Chemical Reactions

7

Chemical change involves substances reacting to form new substances (ACSSU225):

- ★ identify the differences between chemical and physical changes.
- ★ identify evidence that a chemical change has taken place.
- ★ investigate simple reactions such as combining elements to make a compound.
- ★ recognise that the chemical properties of a substance, for example its flammability and ability to corrode, will affect its use.

A Task

Rust is the chemical reaction of iron with oxygen in the presence of moisture.

Plan and conduct an investigation to answer the question: What effect does salt have on the rusting of a nail?

Antoine-Laurent Lavoisier (1743 - 1794)

Chemistry of Fire

Otto von Guericke, 1650, showed that a candle would not burn in a container from which the air had been removed.

Robert Hooke, 1665, proposed that air had a substance that combined with flammable substances to produce a flame.

Antoine-Laurent Lavoisier, 1772, found that the burning of sulfur produced a heavier substance. He thought that the extra weight was the sulfur combining with a gas in the air that he called 'oxygen'.

Lavoisier was known as the father of modern chemistry. For example, by carefully weighing the reactants and the products he showed that if a piece of wood was burned to ashes, the total mass remained unchanged.

7.1 Chemical change

Physical Change

Physical change happens when a substance changes from one form to another form but keeps exactly the same chemical composition.

A physical change can affect the colour, size, or shape but no new products are formed.

With a physical change the substances keep their property (Salt dissolved in water still tastes salty). Sometimes a physical change can be reversed.

The choc bar is changing from one form, solid, to another form, liquid, but is keeping the same chemical composition. It still tastes the same which suggests a physical change.

Examples of **physical change**:

- A sheet of paper is put through a shredder.
- The particles are always moving.
- A yellow paint is mixed with a blue paint to produce green.
- Salt is mixed with water.
- Cutting bread into slices.
- Boiling water.
- Making lemonade by squeezing lemon juice and adding sugar and water.

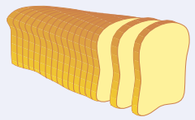
The substance has changed from one form to another but kept the same chemical composition.

Dissolving is always a physical change.

Mixture of sugar, lemon juice, and water with melting ice

Precipitation

Melting ice



Sliced bread

Exercise

1 What is a physical change?

2 Indicate why each of the following are physical changes:

a) The freezing of water (changing from liquid water to solid ice).

b) Dissolving sugar in water.

3 Which of the pictures on the left show a physical change? Explain.

4 Can you think of 10 more examples of physical change?

Chemical Change

Chemical change happens when a new substance is formed.

Chemical change happens when a substance combines with another substance to form one or more new substances.

Chemical change happens when a substance breaks down into two or more substances.

Chemical change is not reversible except with further chemical change.

The rusting of iron is a chemical reaction. Iron combines with oxygen and water to produce a new compound.

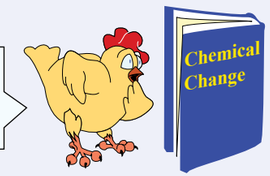
$4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$

Examples of **chemical change**:

- Toasting bread.
- Milk starting to smell bad (bacteria in the milk forming new substances).
- Burning a match.
- Frying an egg.
- Vinegar + baking soda ➔ carbon dioxide.
- A battery producing a current.

Burning is always a chemical change.

This change is irreversible (Try adding carbon dioxide to water and produce vinegar and baking soda).



Frying and egg

Fireworks

Fire

Candle

Exercise

1 What is a chemical change?

2 Indicate why each of the following are chemical changes:

a) The rusting of iron.

b) Toasting bread.

3 Which of the pictures on the left show a chemical change? Explain.

4 Can you think of 10 more examples of chemical change?

Chemical Change

The following evidence can suggest that a chemical, chemical reaction, has taken place:

- Change of colour.
- Change in temperature.
- Change of smell.
- Change of form.
- Production of gases.
- Production of a precipitate.
- Decomposition of organic material.
- Light or sound is produced.

Although the above changes may suggest that a chemical change has taken place, the only conclusive evidence of a chemical change is a chemical analysis.

Temperature

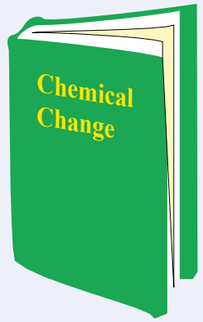
Many reactions either produce energy or absorb energy. A reaction that produces energy will become warmer. A reaction that uses energy will become cooler.

Reactions that produce heat are called **exothermic** reactions. The burning of of fossil fuels such as coal, oil, and gas produces heat. These are **exothermic** reactions.

Reactions that absorb heat are called **endothermic** reactions.

Exothermic and Endothermic

Watch online videos about exothermic and endothermic reactions.



Chemical change

Watch online videos on 'chemical change' and evidence/indications of chemical change.

The burning of wood, an exothermic reaction, is essentially the reaction of cellulose (a sugar), and oxygen to produce carbon dioxide and water. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Activity

Vinegar and baking soda

Materials: Vinegar, baking soda, thermometer, clear small container.

Method:

a) Place about 10 ml of vinegar in a clear container. Add a thermometer and record the temperature of the vinegar.

c) Add about half a teaspoon of baking soda. Record the temperature during the reaction.

d) Is the reaction of vinegar and baking soda an exothermic or endothermic reaction?

Colour Change

A colour change can suggest that a chemical reaction has taken place.

The rusting of iron is evidenced by the typical reddish-brown rust colour.

The colour change due to the ripening of fruit is caused by enzyme reactions. These reactions also change the taste and smell of the fruit.

