard the result of a chemical reaction? Explain your answer.
5. Runners in long-distance races sweat heavily. The water lost due to sweating evaporates from the skin. Is this evaporation an example of a chemical reaction? Explain your answer.
6. What happens when you use shampoo? Is this a chemical reaction?



12.2 Time for a change?

Have you noticed the way that things change? When a tub of ice-cream is left on the table on a warm day, the ice-cream melts. When water is heated, it may turn into a vapour. When an apple is sliced, it turns brown. In chapter 3, we looked at some of these changes when we studied the changes of state that matter may undergo as a result of adding or removing energy. For example:

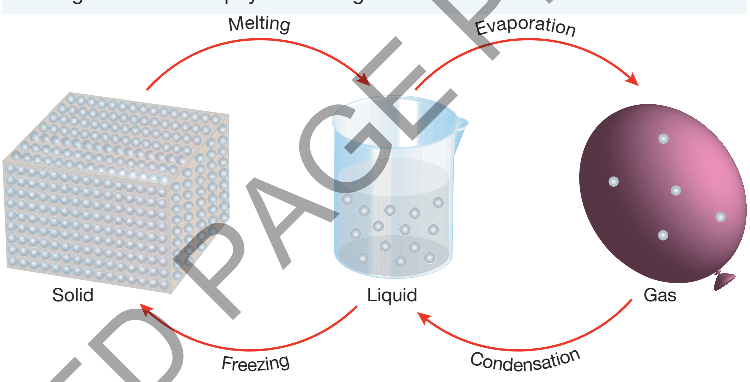
- When energy is added to a solid, it melts to form a liquid. If we keep adding energy to the liquid, it boils or evaporates to form a gas.
- When we remove energy from a gas by cooling it, the gas condenses to form a liquid. If we keep cooling it, that liquid freezes to form a solid.

All of this may explain the ice-cream and the water, but does it explain why the sliced apple turned brown?

12.2.1 Physical changes

All of the changes of state we've described are physical changes. A physical change does not break any bonds between the atoms of a molecule or make different substances with different atoms. When water is in the form of ice, it is made up of water molecules, each of which is made up of one oxygen atom and two hydrogen atoms. When the ice is turned into water or into water vapour, it is still made up of water molecules.

Changes of state are physical changes.



Another characteristic of a physical change is that it is usually reversible. Water can be turned into ice and then back into water again very easily.

12.2.2 Chemical changes

Substances are said to have undergone a chemical change when the particles that make them up undergo change. Usually this occurs when the chemical bonds between particles in molecules are broken or when new chemical bonds are formed. There are a number of different ways that you can tell if a chemical change has occurred:

- A new substance is formed.
- A solid appears or disappears.
- The temperature of the substances changes spontaneously.
- A colour change occurs.
- Bubbles appear.
- A flame appears or light is produced.

When you hard-boil an egg, for example, you can see that a chemical change has taken place because the albumen has changed from a clear liquid to a rubbery white solid, while the yolk has changed from a translucent yellow liquid to a paler yellow, crumbly solid.

Most chemical changes are difficult to reverse. Once the egg has been cooked, you cannot turn it back into its raw state. Obviously a little commonsense is needed here though. For example, if you drop a raw egg and the shell breaks, you cannot reverse what has happened, yet this is not considered to be a chemical change.

When a sliced apple turns brown, this indicates that a chemical change has occurred to the surface of the apple. This particular change is a form of oxidation, a chemical reaction that we will look at in more detail later.

12.2.3 How does a candle burn?

Sometimes, a process that seems very simple is the combination of both physical and chemical changes. Let's look at the example of a burning candle.

When you try to light a piece of solid wax it melts, but it does not burn. If solid wax doesn't burn, how does a candle burn? Is it the string wick that is in the middle of the candle that burns? String burns, but it doesn't burn as a candle does. How then does a candle burn?

When you light the wick of a candle, the solid wax at the top of the candle melts to form a pool of liquid wax. This molten wax is drawn up through the wick by capillary action — the same process by which water soaks upwards through a piece of paper towel. At the top of the wick where the liquid wax is close to the flame's heat, it **evaporates**. Then, two different chemical reactions occur in which the wax vapour **reacts** with oxygen in the air as it burns. In the hottest part of the flame (where the flame is blue), carbon dioxide and water vapour are produced. In the bright yellow section of the flame, sooty particles of carbon, carbon monoxide and water vapour are produced. The carbon particles get hot enough to glow, producing light much in the same way that the hot filament in a light globe does. This is called **incandescence** and it is a physical change rather than a chemical one — once the sooty carbon rises far enough above the flame to cool down, it stops glowing.

The changes in a candle flame

12.2.4 How does a cake rise?

When an acid is added to bicarbonate of soda, a new substance — carbon dioxide gas — is produced. This process is a chemical change and is used in cakes to help them rise during the cooking process.

Baking powder is a mixture of bicarbonate of soda and cream of tartar. When baking powder is added to cakes, the cream of tartar dissolves in the liquids of the cake mixture and forms tartaric acid. This acid is then available to react with the bicarbonate of soda.

Self-raising flour contains baking powder so, when a recipe includes self-raising flour and a liquid, you know that the cooking process will involve a chemical change. The carbon dioxide gas produced during this chemical change rises through the cake mixture as it cooks and helps to aerate it.

INVESTIGATION 12.1

A burning candle

AIM: To investigate what happens when a candle burns

You will need:

safety glasses
candle
jar lid
matches
heatproof mat

- Place a jar lid on a heatproof mat.
- Light a candle and allow a drop of wax to drip onto the jar lid. Place the candle on the drop of wax and fix it to the jar lid.
- Observe the candle and write down as many observations of the burning candle as you can.
- Discuss your observations with others in your group.
- Blow out your candle and you will see the white vapour rising from the top of the wick.
- To confirm that the white vapour is not smoke, carry out the following test.
- Relight the candle. Once it is burning properly, blow it out.
- Quickly light the top of the vapour trail. The flame should run down the vapour to the wick and relight the candle.

Discussion

1. How far is the flame from the solid wax?
2. The solid wax has formed a little pool of liquid wax around the wick. Why has this happened?
3. Describe the odour of the vapour.

CAUTION: Do not smell the vapour directly. Fan the odour to your nose with your hand.

4. Draw a diagram of a candle and its flame. Label this diagram to explain how a candle burns.
5. Explain why lighting the wax vapour causes the candle to relight.

12.2.5 Describing change

Physical and chemical changes can be described using word equations.

For example, melting chocolate can be described by the equation:

solid chocolate → liquid chocolate

The burning of paper can be described by the equation:

paper + oxygen → smoke + ash

INVESTIGATION 12.2

How can you tell a chemical reaction has taken place?

AIM: To investigate changes during a chemical reaction

You will need:

110 g sugar
150 mL cold water
500 mL beaker
hotplate
stirring rod
220 °C thermometer
test tube
patty pans
heatproof mat
2 teaspoons of golden syrup
measuring cylinder

half a spatula of cream of tartar
half a spatula of bicarbonate of soda
laboratory coat and safety glasses

- Mix the sugar, cold water, golden syrup and cream of tartar in the beaker.
- Gently heat and stir the mixture over the hotplate until the sugar has completely dissolved.
- Stop stirring the mixture when it boils.
- Allow the mixture to reach 154°C, and then remove it from the hotplate.

CAUTION: The beaker and the mixture are very hot. Remove them from the hotplate with care.

- Dissolve the bicarbonate of soda in 1–2 mL of warm tap water in the test tube. Pour the dissolved bicarbonate of soda into the sugar mixture, stirring gently.
- Pour the hot mixture into patty pans.
- Allow to cool before examining.

Discussion

What evidence is there that a chemical reaction has taken place?

12.2 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Describe** the difference between a physical and a chemical change.
2. **Recall** two examples of physical change.
3. **Recall** two examples of chemical change.
4. **Identify** which term goes with each definition.

Definition	Term
Change from solid to liquid	Freezing
Change from gas to liquid	Melting
Change from liquid to solid	Condensation
Change from liquid to gas	Evaporation

5. **Recall** which type of physical change can always be reversed by heating or cooling.

Think

6. Copy and complete the table below.

Observation	Physical or chemical change
Water freezing to form snow	
A cake cooking	
Lighting the gas on the stove	
Petrol evaporating at the petrol pump	
Lighting a match	
Steam condensing on the bathroom mirror	
Melting gold to cast gold bars	
Dynamite exploding	
Bleaching a stain	
Dissolving eggshell in acetic acid	

7. Write two word equations to **describe** the changes of state that occur when a candle burns.
8. Write a word equation to **describe** the chemical change that occurs when a candle burns.

9. When you hard-boil an egg, the inside of the egg gets hard. **Explain** why this is a chemical change and not a physical change.

Create

10. Candles are a good example of both physical change and chemical change. Write a poem about a candle burning.

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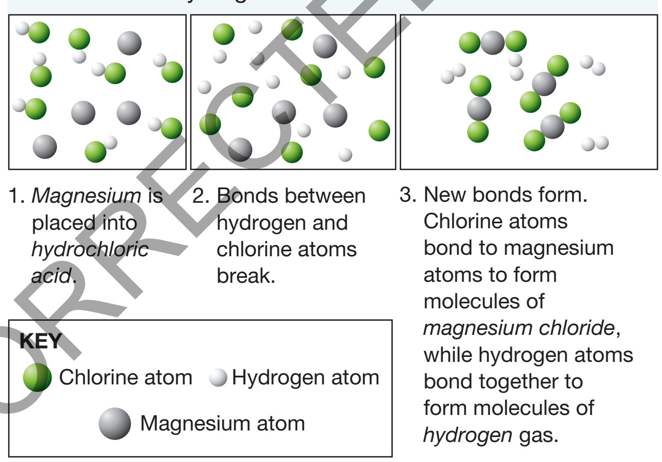
Complete this digital doc: Worksheet 12.1: Physical and chemical changes (doc-0000)

12.3 Describing chemical changes

When a chemical change occurs, new substances are produced. The process of producing new substances is called a **chemical reaction**. Almost all the products you use or wear each day are made by chemical reactions: from cosmetics to concrete, plastics to paper, glass to graphite, stainless steel to shampoo, fibres to food additives, margarine to medicines and many, many more. You can usually tell that a chemical reaction has taken place if there is a change in colour, a gas is given off, heat or light is produced or a **precipitate** (cloudiness) appears.

The reaction between magnesium and hydrochloric acid produces the new substances magnesium chloride and hydrogen.



However, the only way to tell for sure that a chemical reaction has occurred is to identify the substances that are formed and establish that these are different from the original substances.

12.3.1 Reactants and products

In a chemical reaction, the substances that react together are called the **reactants** while the new substances that are formed are called the **products**. In a chemical reaction, the bonds between the atoms of the reactants break and new bonds are made between the atoms to form the products.

For example, the reaction between magnesium metal and hydrochloric acid is shown here.

12.3.2 Chemical reaction experiments

Before you start each of the four experiments on these pages, design a suitable table for recording your observations.

As you do the experiments:

1. Make a note of the appearance of the reactants you are starting with.
2. Observe carefully to detect any changes that occur.
3. Describe the products of the reaction.

Safety glasses should always be worn during experiments involving chemical reactions.

INVESTIGATION 12.3

Magnesium metal in hydrochloric acid

AIM: To investigate the chemical reaction between magnesium and hydrochloric acid

You will need:

heatproof mat
safety glasses
test tube and test-tube rack
1 cm piece of magnesium ribbon
dropping bottle of 0.5M hydrochloric acid

- Put the magnesium into the test tube.
- Add 20 drops of hydrochloric acid to the test tube.

CAUTION: The test tube may become quite hot.

- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

INVESTIGATION 12.4

Heating copper carbonate

AIM: To investigate a chemical reaction in copper carbonate when heated

You will need:

Bunsen burner, heatproof mat and matches
test tube and test-tube rack
safety glasses
test-tube holder
spatula
copper carbonate powder

- Pour two spatulas of copper carbonate into the test tube.
- Using the test-tube holder, heat the test tube. Remember to move the test tube in and out of the flame and point the test tube away from people.
- Stop heating when the copper carbonate has changed colour.
- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

INVESTIGATION 12.5

Sodium sulfate and barium chloride

AIM: To investigate the chemical reaction between sodium sulfate and barium chloride

You will need:

heatproof mat
safety glasses
test tube and test-tube rack
test-tube holder
dropping bottle of 0.1M sodium sulfate solution
dropping bottle of 0.1M barium chloride solution

- Put 20 drops of sodium sulfate solution into the test tube.
- Add 20 drops of barium chloride solution to the test tube.
- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

INVESTIGATION 12.6

Steel wool in copper sulfate solution

AIM: To investigate the chemical reaction between steel wool and copper sulfate

You will need:

heatproof mat
glass stirring rod
safety glasses
1 cm ball of steel wool
test tube and test-tube rack
dropping bottle of 0.5M copper sulfate solution

- Put the steel wool into the test tube, using the glass stirring rod to push it gently to the bottom of the test tube.
- Add copper sulfate solution to the test tube to a depth of 2 cm.
- Record your observations.

Discussion

What observation provides evidence that a chemical reaction has taken place?

12.2.3 Word equations

In mathematics, relationships between numbers are written in the form of equations. In the same way, scientists can write chemical reactions in the form of chemical equations. The simplest form of chemical equation is the **chemical word equation**.

Chemical word equations are written so that the names of the reactants are shown on the left with the reactants separated by a plus sign (+). The reaction itself is represented by an arrow (→) that points to the products of the reaction. The names of the products formed are also separated by plus signs.

Each of the chemical reactions in the experiments on these pages can be described by a word equation.

1. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed:

magnesium + hydrochloric acid → hydrogen gas + magnesium chloride

2. Heating copper carbonate forms copper oxide and carbon dioxide:

heat

copper carbonate → copper oxide + carbon dioxide gas

Although heat is required for this chemical reaction, it is not a substance and therefore is not a reactant. For this reason, 'heat' is written above the arrow.

3. The sodium sulfate and barium chloride in the solution react to form solid barium sulfate and sodium chloride, which remains dissolved in the solution:

sodium sulfate + barium chloride → solid barium sulfate + sodium chloride

4. Steel wool (which is made of iron) dissolves in copper sulfate solution to form iron sulfate solution and copper metal:

iron + copper sulfate solution → iron sulfate solution + copper

12.3.4 Types of chemical reaction

All of the millions of different chemical reactions that happen can be grouped according to the way in which the reactants combine to form the products. Some reactions can belong to more than one category of reaction.

In **decomposition** reactions, a reactant breaks up (or decomposes) to form two or more products. The decomposition is often the result of heating or passing electrical current through the reactant. For example, the Hofmann voltameter seen in chapter 9 decomposes water into hydrogen gas and oxygen gas using electricity:

electricity
water → hydrogen gas + oxygen gas

However, substances such as hydrogen peroxide decompose over time without any stimulus at all:

hydrogen peroxide → water + oxygen gas

A **synthesis** reaction is the opposite form of reaction to decomposition and occurs when two or more reactants combine to form a single substance. The formation of iron sulfide and sodium chloride are both examples of synthesis:

iron + sulfur → iron sulfide

sodium + chlorine gas → sodium chloride

Combustion reactions always have oxygen as a reactant. The burning of octane fuel in a car engine, the formation of rust and even respiration are all examples of combustion:

octane + oxygen gas → carbon dioxide + water

iron + oxygen → iron oxide (rust)

glucose + oxygen gas → carbon dioxide + water

In a **displacement** reaction, metals combined with non-metals in the reactants swap partners to form new combinations. This can be seen in the following examples:

silver nitrate + copper → copper nitrate + silver

lead nitrate + potassium chloride → potassium nitrate + lead chloride

12.3 Exercise: Remember and think

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Remember

1. Write down four observations that could provide evidence that a chemical reaction has taken place.
2. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed.
   (a) **Identify** the products.
   (b) **Identify** the reactants.
3. What is the only real proof that a chemical reaction has taken place?
4. What happens to the atoms in the substances that take part in chemical reactions?
5. Name the four main types of chemical reaction.
6. How is synthesis different from decomposition?

Think

7. Write word equations for the following chemical reactions.
   (a) Methanol is burnt with oxygen in a spirit lamp to produce carbon dioxide and water.
   (b) Sodium metal reacts with chlorine gas to form sodium chloride.
   (c) Hydrogen gas and oxygen gas combine to form water.
   (d) Zinc metal dissolves in hydrochloric acid to form hydrogen gas and zinc chloride.
   (e) Hydrochloric acid reacts with copper to form copper chloride and hydrogen.
   (f) Methane and oxygen react to form water and carbon dioxide.
   (g) Water and sodium nitrate are formed when nitric acid reacts with sodium hydroxide.
8. **Explain** why the reaction that takes place when copper carbonate is heated is called a decomposition reaction.
9. **Identify** each of the following chemical reactions as synthesis, decomposition, burning or displacement reactions (remember that some reactions may be more than one type).
   (a) magnesium + oxygen → magnesium oxide
   (b) calcium carbonate → calcium oxide + carbon dioxide
   (c) potassium + chlorine gas → potassium chloride
   (d) magnesium + aluminium chloride → magnesium chloride + aluminium

Create

10. Performing some chemical reactions can be dangerous. Design a safety poster for one of the experiments you have done.
11. Choose one of the materials below and find out how it is manufactured. Write a report about the chemical reactions used in its production.
    - Glass
    - Soap
    - Margarine
    - Paper
    - Nylon
    - Polyethylene

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12.4 Faster and slower

Not all reactions occur at the same rate. The speed with which a chemical reaction occurs is called its **reaction rate**. The explosive reaction between hydrogen and oxygen to form water is very fast and can release enough energy to propel spacecraft into orbit. Other reactions, such as the rusting of iron, can take weeks, months or even years to be complete.