The colour change of ripening fruit.
Are ripe fruits sweeter than unripe fruits.

Activity

Milk and colour

Materials: Milk, plate, food colouring, detergent, cotton buds.

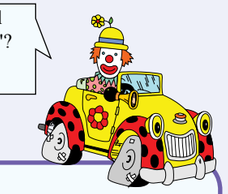
Method:

a) Cover the plate with milk.

b) Add a drop of each food colouring close together in the centre of the plate.

c) Put a drop of detergent on the end of a cotton bud and place it in the middle of the milk and hold for about 20 seconds.

The colours follow the reactions of the detergent with the milk. The detergent breaks apart the water, proteins, and fats in the milk. The detergent chases the fat molecules.



Challenge

Endothermic reactions

An everyday example of an endothermic reaction are cold packs. Bend the pack and the pack becomes cold.

What chemical substances are in the pack?

Challenge

Colour change

Is it possible to have a colour change without a chemical change?

Can you provide five examples?

Exercise

1 Give 5 kinds of evidence that might suggest that a chemical change has taken place?

2 What is an exothermic reaction?

3 What is an endothermic reaction?

4 The rusting of iron can be summarised by the symbolic equation:

$4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$

a) What is the symbol for iron?

b) What is the evidence that rusting is a chemical change?

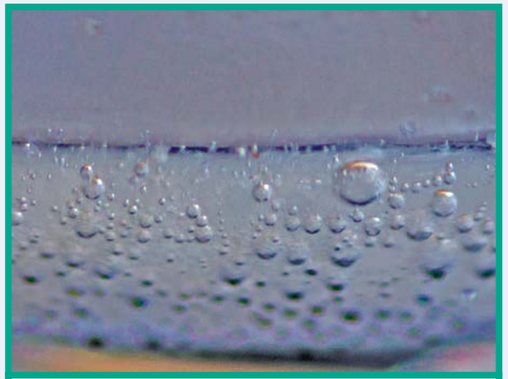
5 What is the evidence that the ripening of fruit is a chemical change?

Bubbles

Bubbles can suggest that a chemical reaction is producing a gas.

Bubbles can also indicate a physical change. The bubbles in softdrink is carbon dioxide being released after being dissolved in the drink.

Bubbles are also produced when water is boiled. Boiling water is a physical change.



The reaction of vinegar and baking soda producing bubbles of carbon dioxide gas. The bubbles slow in activity as either the vinegar or baking soda are used up in the reaction.

Challenge

Bubbles

Is it possible to have bubbles without a chemical change?

Can you provide five examples?

Challenge

Coke-Cola

The reaction between vinegar and baking soda is similar to the reaction between coke-cola and baking soda.
Vinegar is an acid (acetic acid).
Is coke-cola an acid?

What is a test for an acid?

Activity

Coke-Cola and baking soda

Materials: Coke-cola, baking soda, thermometer, clear small container.

Method:

a) Place about 10 ml of coke-cola in a clear container. Add a thermometer and record the temperature of the coke-cola.

b) Add about half a teaspoon of baking soda. Record the temperature during the reaction.

c) Is the reaction of coke-cola and baking soda an exothermic or endothermic reaction?

d) Are bubbles (gas) produced?

Smell

When two or more substances react, a smell, scent, or odour can be produced.

The smell of decomposing organic material suggests that chemical reactions are involved as organic material decomposes/rots.

As many chemical reactions produce poisonous products the use of smell and taste should be avoided.

Chemical Scientists use their knowledge of physical and chemical properties of substances to develop new substances and determine their composition.

- Relevant school subjects are Science, English, Mathematics.
- Courses generally involve a science university degree.

Light

During a chenical reaction energy can be released in the form of light.

Fireflies, some fungi, and some deep sea animals use chemical reactions to produce light.

Most combustion reactions produce energy in the form of light. Combustion reactions always involve oxygen.

A fire is a combustion reaction.

The combustion of the sparkler with oxygen is producing energy in the form of heat and light.

Sparkler + O_2 ➔ burnt sparkler + energy

Precipitate

When two or more reactants are mixed together and a precipitate falls to the bottom of the container then this provides evidence that a chemical reaction is occurring.

A precipitate is the formation of a solid in a solution during a chemical reaction.

Activity

Precipitate

Materials: Baking soda, calcium chloride, clear containers (plastic cups).

Method:

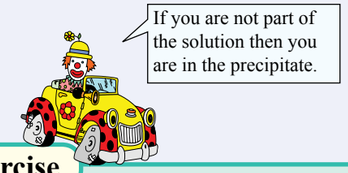
a) Make a solution of about 2 g (half teaspoon) of calcium chloride and 20 mL of water.

b) Make a solution of 2 g (half teaspoon) of baking soda and 20 mL of water.

c) Carefully pour the clear baking soda solution into the calcium chloride solution.

d) Did you notice a precipitate?

e) What is the evidence that a chemical reaction occurred?



Exercise

1 Smell and taste can be used as evidence of a chemical change. Why should the use of smell and taste be avoided?

2 What is combustion?

3 What is a precipitate?

4 Which of the following is a chemical change and which is a physical change?

a) Building a sand castle on the beach.

b) Painting a desk green.

c) Lighting a candle.

d) Cooking biscuits.

e) Bending/snapping a light stick to produce a glow.