Explosions are fast chemical reactions.

Sometimes it is important for the rate of a particular reaction to be either slowed down or made much faster than it would normally occur. There are a number of ways in which we can alter the rate of a chemical reaction.

12.4.1 Changing the temperature

You'll remember from our studies of the particle on pages 98–104 that adding energy in the form of heat causes the particles in a substance to move faster and to collide with each other more often. When particles collide, the bonds between atoms may break and new bonds may form. As the added heat increases the number of collisions, the breaking and creation of bonds occurs faster. In other words, the chemical reaction between substances occurs much faster if you heat them.

Of course, this works the other way as well; cooling the substances involved in a chemical reaction reduces the reaction rate. We make use of this fact when we store food in the refrigerator, rather than leaving it on the kitchen bench. Food goes off when micro-organisms produce chemical substances that degrade the food. Food is much cooler in the fridge than on the bench, and this reduces the rate at which the micro-organisms produce degrading substances.

INVESTIGATION 12.7

The effect of temperature on a reaction

AIM: To investigate the effect of temperature on reaction rate

You will need:

safety glasses
heatproof mat
Bunsen burner
matches
marble chips
test tube
test-tube rack
test-tube holder
dropping bottle of 1M hydrochloric acid

- Carefully slide one or two marble chips to the bottom of the test tube.
- Add hydrochloric acid to half-fill the test tube.
- Observe the reaction.
- Now gently heat the test tube and observe the reaction.

Discussion

1. Has a chemical change occurred? What evidence have you observed?
2. What effect did heat have on the rate of this reaction?
3. In this reaction, the calcium carbonate, which makes up the marble chip, reacts with the hydrochloric acid to form calcium chloride, water and carbon dioxide gas. Write a word equation for this chemical reaction.

12.4.2 Changing the surface area

Have you ever noticed that sugar in granular form dissolves much faster than a sugar cube when you add it to a cup of tea? When you break up a substance into smaller pieces, you increase the surface area of that substance. This means that more particles can immediately come into contact with the particles of another substance, allowing reactions between them to happen much faster.

Bath bombs, for example, are sold as solid balls that are dropped into your bath water to release carbon dioxide gas and scented oil. As the water reacts with the Epsom salts in the bath bomb, it slowly disappears. However, if you crush the bath bomb into a powder and then put it in your bath, it reacts very quickly.

HOW ABOUT THAT!

Have you ever had a composite resin filling in your tooth? The dentist uses blue light or ultraviolet (UV) radiation to set this type of filling. The visible or UV light speeds up the reactions that cause the materials in the filling to harden. Without the UV light, you would be waiting for hours for this type of filling to set.

UV light can speed up the setting of a composite resin filling.

12.4.3 Using a catalyst

Catalysts are chemicals that speed up chemical reactions. They are not reactants because they are not changed by the reaction. For example, catalytic converters in car exhausts use a precious metal, such as platinum, as a catalyst. This enables nitrogen oxide to react with toxic gases, such as carbon monoxide, to form the less harmful carbon dioxide and nitrogen gases; this reaction would not occur in the absence of platinum. This reaction can be shown as:

$$\textbf{carbon monoxide} + \textbf{nitrogen oxide} \xrightarrow{\textbf{platinum}} \textbf{carbon dioxide} + \textbf{nitrogen}$$

Catalysts produced by living organisms are called **enzymes**. Many of the chemical reactions taking place inside your body involve enzymes.

Granular sugar dissolves faster than a sugar cube because it has a larger surface area.

Enzymes are also responsible for some of the changes we see in our food.

If you have ever left a half-eaten apple in your lunch box or locker, you've seen enzymes at work. Apples and other fruits go brown because chemicals in them, called **phenolics**, react with oxygen in the air. The brown chemicals produced are called **quinones**. Enzymes speed up the reaction.

The chemical word equation for this reaction is:

$$\text{phenolics} + \text{oxygen} \xrightarrow{\text{enzymes}} \text{quinones}$$

The human body produces many different enzymes to speed up the digestion of our food. Amylase helps us digest starches, protease is needed for protein digestion, and lipase must be present if we are to digest fats and oils.

Apples go brown when phenolics react with oxygen in the air.

12.4.4 Changing the concentration

The concentration of a solution depends on how much solute is dissolved in a set amount of solvent. The more solute that is dissolved, the greater the concentration of the solution is. The more concentrated that a solution is, the more particles of solute it contains that can react with other substances. If there are more particles available for a chemical reaction, the reaction will occur faster. So, use more concentrated solutions to make a reaction go faster, and use more dilute solutions to make a reaction go more slowly.

INVESTIGATION 12.8

Changing the reaction rate

AIM: To investigate how to change the rate of a reaction

You will need:

safety glasses
heatproof mat
test tubes and test-tube rack
white chalk
mortar and pestle
spatula
0.5M hydrochloric acid
1M hydrochloric acid
measuring cylinder

Hydrochloric acid reacts with chalk to produce carbon dioxide gas, water and calcium chloride.

- Put a small amount of chalk in a test tube and add enough hydrochloric acid to cover it. Observe the chemical reaction.
- Discuss with your partner how you could use this reaction to demonstrate one of the following hypotheses.
  (a) Increasing the concentration or amount of reactants speeds up a chemical reaction.
  (b) Increasing the surface area of reactants speeds up a chemical reaction.
  (c) Decreasing the concentration or amount of reactants slows a chemical reaction.

- Design your experiment and write down the method that you have chosen.
- Predict the results you would expect to obtain that would support the hypothesis you have chosen.
- Perform the experiment.
- Prepare a report of your findings.

12.4 Exercise: Remember and think

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Remember

1. **Define** the term 'rate of a chemical reaction'.
2. **Describe** four different methods of changing the rate of a reaction.
3. **Explain** how heating increases the rate of a reaction.
4. **Define** the term 'catalyst'.
5. **Explain** why a catalyst is not considered a reactant.
6. **Compare** enzymes and catalysts.

Think

7. Does a refrigerator stop food from rotting or does it just slow the rotting? **Explain** your answer.
8. Food keeps well in a refrigerator. **Deduce** why it keeps even longer in the freezer.
9. **Propose** why some washing powders contain enzymes.
10. **Deduce** why the word 'enzyme' appears over the arrow in the chemical word equation for the browning of fruit.

Investigate

11. Amylase, pepsin and lipase are all enzymes found in the human digestive system.
    (a) **Investigate** how they are involved in digestion.
    (b) Write a chemical word equation for the reactions that they speed up.

Use Data

12. In an experiment investigating how temperature affects the reaction rate of an unknown metal in acid, students collected the following data.

Temperature (°C)	Reaction time (seconds)
10	60
20	53
30	48
40	44
50	40
60	35
70	30
80	24
90	18

    (a) **Construct** a line graph that shows how increasing the temperature affected the reaction rate. Put temperature on the horizontal axis and time on the vertical axis.
    (b) **Predict** how long the reaction would take if the temperature was:
        (i) 65 °C
        (ii) 95 °C.
    (c) **Describe** the shape of the graph.
    (d) **Propose** a change to the experiment that would cause the reaction to occur faster.

13. Change the temperature, concentration and surface area in the **Reaction rates** interactivity in the Resources tab to see how they affect the rate of a reaction; then decide how the rates of particular reactions could be changed.

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Tryout this interactivity: Reaction rates (int-0230)

12.5 Rusting is a chemical reaction

Corrosion is a chemical reaction between a metal and substances in its environment that results in the metal being 'eaten away'. The most common form of corrosion that we encounter is the corrosion of iron, a process referred to as rusting. Over time, rusting can cause enormous damage to buildings, bridges, ships, railway tracks and cars.

When iron reacts with water and oxygen in the air it forms iron oxide and other iron compounds that make up the familiar red-brown substance known as **rust**. Rusting is a chemical reaction that can be represented by the following word equation:

iron + water + oxygen → rust

Even strong buildings and bridges that are made from steel, an alloy of iron, are weakened by rusting. The Sydney Harbour Bridge, for example, is continually being painted to protect it from moisture and the air, which would cause its steel girders to rust. Ships and cars are also constructed largely of steel. Despite the strength of the steel, they need to be protected from the corrosive effects of the environment.

12.5.1 Speeding up rusting

Some substances in the environment make the rusting reaction happen much more quickly. One of the most effective of these is salt. Steel dinghies that are used in the ocean rust much faster than those that are used only in fresh water. This is because the salt in the water allows the reaction between the oxygen in the air and the iron in the steel to occur much faster.

Some chemicals released from factories may not be corrosive themselves but may allow the rusting process to occur faster. Even the exhaust from aircraft can speed up rusting. Research by the CSIRO has found that corrosion rates in a large city are highest near airports, industrial plants, sewage treatment works and large bodies of salt water.