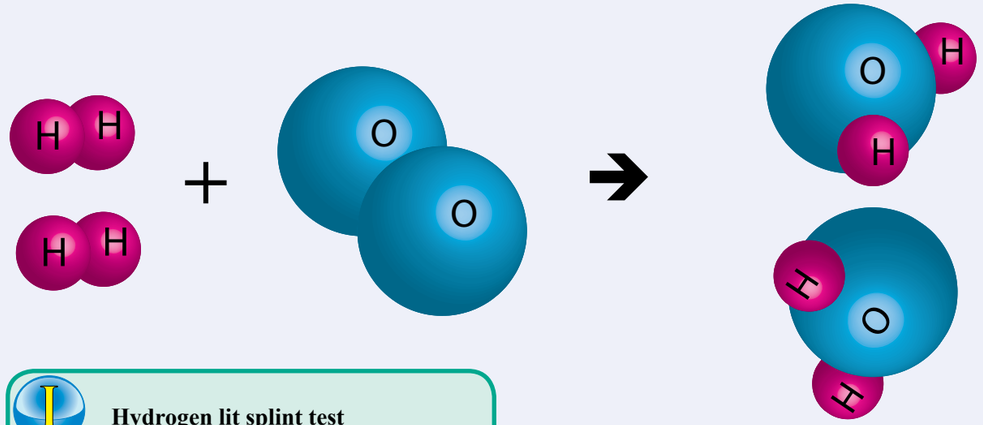
5 The chemical reaction of baking soda and calcium chloride produces a precipitate. The symbolic equation is:

$2NaHCO_3 + CaCl_2$ ➔ $CaCO_3 + 2NaCl + CO_2 + H_2O$

Can you deduce the symbolic formula of the precipitate?

7.2 Simple Reactions

Hydrogen + Oxygen ➔ Water



Hydrogen lit splint test

Watch online videos that show the 'lit splint test for hydrogen'.

Combination

Combination reactions occur when two or more substances combine to form a new substance.

The **reactants** are the starting substances.

The **products** are the result of the chemical reaction.

$$X + Y \rightarrow XY$$

In the above chemical equation, the reactants X and Y combine to form the product XY.

Example:

Using a lit splint to test for hydrogen (In the test, the reactants hydrogen and oxygen combine to produce the product water).

hydrogen + oxygen ➔ water

$2H_2 + O_2 \rightarrow 2H_2O$

Be careful. The reaction of hydrogen with oxygen (lit splint) is explosive even with small amounts of hydrogen.

Activity

Make and Test for Hydrogen

Materials: Dilute hydrochloric acid, zinc, test tube, test tube rack, splint, bunsen burner.

Method:

a) Place a small amount of zinc in a test tube. Add about a quarter of a test tube of dilute hydrochloric acid.

$2HCl + Zn \rightarrow ZnCl_2 + H_2$

b) Light a splint and place it in the mouth of the test tube. If it 'pops' then hydrogen is present.

c) If there is no 'pop' then you probably don't have enough hydrogen. Hydrogen is lighter that air, so catch it with another test tube inverted over the first test tube?

Combustion

Combustion reactions, or burning, occur when a compound combines with oxygen from the air. The compound usually contains carbon.

Combustion reactions are normally exothermic - They produce heat.

Example:

Burning coal is an example of a combustion reaction. Coal is essentially carbon.

carbon + oxygen ➔ carbon dioxide + heat

$C + O_2 \rightarrow CO_2 + heat$

A coal power station in Victoria. The combustion of carbon produces considerable heat to produce steam to turn turbines to produce electricity. $C + O_2 \rightarrow CO_2 + heat$

Roughly 1.9 tonnes of CO_2 is produced for every tonne of coal burnt.

Burning Magnesium

Watch online videos demonstrating the burning of magnesium.

Magnesium, Mg, is one of the most common elements on Earth. Pure magnesium is a soft silver white metal. It burns in air with a strong white light. Magnesium is used in flares and fireworks.

magnesium + oxygen ➔ magnesium oxide

$2Mg + O_2 \rightarrow 2MgO$

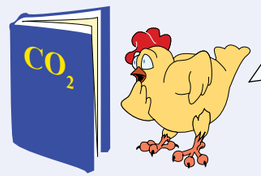
Burning Magnesium in Dry Ice

Watch online videos demonstrating the burning of magnesium in dry ice.

Burning magnesium in dry ice shows that combustion can happen without oxygen.

magnesium + carbon dioxide ➔ magnesium oxide + carbon

$2Mg + CO_2 \rightarrow 2MgO + C$



Dry ice is solid carbon dioxide. A temperature of about -80°C is needed to solidify carbon dioxide gas.

Exercise

1 What is a combination reaction?

2 In the chemical reaction: $X + Y \rightarrow XY$, which are the reactants and which are the products?

3 What is the test for hydrogen?

4 Hydrogen will react explosively with oxygen to produce water. Write the symbolic equation.

5 What is a combustion reaction?

6 Write the symbolic equation for the burning of carbon.

7 Write the symbolic equation for the burning of magnesium.

8 When heated, a mixture of iron (Fe) and sulphur (S) will combine chemically to produce iron sulphide (FeS). Attempt to write the symbolic equation for this chemical reaction.

9 Attempt to write the symbolic equation for the burning of sulphur to produce sulphur dioxide (SO_2).

Decomposition

Decomposition reactions occur when a substances breaks down to form two or more new substances.

The **reactant** is the starting substance.

The **products** are the result of the chemical decomposition.

$$XY \rightarrow X + Y$$

In the above chemical equation, the reactant XY decomposes to form the products X and Y.

Example:

The reactant calcium carbonate (limestone), when heated, decomposes into the products calcium oxide and carbon dioxide.

calcium carbonate ➔ calcium oxide + carbon dioxide

$CaCO_3 \rightarrow CaO + CO_2$

Some Decomposition Reactions

Heating sugar (sucrose):

sugar ➔ carbon + water

$C_{12}H_{22}O_{11} \rightarrow C + H_2O$

Electrolysis of water:

water ➔ hydrogen + oxygen

$H_2O \rightarrow H_2 + O_2$

Heating limestone:

calcium carbonate ➔ calcium oxide + carbon dioxide

$CaCO_3 \rightarrow CaO + CO_2$

Heating Malachite:

malachite ➔ copper oxide + carbon dioxide + water

$CuCO_3.Cu(OH)_2 \rightarrow CuO + CO_2 + H_2O$

A bit of trivia

- Explosives, containing nitroglycerin, when detonated decompose into carbon dioxide and water.
- An explosion is a rapid expansion of gases.
- Cement is made by heating limestone to around 1500°C, and grinding the decomposed calcium carbonate into a powder mixed with clay.

Decomposition: the separation of a substance into simpler substances as a result of heat, light, chemical activity, or biological activity.

Activity

Decomposition of Sugar

Materials: Household sugar, test tube, test tube holder, test tube rack, bunsen burner.

Method:

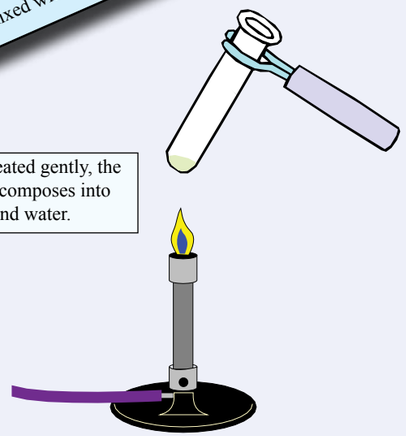
a) Place a small amount of sugar (sucrose) in a test tube. Heat it gently over a bunsen burner until a black sticky solid remains in the test tube (Don't try to clean the test tube).

$C_{12}H_{22}O_{11} \rightarrow C + H_2O$

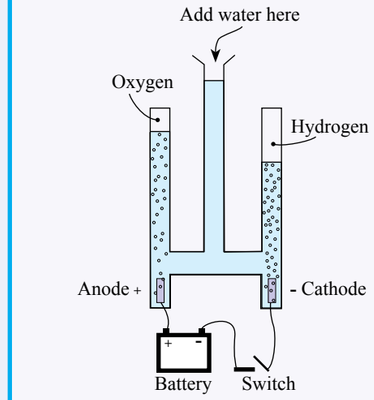
1 What is the evidence that a chemical reaction has taken place?

2 What is the sticky black substance at the bottom of the test tube?

3 Did you notice water moisture forming at the cooler top of the test tube?



When heated gently, the sugar decomposes into carbon and water.



Passing an electric current through water separates it into the elements hydrogen and oxygen. This is called 'electrolysis of water'.

Activity

Decomposition of Calcium Carbonate

Materials: Limestone (calcium carbonate), bunsen burner, tripod, heat mat, gauze mat, tongs.

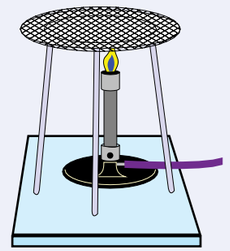
Method:

Place a small amount of calcium carbonate on the edge of the gauze mat. Heat the calcium carbonate for 5-10 minutes.

calcium carbonate ➔ calcium oxide + carbon dioxide

$CaCO_3 \rightarrow CaO + CO_2$

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



Electrolysis of Water

Watch online videos about 'electrolysis of water'.

Challenge

Electrolysis of Water

Design your own electrolysis of water equipment using only household materials.

Test for oxygen.

Test for hydrogen.

Exercise

1 What is a decomposition reaction?

2 In the chemical reaction: $XY \rightarrow X + Y$, which are the reactants and which are the products?

3 The electrolysis of water decomposes water into hydrogen and oxygen.

a) Write the symbolic equation for this chemical reaction.

b) What is a test for hydrogen?

c) What is a test for oxygen?

4 When calcium carbonate is heated it decomposes into calcium oxide and carbon dioxide ($CaCO_3 \rightarrow CaO + CO_2$).

What would you expect to happen if magnesium carbonate ($MgCO_3$) was heated?

5 When sucrose ($C_{12}H_{22}O_{11}$) is heated it decomposes into carbon and water ($C_{12}H_{22}O_{11} \rightarrow C + H_2O$).

What would you expect to happen if glucose ($C_6H_{12}O_6$) was heated?

7.3 Chemical Properties

Chemical Properties

The **chemical property** of a substance describes the **chemical changes** that may occur with the substance.

The chemical and physical properties of a substance determines its use.

Example:

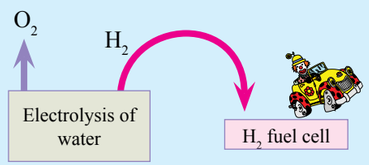
Hydrogen is the most flammable of all known substances. Hydrogen, in combination with oxygen, is used to power rockets.

$2H_2 + O_2 \rightarrow 2H_2O$

An Atlas V rocket using kerosene and liquid oxygen to power its first stage. The rocket uses liquid hydrogen and liquid oxygen to power the upper stage.

Chemical properties of Hydrogen (H_2):

Flammability:
Hydrogen reacts slowly with oxygen to form water. However, when a spark or catalyst such as platinum is added the chemical reaction of hydrogen and oxygen becomes explosively violent.