Rusting is much slower in very dry environments such as deserts. In the Mohave Desert in southern California, hundreds of aircraft that are not in immediate use by

The planes in the Mojave Desert 'boneyard' are preserved from rusting by the dry desert air and low rainfall.

HOW ABOUT THAT!

City councils face problems caused by the action of dogs on metal lampposts. The corrosive properties of the dogs' urine rusts the steel of the lampposts a few centimetres above the ground.

airlines are stored in the open air. Due to the extremely low humidity — the rainfall is nearly zero — rusting occurs extremely slowly. As a result, some of the aircraft are still structurally sound despite being exposed for nearly twenty years!

INVESTIGATION 12.9

Observing rusting

AIM: To observe rusting under different conditions

You will need:

3 glass Petri dishes
fresh water
salt water
3 small beakers
steel wool without soap
permanent marker pen

- Set out your three Petri dishes. Half-fill the first dish with fresh water and the second dish with salt water. The third dish will be left unfilled at this stage.
- Place a small amount of steel wool in the middle of each of the Petri dishes.
- Turn the small beakers upside down and use them to cover the steel wool pieces.
- Mark the level of the water on the outside of the beakers for the first and second dishes.
- Construct a table in which you can record your observations over several days.
- Leave the Petri dishes in a safe place for three or four days. During this time, if needed, top up the fresh water and salt water in the dishes back to the marked lines.
- Observe the condition of the steel wool in each dish after four days and enter your observations in your prepared table.

Discussion

1. Did the water level change during the four-day period? If so, give a possible explanation for the change.
2. Which of the three samples of steel wool had (a) the most rust, (b) the least rust?
3. Does salt water cause rusting to occur faster than, slower than or at the same rate as fresh water?
4. Predict what would happen if the air had been completely removed from the three beakers for the duration of the experiment. Justify your response.
5. Suggest why people who live in seaside resorts have problems with their cars rusting.

12.5.2 Rust protection

The layer of rust that forms on an iron object flakes off the metal, allowing air and moisture to get through to the iron below. This causes more rusting to occur, and eventually the iron becomes a heap of rust. It is important to protect iron and steel from corrosion, especially if it is part of a bridge or the hull of a ship.

There are several ways to protect iron and steel from rusting. One way is to prevent oxygen or moisture from contacting the metal. This is called **surface protection**. The metal can be protected by coating it with paint, plastic or oil. If the surface protection becomes scratched or worn off, the metal below can be attacked by moisture and oxygen and rusting will occur. Examine the painted surface of an old car. Wherever the paint has chipped off you will find that corrosion has occurred and the rust can be seen.

Another way to protect iron from rusting is to coat it with a layer of zinc. This is called **galvanising**. Zinc is a more reactive metal than iron, which means that it is more likely to take part in chemical reactions. When zinc and iron are in the presence of moisture and oxygen, it is the zinc that reacts, leaving the iron unaffected. Many roofing materials and garden sheds are made from galvanised iron. You can also buy galvanised nails.

12.5.3 Rusting can be useful

Not all rusting is bad. You can buy, from a pharmacy, hand warmers, which are commonly used by skiers and campers. These packages produce heat when you shake them. The contents of the packet include powdered iron, water, salt and sawdust. When the packet is shaken vigorously, the iron undergoes a rusting reaction, which produces heat.

INVESTIGATION 12.10

Preventing rust

AIM: To investigate surface protection to prevent rust

You will need:

6 new iron nails
6 test tubes
test-tube rack
nail varnish and remover
vaseline
2 cm long strips of zinc, magnesium ribbon and copper
salt water
permanent marker pen

- Check that the nails do not show any signs of rusting; replace any that do.
- Put the test tubes in the rack and use the felt pen to number them 1 to 6.
- Prepare the nails as follows and then place them into separate test tubes.
  1. Nail left unaltered (this is your control)
  2. Nail painted with two coats of nail polish, letting it dry between coats
  3. Nail covered with a thick layer of vaseline or other grease
  4. Nail with magnesium strip coiled around it
  5. Nail with copper strip coiled around it
  6. Nail with zinc strip coiled around it
- Fill the test tubes with salt water so that the nails are completely covered. Mark the water levels with the pen.
- Leave for several days, adding salt water as required to keep the water level at the marks on the test tubes.
- Remove the nails and examine them closely, using the control for comparison. You will first need to remove the nail polish from nail 2 with nail polish remover and wipe the vaseline from nail 3.

Discussion

1. Rank the nails in order from least corroded to most corroded.
2. Which of the metals — magnesium, copper or zinc — prevented the formation of rust on the nail?
3. Describe the appearance of the magnesium, copper and zinc strips after they have been removed from their nails. Account for the changes in their appearance.

HOW ABOUT THAT!

When the Sydney Harbour Bridge was completed in 1932, it was initially given three coats of paint — 272 000 litres worth — to protect it from rust. However, as the paint is degraded by the UV radiation in sunlight, the bridge has needed to be continuously repainted ever since to maintain its rust-free condition. That's a lot of paint!

[Below] Painting the Sydney Harbour Bridge is a never-ending job.

12.5 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the terms 'corrosion', 'rusting and 'surface protection'.
2. **Explain** what galvanised iron is and what advantage it has over iron.
3. **Describe** the conditions that lead to rusting.
4. **Explain** why steel-hulled vessels used in the ocean rust faster than those used in fresh water.

Think

5. **Explain** why rusting occurs faster near Botany Bay than in areas further away from the sea.
6. **Discuss** how galvanising can protect iron from rusting if the zinc coating corrodes more quickly than the iron.
7. **Suggest** why the powdered iron in handwarmers used by skiers and campers rusts much more quickly than an iron nail.
8. When a car gets chips in its paintwork, why do you think it is important for them to be covered again either with paint or varnish?

Investigate

9. Do other metals corrode in the same way that iron does? Design an experiment to find the answer to this question using strips of copper, magnesium, zinc, lead and aluminium. Use sandpaper to remove any coating caused by corrosion from the metal strips; they should be shiny to start with.
10. Corrosion is found in many places. Survey your school for rust spots. **Account** for your findings.
11. If you have access to an old car, survey it carefully and record all the rust spots on the car. **Explain** why some parts of the car are more likely to rust.
12. Aluminium corrodes quite quickly, yet it is used to make soft-drink cans. **Investigate** why aluminium cans are not corroded by the drinks they store.
13. Use the **How rust works** weblink in the Resources tab to watch a video about rust and the corrosion of iron.

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Complete this digital doc: Worksheet 12.4: Rusting (doc-0000)

Explore more with this weblink: How rust works

12.6 Feel the burn

Burning is a chemical reaction that involves combining oxygen with a fuel, which usually produces heat and gases. Reactions that involve oxygen as a reactant are called **combustion** or **oxidation** reactions.

Many other oxidation reactions can occur. The rusting of iron to form iron oxide is an oxidation reaction. In fact, rusting could correctly be described as a very slow type of burning reaction!

HOW ABOUT THAT!

A *backdraught* occurs when a fire in a closed room dies down because it has been starved of oxygen, but flammable gases continue to stream out of the hot materials in the room. When a door to the room is opened, air is quickly drawn inside, restoring the supply of oxygen and allowing the fire to reignite. The resulting fire consumes all the flammable gases in a few seconds and produces sufficient heat to ignite any remaining materials in the room. This is very dangerous to firefighters.

12.6.1 Burning fossil fuels

When a **fossil fuel** reacts with oxygen, heat is produced, along with carbon dioxide and water vapour. Fossil fuels are those fuels that are formed from the remains of living things. Petrol, natural gas and coal are fossil fuels.

The oxyacetylene torch

To obtain temperatures as high as 3000 °C — hot enough to melt iron and weld metals — acetylene fuel is mixed with pure oxygen in an oxyacetylene torch.

acetylene + oxygen → carbon dioxide + water

An oxyacetylene torch is used in construction work.

The car engine

Car engines work by the combustion of petrol or gas in the cylinders. A mixture of air and fuel is drawn into each cylinder and ignited by a spark from the spark plug. The fuel reacts rapidly with oxygen in the air. The resulting explosion pushes the piston, which turns the drive shaft. The products of the reaction, carbon dioxide and water vapour, leave the car engine through the exhaust pipe.

Rocket fuels

Liquid and solid fuels are both used in spacecraft. When these fuels are burned, they provide sufficient thrust to launch a space shuttle into orbit hundreds of kilometres from Earth. Liquid hydrogen and liquid oxygen react to power the shuttle's main engines.

hydrogen + oxygen → water

Most of the thrust required to launch the shuttle into orbit comes from chemical reactions in the solid fuel, which is located in the solid rocket boosters. In space, liquid fuel such as hydrazine is oxidised to produce an enormous volume of gas. As the gas is released, the rocket is thrust forwards. By controlling the direction of the thrust, it is possible to steer the rocket.

Oxidation reactions provide the thrust to launch a space shuttle.