Reactivity:
At high temperatures hydrogen becomes very reactive and is one of the few substances that will react with nitrogen.

Hydrogen, in the presence of a catalyst, will react with unsaturated fats and oils to produce solid fats.

Uses of Hydrogen (H_2):

Flammability:
Hydrogen is used as a rocket fuel.

$H_2 + O_2 \rightarrow H_2O$

Fuel cells change the chemical energy of the reaction between hydrogen and oxygen into electricity. Fuel cells can be used to power engines.

Reactivity:
Hydrogen is used to make ammonia. Ammonia is an important source of fertilisers.

$H_2 + 3N_2 \rightarrow 2NH_3$

Hydrogen is thus used to produce solid fats such as margarine from unsaturated vegetable oils.

Chemical properties of Iron (Fe):

The abundance, low cost, and high strength of iron has resulted in iron being the most used metal.

Steel is iron mixed with small amounts of other elements such as carbon to make the iron harder and stronger. An **alloy** is a mixture of elements. Steel is an alloy of iron and mainly carbon.

Reactivity:
Iron rusts in damp air but not in dry air.

The presence of salt and moisture increases the rusting.

The prevention of rusting is helped by coating the steel with zinc. This is called galvanisation.

Stainless steel is an alloy of iron with chromium added. The stainless steel is protected by an outer layer of chromium oxide. The outer chromium reacts with oxygen in the air to form the protective layer.

chromium + oxygen ➔ chromium oxide

$4Cr + 3O_2 \rightarrow 2Cr_2O_3$

Reactivity:
Iron, with moisture, will react with the oxygen in the air to form rust.

iron + oxygen ➔ iron oxide

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Word Bank

Add the following words to your word bank by writing the word, a definition of the word, and a sentence or phrase using the word:

Word	Definition	A sentence
Physical change		
Chemical change		
Exothermic reaction		
Endothermic reaction		
Reactant	X and Y are reactants in the following reaction X + Y ➔ XY	The reactants are the starting substances in a chemical reaction
Combination reaction		
Decomposition reaction		
Chemical property		

Learning Power

Can you spend about 30 seconds looking at a word, and then write down the word and its definition without looking?

Can you write down all words, and their definition, without looking?

Exercise

1. What is meant by the chemical property of a substance?
2. A chemical property of hydrogen is that it will react explosively with oxygen.
   a) Attempt to write the symbolic equation for the reaction of hydrogen with oxygen.
   b) Suggest a possible use for hydrogen given that it will react explosively with oxygen.
3. Briefly describe a hydrogen fuel cell.
4. What is the difference between iron and steel?
5. The rusting of steel is essentially a reaction between iron and oxygen in the air.
   a) Attempt to write the symbolic equation for the reaction of iron (Fe) with oxygen.
   b) Suggest three ways of preventing rust (basically preventing the oxygen from making contact with the iron).

7.4 Science knowledge

Ripening and Rotting Fruit

When a fruit is picked from a plant it immediately loses its supply of oxygen, water, and nutrients.

The cells of the fruit then begin to die because of this lack of oxygen, fruit, and nutrients.

Rotting fruit

Watch online videos of 'rotting fruit'.
Note the evidence of chemical change.

The stages of a piece of fruit:

1. Unripe fruit contains a lot of starch and is sour.
2. As the fruit ripens, the starches change to sugars (glucose and fructose) and becomes sweeter.

   starch + water ➔ fructose

   $C_6H_{10}O_5 + H_2O \rightarrow C_6H_{12}O_6$
3. When the fruit is picked most of the starches have changed to sugars and microbes begin to feed off the sugars.

Activity

Test for starches and sugars in fruit.

Materials: Fruit and Iodine

Method:

Apply a drop of iodine to fruit flesh:

- Dark-blue indicates starches.
- Taking 2-3 seconds to become dark-blue indicates that some starch is present.
- Yellow indicates mostly sugar.

Micobes, small organisms and fungi, feed off the sugars in the fruit and use the energy produced by the breakdown of the sugar to keep alive.

fructose + oxygen ➔ carbon dioxide + water

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

How to prevent the rotting of fruit:

- Keeping fruit in fridges and freezers slows down the chemical decay reactions.
- Add preservatives to prevent the involvement of oxygen and microbes in the chemical decay reactions.
- Cook and bottle to keep the oxygen and microbes away from the fruit.

Exercise

1 What is the evidence that rotting fruit is a chemical change?

2 Essentially the ripening of fruit is a chemical change from starch to fructose (a sugar) summarised by:

$C_6H_{10}O_5 + H_2O \rightarrow C_6H_{12}O_6$

a) Is this a combination or decomposition reaction?

b) What is the difference between starch and fructose (a sugar)?

3 What are the two factors mostly responsible for the rotting of fruit?

4 Is the breakdown of fructose an exothermic or endothermic reaction? Explain.

Hydrogen Fuel Cell

Fuel cells change the chemical energy of the reaction between hydrogen and oxygen into electricity.

Fuel cells have been used to power engines in cars, buses, boats, submarines, etc.

The major source of hydrogen is from the steam treatment of natural gas. High temperature steam reacts with methane to produce carbon dioxide and hydrogen.

steam + methane ➔ hydrogen + carbon dioxide

$H_2O + CH_4 \rightarrow H_2 + CO_2$

Fuel cells essentially consist of an anode (positive), a cathode (negative), an electrolyte, and fuel such as hydrogen and oxygen.