INVESTIGATION 12.11

Burning magnesium

AIM: To observe combustion of magnesium

You will need:

safety glasses
Bunsen burner, heatproof mat and matches
tongs
2 cm piece of magnesium ribbon
sandpaper

- If the magnesium ribbon is dull, use sandpaper to remove the dull layer.
- Hold the magnesium ribbon with tongs in the Bunsen burner flame.

CAUTION: Do not look directly at the flame — eye damage may occur.

- After burning the magnesium metal, observe the product of burning that is left.

Discussion

1. Describe the magnesium metal before burning.
2. During burning, the magnesium reacted with oxygen in the air by combining with it to form magnesium oxide. Describe the magnesium oxide.
3. How do you know that a chemical reaction has taken place?
4. Write a word equation for the chemical reaction.

INVESTIGATION 12.12

Burning paper

AIM: To observe the combustion of paper

You will need:

Bunsen burner, heatproof mat and matches
safety glasses
tongs
gas jar
limewater
paper
deflagrating spoon

- Pour 10 mL of limewater into the gas jar.
- Put a ball of scrunched-up paper into the deflagrating spoon.
- Light the paper and lower it into the gas jar.
- When burning has stopped, remove the deflagrating spoon and cover the jar.
- Shake the gas jar and observe the colour of the limewater.

Discussion

1. What happened to the limewater?
2. What gas was given off by the burning paper?

12.6 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Define** the term ‘burning’.
2. **Explain** what evidence there is that burning is a chemical reaction.

3. **Define** the term ‘fossil fuel’. List three examples of fossil fuels.
4. List and **describe** three examples of useful oxidation reactions.
5. Write a word equation for each of the examples in question 4.
6. Is rusting an example of burning? **Explain.**
7. **Recall** the three different one-word names given to the chemical reactions in which fuels react with oxygen.

Think

8. Complete this word equation.
   fuel + ___________ → ___________ + **water vapour**
9. Name at least one fuel that is *not* a fossil fuel.
10. The hydrogen and oxygen used to launch space shuttles are cooled so that they are stored as liquids. **Explain** why the water produced in the reaction between the liquid hydrogen and liquid oxygen is in the form of a vapour rather than a liquid.
11. Can cell respiration be described as burning? **Explain**.

Investigate

12. Fire has always been present in Australia and is a major cause of change in the environment. Find out how Australian Aborigines traditionally used fire to benefit themselves and the environment.
13. Fire extinguishers are used to fight fires. One type of fire extinguisher, the soda–acid type, is commonly found in public buildings. When this fire extinguisher is turned upside down, a chemical reaction takes place inside the fire extinguisher to produce the liquid that spurts out of the nozzle. **Investigate** what is inside the soda–acid fire extinguisher and **explain** how it works. **Construct** a poster on how this fire extinguisher works.

Create

14. Choose one fuel from the list below and **construct** a poster on the use of this particular fuel. Include in your poster where it comes from, what it is used for and a word equation for its oxidation reaction.

methane	ethanol
butane	propane
kerosene	lignite
diesel	acetylene

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Complete this digital doc: Worksheet 12.5: Combustion (doc-0000)

12.7 Acids and bases

Acids and **bases** are two groups of chemicals that affect you every day. In your stomach, acids help to digest your food, and, in your mouth, bacteria produce acids that can destroy the enamel of your teeth. Most cleaning agents, including soap, are bases that can dissolve oil and grease from surfaces.

Some common acids and bases are found around the home.

In industry, acids are used to produce a wide range of products including drugs, explosives, fertilisers and plastics.

The products shown in the photographs below are examples of acids and bases that can be found around the home.

12.7.1 Sour and bitter

Many of the foods you eat contain acids. Tomatoes, citrus fruits, vinegar and lemonade are all acidic. Acids have a sour taste; in fact, the name acid comes from the Latin word *acidus* meaning 'sour'. Some acids, like the acid found in car batteries (sulfuric acid), are very **corrosive**. They react with solid substances, 'eating' them away.

Bases have a bitter taste and feel slippery or soapy to touch. Some bases are very corrosive, especially caustic soda (sodium hydroxide). Caustic soda breaks down fat, hair and vegetable matter and is the main ingredient in drain cleaners. Other bases are used in soap, shampoo, toothpaste, dishwashing liquid and cloudy ammonia as cleaning agents. Bases that can be dissolved in water are called **alkalis**. Some common acids and bases are listed in the tables below.

Acid–base **indicators** are substances that can be used to tell whether a substance is an acid or a base. Some common indicators are listed in the table below. Acid–base indicators react with acids and bases and produce different colours in each. Some of them are natural dyes, while others are artificially made.

Common acids and bases

Acid	Uses
Hydrochloric acid	• To clean the surface of iron during its manufacture • Food processing • The manufacture of other chemicals • Oil recovery
Nitric acid	• The manufacture of fertilisers, dyes, drugs and explosives
Sulfuric acid	• The manufacture of fertilisers, plastics, paints, drugs, detergents and paper • Petroleum refining and metallurgy
Citric acid	• Present in citrus fruits such as oranges and lemons • Used in the food industry and the manufacture of some pharmaceuticals
Carbonic acid	• Formed when carbon dioxide gas dissolves in water • Present in fizzy drinks
Acetic acid	• Found in vinegar • The production of other chemicals, including aspirin

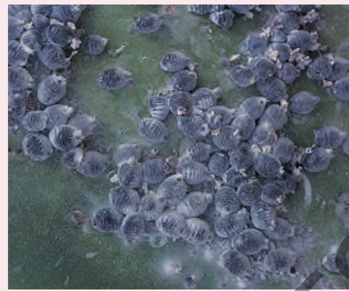
Base	Uses
Sodium hydroxide (caustic soda)	• The manufacture of soap • As a cleaning agent
Ammonia	• The manufacture of fertilisers • As a cleaning agent
Sodium bicarbonate	• To make cakes rise when they cook

Indicators and their colours in acids and bases

Indicator	Colour in acid	Colour in base
Methyl orange	Orange	Yellow
Litmus (made from lichens)	Red	Blue
Bromothymol blue	Yellow	Bluish-purple
Phenolphthalein	Colourless	Pink
Red wine	Red	Green
Red cabbage juice	Red	Yellow

HOW ABOUT THAT!

Cochineal is a red dye made from the dried and ground-up bodies of female scale insects (*Dactylopius coccus*). These insects live on cactus plants in Mexico. Cochineal is used as a food colouring but is also an acid–base indicator.