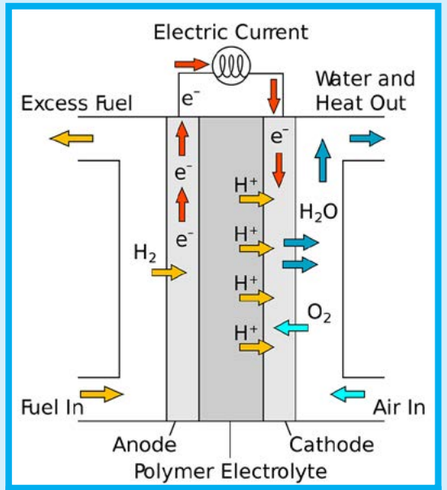
The fuel/electrolyte pushes electrons from the anode to the cathode and through connections to power an application such as an electric motor.

The **advantages** of a hydrogen fuel cell:

- 1 kg of hydrogen may do as much work as 2 L of petrol mainly because a hydrogen fuel cell is more efficient than an internal combustion engine.
- A fuel cell has no greenhouse gas emissions (1 L of petrol can produce 2 kg of carbon dioxide).

Disadvantages of a hydrogen fuel cell:

- An expensive source of power compared to the combustion of fossil fuels.
- The extraction of hydrogen from natural gas also produces carbon dioxide.



The inputs of the fuel cell are hydrogen over the anode and oxygen from the air over the cathode.
The outputs are electrons and water.
The net equation is: $H_2 + O_2 \rightarrow H_2O$

Debate the following:

Governments should make it a priority to develop hydrogen fuel cells.

Exercise

1 Describe a hydrogen fuel cell.

2 The net chemical reaction in a hydrogen fuel cell is:

$H_2 + O_2 \rightarrow H_2O$

a) Is this a combination reaction or a decomposition reaction?

b) What are the products of a hydrogen fuel cell?

3 What are three advantages and three disadvantages of hydrogen fuel cells?

7.5 Science inquiry

Science Inquiry

Science inquiry skills are important in science, and in any situation that requires critical thinking. The process of thinking in logical steps allows us to answer questions about the world around us.

Science inquiry skills include:

- questioning and predicting.
- planning and conducting.
- processing and analysing.
- evaluating.
- communicating.

Variables

The **independent variable** is the variable that is changed. In graphs, the independent variable is plotted on the x-axis.

The **dependent variable** is the variable that is measured. In graphs, the dependent variable is plotted on the y-axis.

The **controlled variables** are all of the other variables that are to be kept constant.

Investigation variables

Watch a couple of 'investigation variables' or 'fair testing' videos.

Planning & Conducting

Think about and organise an experiment to answer the question.

Planning an experiment is to describe in detail, the step-by-step procedures to follow.

Collect your data and write it in a prepared data table.

Processing & Analysing

Summarise the data in the form of a graph or chart to help in understanding the data and to identify relationships.

Charts, graphs, and tables are also a great way of presenting investigation data to others.

The analysis of the data in a graph involves looking for trends, patterns and relationships in the graph.

Are you able to draw a conclusion from your experimental data?

Evaluating

Did your experiment provide an answer to the question?

How good was your data?

Would you do anything different if you repeated your experiment?

Communicating

Write a report using scientific language.

Present your report to your target audience using digital technology.

Examples of reports are shown in Chapter 1.

Science Investigations

Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem.

Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations.

Yeast and sugar

Put a teaspoon of yeast in a bottle.

Add a teaspoon of sugar to the bottle.

Add half a cup of warm water to the bottle and mix the contents.

Put a balloon over the mouth of the bottle.

How quickly will the balloon fill?

How large will the balloon become?

Yeast and sugar

Watch a couple of videos on 'balloon and yeast'.

Yeast and sugar

Baker's yeast is used to produce lighter and tastier bread. Yeast is a single celled organism.

The feeding of yeast on sugar can be summarised as:

sucrose + water ➔ ethanol + carbon dioxide

$2C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_2H_5OH + 2CO_2$

Baker's yeast. The packet has just been opened.

Activity

Conduct investigations to answer each of the following questions.

Questioning & Predicting

How much sugar is needed to get optimum production from a teaspoon of yeast?

Prediction: **Well? What is your prediction?**

Questioning & Predicting

Is carbon dioxide produced when yeast feeds on sugar?

Prediction: **Well? What is your prediction?**

Questioning & Predicting

Does temperature affect the rate at which yeast feeds on sugar?

Prediction: **Well? What is your prediction?**

Questioning & Predicting

Is the mass of the reactants equal to the mass of the products after yeast feeds on sugar?

Prediction: **Well? What is your prediction?**

7.6 Chapter Review

Physical change happens when a substance changes from one form to another form but keeps exactly the same chemical composition.

A physical change can affect the colour, size, or shape but no new products are formed.

With a physical change the substances keep their property (Salt dissolved in water still tastes salty). Sometimes a physical change can be reversed.

Chemical change happens when a new substance is formed.

Chemical change happens when a substance combines with another substance to form one or more new substances.

Chemical change happens when a substance breaks down into two or more substances.

Chemical change is not reversible except with further chemical change.

Examples of **physical change**:

- A sheet of paper is put through a shredder.
- The particles are always moving.
- A yellow paint is mixed with a blue paint to produce green.
- Salt is mixed with water.
- Cutting bread into slices.
- Boiling water.

Examples of **chemical change**:

- Toasting bread.
- Milk starting to smell bad (bacteria in the milk forming new substances).
- Burning a match.
- Frying an egg.
- Vinegar + baking soda ➔ carbon dioxide.
- A battery producing a current.

When ready, cover the information above and answer the questions below.

Exercise

1 What is a physical change?

2 Indicate why each of the following are physical changes:

a) The freezing of water (changing from liquid water to solid ice).

b) Dissolving sugar in water.

c) Making lemonade by squeezing lemon juice and adding sugar and water.

3 Can you think of 5 more examples of physical change?

Exercise

4 What is a chemical change?

5 Indicate why each of the following are chemical changes:

a) The rusting of iron.

b) Toasting bread.

c) A rotting piece of fruit.

d) Tarnishing, browning, of silver.

6 Can you think of 5 more examples of chemical change?

The following **evidence** can suggest that a chemical reaction has taken place:

- Change of colour.
- Change in temperature.
- Change of smell.
- Change of form.
- Production of gases.
- Production of a precipitate.
- Decomposition of organic material.
- Light or sound is produced.

Although the above changes may suggest that a chemical change has taken place, the only conclusive evidence of a chemical change is a chemical analysis.

Many reactions either produce energy or absorb energy.

Reactions that produce heat are called **exothermic** reactions. The burning of of fossil fuels such as coal, oil, and gas produces heat. These are **exothermic** reactions.

Reactions that absorb heat are called **endothermic** reactions.

A **colour change** can suggest that a chemical reaction has taken place.

The rusting of iron is evidenced by the typical reddish-brown rust colour. The colour change due to the ripening of fruit is caused by enzyme reactions. These reactions also change the taste and smell of the fruit.

Bubbles can suggest that a chemical reaction is producing a gas.

Bubbles can also indicate a physical change. The bubbles in softdrink is carbon dioxide being released after being dissolved in the drink.

Bubbles are also produced when water is boiled. Boiling water is a physical change.

During a chenical reaction energy can be released in the form of **light**. Fireflies, some fungi, and some deep sea animals use chemical reactions to produce light.

Most combustion reactions produce energy in the form of light. Combustion reactions always involve oxygen. A fire is a combustion reaction.

When two or reactants are mixed together and a **precipitate** falls to the bottom of the container then this provides evidence that a chemical reaction is occurring.

A precipitate is the formation of a solid in a solution during a chemical reaction.

When ready, cover the information above and answer the questions below.

Exercise

1 Give 5 kinds of evidence that might suggest that a chemical change has taken place?

2 What is an exothermic reaction?

3 What is an endothermic reaction?

4 The rusting of iron can be summarised by the symbolic equation:

$4Fe + 3O_2 + 6H_2O \rightarrow Fe(OH)_3$

a) What is the symbol for iron?

b) What is the evidence that rusting is a chemical change?

5 What is the evidence that the ripening of fruit is a chemical change?

6 Smell and taste can be used as evidence of a chemical change. Why should the use of smell and taste be avoided?

7 What is a precipitate?

Exercise

8 Which of the following is a chemical change and which is a physical change?

a) Building a sand castle on the beach.

b) Painting a desk green.

c) Lighting a candle.

d) Cooking biscuits.

e) Bending/snapping a light stick to produce a glow.

9 The chemical reaction of baking soda and calcium chloride produces a precipitate.

The symbolic equation is:

$2NaHCO_3 + CaCl_2 \rightarrow CaCO_3 + 2NaCl + CO_2 + H_2O$

Can you deduce the symbolic formula of the precipitate?

Combination reactions occur when two or more substances combine to form a new substance.
The **reactants** are the starting substances.
The **products** are the result of the chemical reaction.

$$X + Y \rightarrow XY$$

In the above chemical equation, the reactants X and Y combine to form the product XY.

Example:
Using a lit splint to test for hydrogen (The reactants are hydrogen and oxygen. The product is water).

hydrogen + oxygen ➔ water

$2H_2 + O_2 \rightarrow 2H_2O$

Combustion reactions, or burning, occur when a compound combines with oxygen from the air. The compound usually contains carbon.

Example:
Burning coal is an example of a combustion reaction. Coal is essentially carbon.

carbon + oxygen ➔ carbon dioxide

$C + O_2 \rightarrow CO_2$

Decomposition reactions occur when a substances breaks down to form two or more new substances.

The **reactant** is the starting substance.

The **products** are the result of the chemical decomposition.

$$XY \rightarrow X + Y$$

In the above chemical equation, the reactant XY decomposes to form the products X and Y.

Example:
Calcium carbonate (limestone), when heated, decomposes into calcium oxide and carbon dioxide.

calcium carbonate ➔ calcium oxide + carbon dioxide

$CaCO_3 \rightarrow CaO + CO_2$

Other examples:
Heating sugar (sucrose):

sugar ➔ carbon + water

$C_{12}H_{22}O_{11} \rightarrow C + H_2O$

Electrolysis of water:

water ➔ hydrogen + oxygen

$H_2O \rightarrow H_2 + O_2$

When ready, cover the information above and answer the questions below.

Exercise

1 What is a combination reaction.

2 In the chemical reaction: $X + Y \rightarrow XY$, which are the reactants and which are the products?

3 What is the test for hydrogen?

4 Hydrogen will react explosively with oxygen to produce water. Write the symbolic equation.

5 What is a combustion reaction?

6 Write the symbolic equation for the burning of oxygen.

7 Write the symbolic equation for the burning of magnesium.

8 When heated, a mixture of iron (Fe) and sulphur (S) will combine chemically to produce iron sulphide (FeS). Attempt to write the symbolic equation for this chemical reaction.