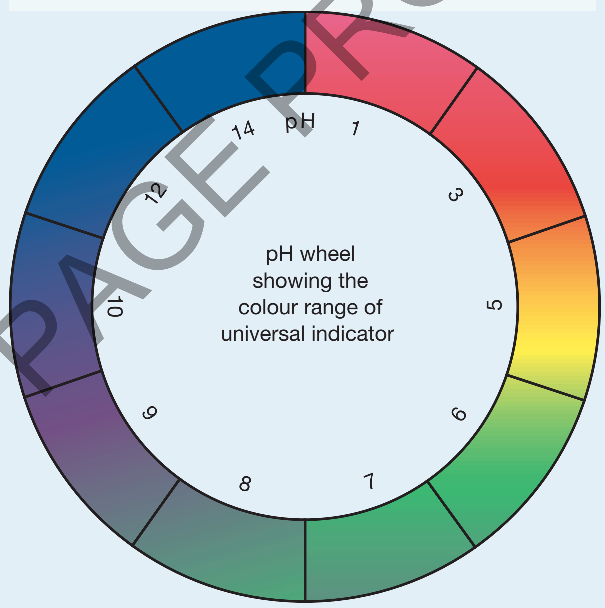

An unusual indicator — *Dactylopius coccus*

MEASURING PH

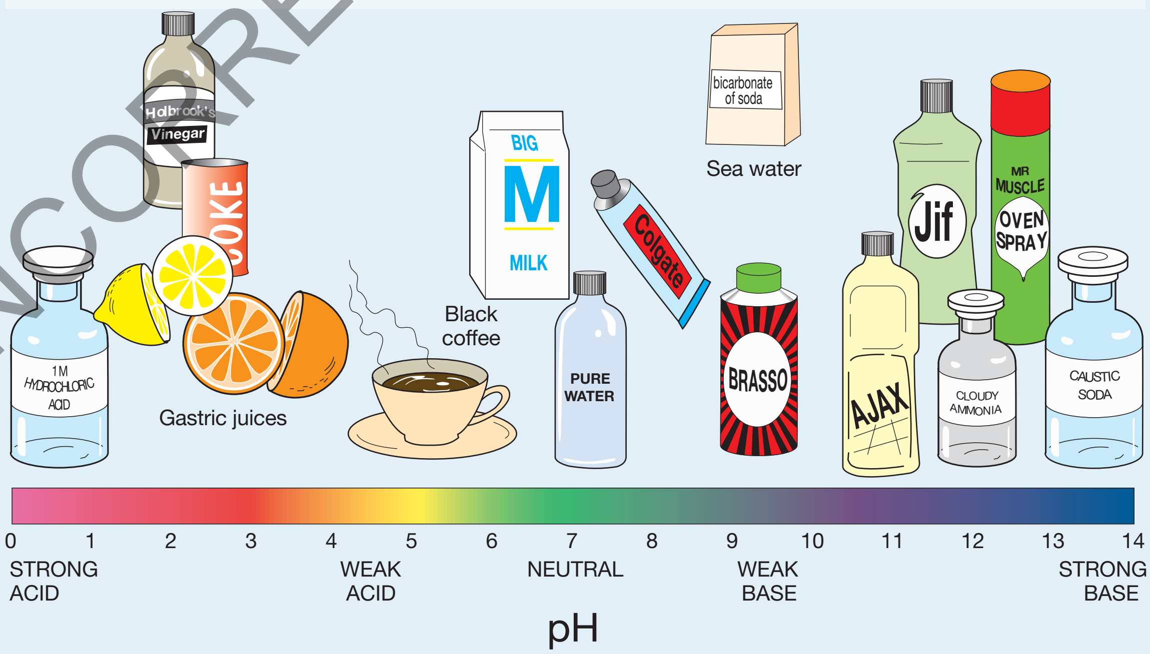
You can describe how acidic or basic a substance is by using the numbers on the **pH scale**. The pH scale ranges from 0 to 14. Low pH numbers (less than pH 7) mean that substances are acidic. High pH numbers (more than pH 7) mean that substances are basic. If a substance has a pH of 7 it is said to be neutral — neither acidic nor basic. This is shown on the pH scale below. Acids and bases can be graded from strong to weak. For example, a strong acid has a very low pH (pH 0 or 1) and a strong base has a very high pH (pH 13 or 14).

pH can be measured using a pH meter or a special indicator called universal indicator. Universal indicator is a mixture of indicators and it changes colour as the strength of an acid or base changes. The colour range of universal indicator is shown at right.

The colour range of universal indicator. It is pink in strong acid (pH 1), blue in strong base (pH 14) and green in neutral solutions (pH 7).



The pH values of some common substances



12.7.2 Garden-grown indicators

Hydrangeas are a popular hedging plant in Australia, producing clusters of flowers. While white hydrangeas stay the same colour all the time, the flowers of the coloured variety change shade according to the pH of the soil in which it is growing. If the soil has a pH of about 5 or less, the hydrangea's flowers will be blue-violet. As the soil becomes less acidic, the flowers change to a bright pink. The colours of the hydrangeas can be purposely changed over a few months by adding different substances to the soil. If you add iron or aluminium sulfate to the soil of a pink hydrangea, the flowers will become blue. If you have blue flowers and want them pink, calcium carbonate can be added.

Hydrangeas are pH sensitive.

12.7.3 Neutralisation reactions

When an acid and a base react with each other, the products are neither acids nor bases. Such a reaction is called a **neutralisation** reaction. Water is always one of the products of a neutralisation reaction. The word equation for a neutralisation reaction is:

acid + base → salt + water

Sometimes, a gas is produced as well as a salt and water. For example, when hydrochloric acid is added to sodium hydroxide, water and sodium chloride are produced. Both of these substances have a neutral pH:

hydrochloric acid + sodium hydroxide → water + sodium chloride

To neutralise something means to stop it from having an effect. To stop an acid from having an effect, a base can be added to it. Similarly, to stop a base from having an effect, an acid can be added. So, the pain caused by the acidic sting of an ant can be relieved by adding a weak base, such as sodium bicarbonate (baking soda). Adding a weak acid such as vinegar can relieve the pain caused by the alkali in the sting of a wasp.

HOW ABOUT THAT!

Indigestion is a very old problem and, without an antacid tablet in sight, many ancient civilisations developed some very interesting ways of treating it. The Egyptians recommended crushing a hog's tooth and putting it inside of four sugar cakes, which they would then eat. They also believed that swallowing crushed and powdered limestone would help. Interestingly enough, scientists believe that this last one may have worked because the main component of limestone is calcium carbonate. Favourite treatments in medieval England were a bit yummier and involved chewing mint leaves or drinking teas brewed from thyme or pomegranate peel.

12.7.4 When your stomach rumbles

Have you ever had **indigestion**? Do you burp? Does your stomach rumble? These things happen as a result of the chemical reactions in your stomach.

Your stomach contains hydrochloric acid, which helps food digestion. However, if it becomes too acidic you may experience a burning feeling. This is called indigestion. The treatment for indigestion is to take an **antacid** powder or tablet. An antacid contains a base, which neutralises the excess acid in the stomach and relieves the pain. As in all neutralisation reactions, a salt and water are produced. One commonly used antacid is milk of magnesia. It consists of a solid base, magnesium oxide suspended in water. The base reacts with the hydrochloric acid in your stomach. The word equation for this chemical reaction is:

$$\underset{\textbf{base}}{\textbf{magnesium oxide}} + \underset{\textbf{acid}}{\textbf{hydrochloric acid}} \rightarrow \underset{\textbf{salt}}{\textbf{magnesium chloride}} + \textbf{water}$$

The products are magnesium chloride (a salt), and water.

INVESTIGATION 12.13

Antacids

AIM: To investigate the effect of an antacid on pH

You will need:

safety glasses
heatproof mat
100 mL conical flask
universal indicator
0.05M hydrochloric acid solution
spatula
antacid powder (e.g. Eno salts or Mylanta)

- Pour some hydrochloric acid into the conical flask.
- Add 2 or 3 drops of universal indicator.
- Note the colour of the solution, and determine its pH.
- The acid in the conical flask represents the stomach fluids.
- Add a spatula of antacid powder to the conical flask and gently swirl the flask.
- Observe the reaction and note the colour of the solution and the pH.

Discussion

1. What happened to the pH of the solution when the antacid was added?
2. Was the level of acidity reduced by the antacid?

12.7 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Recall** at least three uses of acids and three uses of bases.
2. How can acids be **distinguished** from bases?
3. **Compare** the common properties of some acids and bases.
4. **Describe** the difference between a base and an alkali.
5. What is a neutralisation reaction?
6. **Recall** which acid or base is used:
   (a) to make cakes rise
   (b) in fizzy drinks
   (c) in drain cleaners
   (d) in vinegar

(e) in cleaning agents
(f) in car batteries.
7. **Define** the term 'acid–base indicator'.
8. **Explain** how antacids relieve indigestion.
9. **Explain** what causes the burning sensation in your stomach when you have indigestion.
10. **Recall** which type of substance has a pH value:
(a) less than 7 (b) more than 7 (c) equal to 7.

Think

11. When you take antacid tablets for an upset stomach, does the pH of your stomach contents increase or decrease? **Explain** your answer.
12. What is the pH of soil that produces pink hydrangeas?
13. Is aluminium sulfate an acid or a base? **Explain** your answer.
14. Some antacids containing calcium carbonate produce a gas as they work, making you burp. What gas is most likely produced?
15. What would be the result of putting vinegar on a bee sting?
16. **Explain** why our stomachs are not damaged when we consume acidic food and drinks.

Create

17. Design and **construct** a hazard warning label for a:
(a) bottle of concentrated hydrochloric acid
(b) car battery
(c) bottle of drain cleaner that contains mainly caustic soda.

Use data

18. A pH meter was used to measure the pH of five different substances, and the results are shown in the table below. **Identify** which substance could be:
(a) a weak base
(b) vinegar
(c) pure water
(d) a strong base.

Substance	A	B	C	D	E
pH value	6.0	12.0	3.0	7.0	8.0

19. Which two of the substances in question 18 would you expect to be the most corrosive? **Justify** your answer.
20. **Construct** a bar graph to display the pH values of the five substances in question 18.

Investigate

21. **Investigate** what a peptic ulcer is, how it is caused and how it can be treated.
22. Play the **pH rainbow** interactivity in the Resources tab and drop liquids in their correct positions on the pH scale.

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Complete this digital doc: Worksheet 12.6: Acids and bases (doc-0000)

Try out this interactivity: pH rainbow (int-0101)

12.8 Acid rain

Science as a human endeavour

It's hard to believe that rain is responsible for the deterioration of the statue in the picture below. Of course, this isn't just normal rain but **acid rain** — rain that has a very low pH. In heavily industrialised areas of the world, acid rain is a huge problem not just for the damage that it does to statues and buildings but also for the entire ecosystem of these regions. Forests, crops and lakes in neighbouring non-industrial regions are also affected by acid rain blown in from industrial areas.

You can see the damaging effects of acid rain on this statue.

1908

1969

12.8.1 What causes acid rain?

While distilled water is neutral (pH = 7), normal rain is slightly acidic with a pH of about 5.7. This is because the rain reacts with carbon dioxide in the air to produce a dilute form of carbonic acid — the same acid that forms in fizzy soft drinks:

water + carbon dioxide → carbonic acid

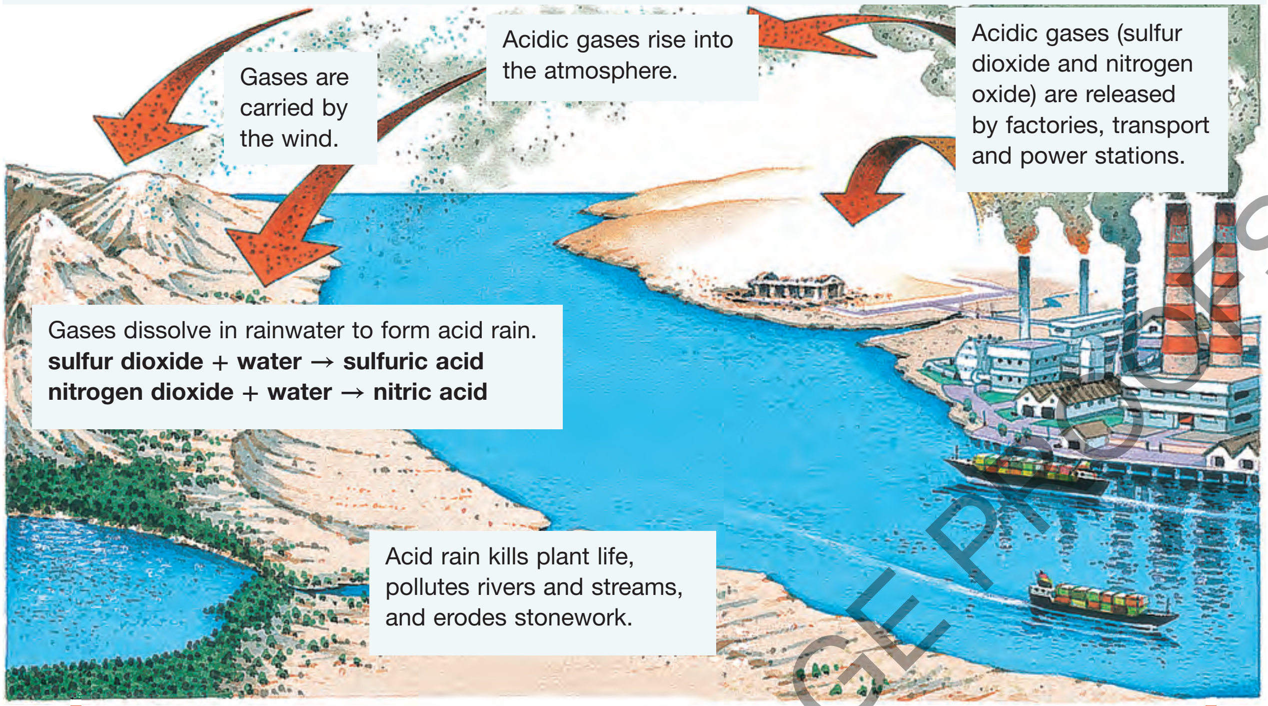
However, if concentrations of sulfur dioxide and nitrogen oxide in the atmosphere are high, these gases react with water in the air to produce sulfuric, nitric and other acids. When the rain falls, it is far more acidic than it would normally be and is known as acid rain. The lowest pH recorded for acid rain is 2.1.

If acid rain falls as snow, **acid snow** can build up on mountains. When this snow melts, huge amounts of acid are released in a short time into waterways.

12.8.2 Where do the gases come from?

Most of the gases that cause acid rain come from the burning of fossil fuels (natural gas, oil and coal) in industry, power stations, the home and cars. North America and Europe have a greater problem with acid rain because they use coal with a higher sulfur content than Australian coal. The sulfur dioxide released by volcanoes also contributes to acid rain.

The formation and effects of acid rain



When acid rain eats into buildings and statues, it is reacting with calcium carbonate in the marble or limestone.

calcium carbonate + acid rain → gypsum + water + carbon dioxide

The gypsum formed by acid rain on a statue is a powdery dust (calcium sulfate), which is washed away by the rain and the statue is slowly eaten away.

Acid rain damages the cells on the surface of leaves and affects the flow of water through plants. It also makes plants more likely to be damaged by frosts, fungi and diseases. In northern Europe, entire forests have died as a result of acid rain.

Acid rain collects in streams, rivers and lakes, making the water more acidic. Acid rain causes the pH of lakes to fall. Some aquatic plants and animals cannot tolerate these acidic conditions and die.

'Dead lakes' are lakes and water bodies in which the pH of the water has been reduced so much by acid rain falling into them that they no longer support animal or plant life. These lakes may have a pH as low as 4.1.

INVESTIGATION 12.14

Investigating acid rain

AIM: To model the effect of acid rain on plant growth

Design and carry out an experiment to investigate the effect of acid rain on the growth of plants.

You will need:

empty milk cartons
potting soil
distilled water
vinegar (or 0.1M hydrochloric acid solution)
measuring cylinder
seeds (such as lucerne, peas, cress and beans)
universal indicator

- Cut the milk cartons so that they are about 10 cm high. These will make suitable containers for growing the seeds, five seeds per container.
- Test the effect of water with different pH values on the growth of the seeds. To ensure that your tests are fair, you will need to keep everything the same in your experiment, except the one thing that you are varying. In this case you are varying the acidity (pH) of the water that you are putting on the plants.
- Prepare a report on your investigation. This could be a written report, a video, a wall chart or an oral presentation.

12.8.3 Solving the problem

The problem of acid rain and all the damage that it causes can be solved only by reducing the release of acidic gases into the air. Some ways of doing this include:

- looking for alternative ways of producing electricity
- encouraging people to use public transport or to car pool.
- using low-emission vehicles
- ensuring that all industrial chimneys are fitted with well-maintained emission scrubbers
- coal 'cleaning', in which coal is pulverised and sulfur-laden minerals are removed
- using low-sulfur coal in power plants
- fluidised bed combustion, a process where coal is passed over a bed of limestone as it is burned, allowing sulfur dioxide to be absorbed and, therefore, decreasing the amount of sulfur entering the atmosphere.

HOW ABOUT THAT!

The connection between atmospheric pollution and acidic rain was first made in Manchester in 1852 by the Scottish chemist Robert Angus Smith. However, the term 'acid rain' was not actually used until the 1970s when the phenomenon became more common.

12.8 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

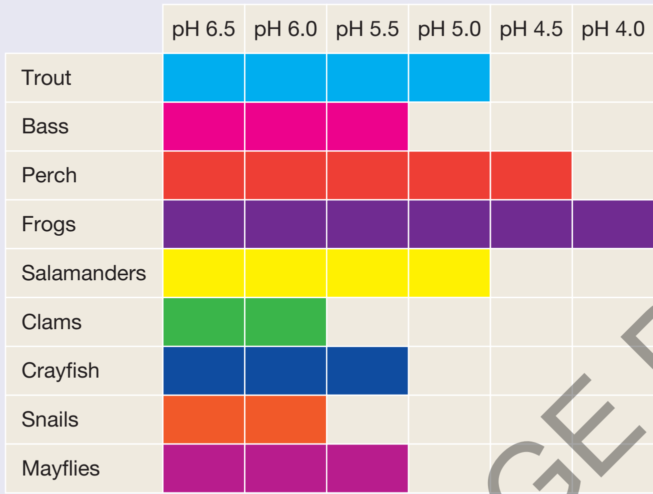
Remember

1. **Define** the term 'acid rain', and **explain** how it is produced.
2. **Explain** why rain is slightly acidic even without air pollution.
3. **Describe** two different ways in which acid rain can harm the plants and animals in streams and lakes.
4. Complete this word equation.

   acid rain + calcium carbonate → ___________

Think

5. Motor vehicles make a large contribution to the acid rain problem. Most of them use fuel that releases acidic nitrogen oxides when it is burned. Write an account that **discusses** how motor vehicle pollution could be reduced over the next thirty years.
6. The diagram below shows the organisms that are normally found in a particular lake and the pH of water that they are able to tolerate.



   (a) Which of these species would start to die first if the lake water started to increase in acidity?
   (b) Which of the species is the most tolerant of high acid levels in the lake? **Explain**.
   (c) Which species would remain if the acidity of the lake water increased until it had a pH of 5.0?

Create

7. Write a newspaper article that **analyses** the devastation caused by acid rain.
8. **Construct** a wall chart that explains how acid rain is formed in our environment and the damage that it can cause.

Investigate

9. Use the library to **investigate** which countries are most affected by acid rain.
10. **Investigate** how damage caused by acid rain could be stopped or at least reduced.
11. Flue gas desulfurisation 'scrubbers' are used to remove sulfur dioxide from burned coal, reducing the amount that enters the atmosphere. Research this process and answer the following questions.
   (a) What are the main components of these scrubbers?
   (b) What are the government guidelines concerning the fitting of these devices to industrial chimneys? Are they compulsory in Australia?
   (c) What volume of sulfur dioxide is produced by factories and power stations in Australia? How does the volume compare with that produced by other countries?
   (d) What penalties are levied against producers of emissions? Which government department or authority is in charge of investigating polluters?

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Watch this eLesson: The rain is burning!: See some of the destruction that acid rain has caused on Earth. Learn why acid rain is created and how we can stop it from occurring.
Searchlight ID: eles-0065

Complete this digital doc: Worksheet 12.7: Acid rain (doc-0000)

12.9 Review

12.9.1 Chemical Changes

- **recall** the physical changes that matter may undergo 12.1
- **compare** a chemical change with a physical change 12.1
- **define** the term 'chemical reaction' 12.2
- **describe** how you can tell if a chemical reaction has taken place 12.2

12.9.2 Describing reactions

- **construct** word equations to describe chemical reactions 12.2
- **define** the term 'precipitate' 12.2
- **distinguish** between reactants and products 12.2
- **identify** the reactants and products in word equations 12.2
- give two examples each of combustion (oxidation), synthesis, decomposition and displacement reactions 12.2

12.9.3 Reaction rates

- **define** the term 'reaction rate' 12.3
- **describe** processes that allow the rate of a chemical reaction to be changed 12.3
- **distinguish** between processes that speed up a reaction and those that slow a reaction 12.3
- **explain** why increasing temperature, surface area or concentration makes a reaction occur faster 12.3

12.9.4 Common reactions

- **explain** the process of rusting 12.4
- **compare** rusting and combustion 12.4, 12.5
- **describe** how rusting can be prevented or slowed 12.4
- **construct** word equations to describe common oxidation reactions 12.5

12.9.5 Acids and bases

- **distinguish** acids from bases and alkalis 12.6
- **describe** the function of acid–base indicators and give three examples of these indicators 12.6
- **identify** acids, neutral substances and bases (alkalis) according to their pH 12.6
- **explain** how antacids settle a rumbling stomach 12.6
- **describe** what is meant by neutralisation 12.6
- **discuss** the causes of acid rain and its effects on the environment 12.7

Individual pathways

ACTIVITY 12.1
Revising chemical changes
doc-10573

ACTIVITY 12.2
Investigating chemical changes
doc-10574

ACTIVITY 12.3
Investigating chemical changes further
doc-10575

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FOCUS ACTIVITY

Imagine that you live near a factory or power station that is producing acidic gases and causing harm to the environment. You wish to be elected to the local government board to stop this problem. Write a speech that you could give at an election meeting to clarify the issue.

Access more details about focus activities for this topic in the Resources tab.

12.9 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. **Identify** each of the following as either a chemical or a physical change.
   (a) The wax on a burning candle melts.
   (b) The wax vapour at the top of candle wick burns with oxygen to produce carbon dioxide, water vapour and heat.
   (c) Calcium carbonate is dissolved by hydrochloric acid to form calcium chloride, water and carbon dioxide gas.
   (d) Hydrogen gas explodes with oxygen gas to form water.
2. Write word equations for each of the chemical changes in question 1.
3. **Explain** how you know that:
   (a) toasting bread is not a physical change
   (b) rusting of a nail is not a physical change.
4. Some chemical reactions can be useful. **Recall** three examples of useful chemical reactions.
5. Catalysts are sometimes added to the reactants taking part in a chemical reaction.
   (a) **Define** the term 'catalyst'.
   (b) When a word equation is written to describe a chemical reaction, catalysts are not included as either reactants or products. **Explain** why.
6. Rusting is an example of a slow chemical reaction.
   (a) **Recall** the three reactants of rusting.
   (b) **Identify** the product of the rusting reaction.
7. For each of the following reactions, **propose** methods to make the reaction happen more quickly.
   (a) Burning a pile of dry leaves
   (b) Cooking potatoes
   (c) Dissolving marble chips in acid
   (d) Removing a stain using bleach
   (e) Making an iron nail go rusty
   (f) Letting milk go sour
8. Just as chemicals can be grouped or classified, so can chemical reactions. **Recall** the names given to the following two groups of chemical reactions.
   (a) Reactions of metals with oxygen
   (b) Reactions of acids with bases
9. Imagine that you are given a safe, but unknown, liquid and are asked to decide if it is an acid, a base or neutral. You are provided with an acid–base indicator that is safe to use, but it does not have a label on it. You don't know what the colour changes to the indicator mean.
   Outline a step-by-step procedure to describe how you could find out whether the substance is an acid, a base or neutral. You are permitted to use common substances found in just about any kitchen.

10. Each of the four photographs below (a, b, c, d) shows a chemical reaction taking place. **Compare** these chemical reactions.

(a)

(b)

(c)

(d)

11. Some chemicals react as soon as they come into contact with each other. Others need a trigger to get them started. **Identify** two things that can trigger a combustion reaction.
12. The setting of concrete is a chemical reaction that takes place between concrete and water. It is a very slow reaction. Give at least two reasons why scientists may be asked to find ways to speed up the reaction.

13. The oxyacetylene torch shown here is used to melt metals to allow them to be joined together.
    (a) **Identify** what type of chemical reaction takes place in the oxyacetylene torch.
    (b) What evidence is there in the photo that may help you **justify** your answer to part (a)?
14. Many dentists believe that the increase in cavities in young adults is due to the increased consumption of soft drinks at a younger age. They theorise that a chemical reaction takes place between the tooth enamel and the acid in the soft drink.
    (a) **Recall** what acid is found in soft drinks.
    (b) **Design** an experiment that will allow you to investigate the effects of the soft-drink acid on teeth. (*Hint:* Find out what material(s) teeth are made from.)
15. **Identify** which of the following are displacement reactions and which are synthesis reactions.
    (a) magnesium + oxygen → magnesium oxide
    (b) iron + copper sulfate → copper + iron sulfate
    (c) potassium chloride → potassium + chlorine
    (d) ethane + oxygen → carbon dioxide + water
    (e) lead nitrate + potassium iodide → potassium nitrate + lead iodide

Test yourself

1. Which one of the following would you describe as a chemical change?
   (A) Ice-cream melting in the sun
   (B) A match burning
   (C) Breaking an egg
   (D) Boiling water for a cup of tea **(1 mark)**
2. Which of the following is *not* a reaction with oxygen as one of the reactants?
   (A) Combustion
   (B) Oxidation
   (C) Rusting
   (D) Neutralisation **(1 mark)**
3. Which substance is used to coat iron in the process of galvanisation?
   (A) Gallium
   (B) Zinc
   (C) Paint
   (D) Salt **(1 mark)**

4. Consider this word equation for a chemical reaction:

magnesium + hydrochloric acid → magnesium chloride + hydrogen gas

The reactants in this equation are
(A) magnesium and hydrogen gas.
(B) magnesium chloride and hydrogen gas.
(C) magnesium and hydrochloric acid.
(D) magnesium, hydrochloric acid, magnesium chloride and hydrogen gas. **(1 mark)**

5. Have you ever noticed how things made of silver, such as expensive cutlery, old tea services and even jewellery, get a black film over them if they are not used often? That black film, called silver tarnish, is a form of corrosion that occurs when sulfur in the air reacts with the silver metal forming a blackish layer of silver sulfide. You can see the same thing happening much faster if you use a silver teaspoon to eat an egg at breakfast – the sulfur from the egg yolk comes into direct contact with the silver and tarnish forms on the teaspoon in a matter of minutes.

The good thing is that you can use a bit of knowledge about chemical reactions to remove the tarnish. One of the easier methods of cleaning tarnished silver is to wrap a sheet of aluminium foil loosely around the object and then place it in a tub of warm water that has had bicarbonate of soda (sodium bicarbonate) dissolved in it. It is important that the aluminium foil is completely covered by the warm water and that the warm water can get inside the foil. Over time, aluminium from the foil reacts with the silver sulfide of the tarnish to form aluminium sulfide and silver (which remains on your object).

silver sulfide + aluminium → aluminium sulfide + silver

This reaction can take anywhere between a few minutes and a few hours depending on the size of your silver object and how much tarnish there is to remove. When the tarnish has all gone, the silver object is rinsed in clean water to remove any aluminium sulfide.

(a) **Explain** why hot water rather than cold water is used in this method of cleaning silver. Use your knowledge of particle theory to support your answer. **(1 mark)**
(b) Draw a labelled scientific diagram of the set-up for cleaning silver. **(1 mark)**
(c) Does this method work if you use copper foil rather than aluminium foil? Design an experiment that will allow you to find out. **(2 marks)**
(d) This method normally takes a few hours to work. **Describe** at least two methods you could use to make this process happen faster. Use examples you have encountered in your study so far to **justify** why you think these methods would work. **(2 marks)**

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Complete this digital doc: Worksheet 12.8: Chemical reactions puzzles (doc-0000)

Complete this digital doc: Worksheet 12.9: Chemical reactions summary (doc-0000)