Exercise

9 Attempt to write the symbolic equation for the burning of sulphur to produce sulphur dioxide (SO_2).

10 What is a decomposition reaction?

11 In the chemical reaction: $XY \rightarrow X + Y$, which are the reactants and which are the products?

12 The electrolysis of water breaks decomposes water into hydrogen and oxygen. Write the symbolic equation for this chemical reaction.

a) What is a test for hydrogen?

b) What is a test for oxygen?

13 When calcium carbonate is heated it decomposes into calcium oxide and carbon dioxide ($CaCO_3 \rightarrow CaO + CO_2$).
What would you expect to happen if magnesium carbonate ($MgCO_3$) was heated?

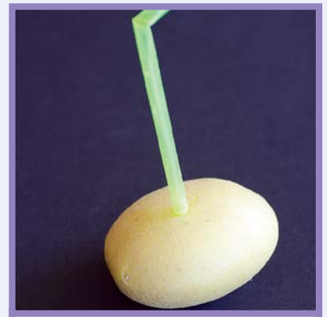
14 When sucrose ($C_{12}H_{22}O_{11}$) is heated it decomposes into carbon and water ($C_{12}H_{22}O_{11} \rightarrow C + H_2O$).
What would you expect to happen if glucose ($C_6H_{12}O_6$) was heated?

A Sweet Trick

Jab/stab a potato with a straw
Watch some online videaos showing how to do this trick.

1 Challenge your audience to stick a straw into a potato.

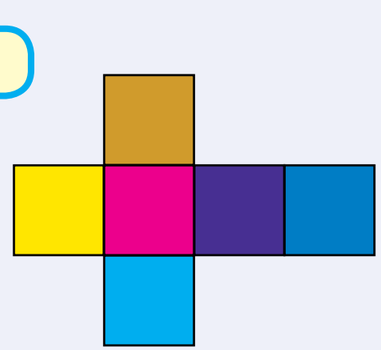
2 Fold over the straw so that it fits in your fist and traps air in the straw.

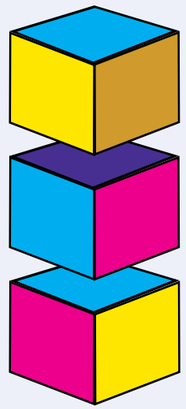


3 Holding the straw tightly, quickly jab the straw into the potato.

A Couple of Puzzles

1 The net shown has been folded to make a box. Which box?

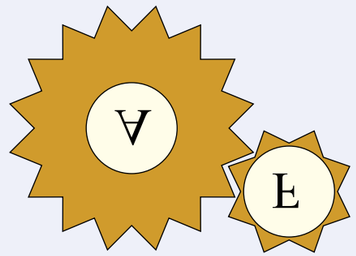




2 Place each of the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9 in each square so that the sum of each row and column is as shown.

			18
			7
			20
14	13	18	

3 Cog A has 16 teeth and cog F has 8 teeth. How many turns must cog F make so that both letters are upright?



The **chemical property** of a substance describes the **chemical changes** that may occur with the substance. The chemical and physical properties of a substance determines its use.

Hydrogen is the most flammable of all known substances. Hydrogen, in combination with oxygen, is used to power rockets.

$H_2 + O_2 \rightarrow H_2O$

Hydrogen will combine with nitrogen. Hydrogen is used to make ammonia. Ammonia is an important source of fertilisers.

$H_2 + 3N_2 \rightarrow 2NH_3$

Iron, with moisture, will react with the oxygen in the air to form rust.

iron + oxygen ➔ iron oxide

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Stainless steel is an alloy of **iron** with chromium added. The outer chromium reacts with oxygen in the air to form a rust protective layer.

chromium + oxygen ➔ chromium oxide

$4Cr + 3O_2 \rightarrow 2Cr_2O_3$

Fruit ripening can be summarised as starches changing to sugars (glucose and fructose) and becoming sweeter.

starch + water ➔ fructose

$C_6H_{10}O_5 + H_2O \rightarrow C_6H_{12}O_6$

The **rotting of fruit** can be summarised as small organisms and fungi breaking down the sugars for living energy

fructose + oxygen ➔ carbon dioxide + water

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

Fuel cells change the chemical energy of the reaction between hydrogen and oxygen into electricity. Fuel cells have been used to power engines in cars, buses, boats, submarines, etc.

Fuel cells are more efficient than internal combustion engines.

Fuel cells don't have green house emissions.

Fuel cells are an expensive source of power.

The extraction of hydrogen, as fuel for fuel cells, from natural gas produces carbon dioxide.

When ready, cover the information above and answer the questions below.

Exercise

1 What is is meant by the chemical property of a substance?

2 A chemical property of hydrogen is that it will react explosively with oxygen.

a) Attempt to write the symbolic equation for the reaction of hydrogen with oxygen.

b) Suggest a possible use for hydrogen given that it will react explosively with hydrogen.

3 What is the difference between iron and steel?

4 The rusting of steel is essentially a reaction between iron and oxygen in the air.

a) Attempt to write the symbolic equation for the reaction of iron (Fe) with oxygen.

b) Suggest three ways of preventing rust (basically preventing the oxygen from making contact with the iron).

Exercise

5 What is the evidence that rotting fruit is a chemical change?

6 Essentially the ripening of fruit is a chemical change from starch to fructose (a sugar) summarised by:

$C_6H_{10}O_5 + H_2O \rightarrow C_6H_{12}O_6$

Is this a combination or decomposition reaction?

b) What is the difference between starch and fructose (a sugar)?

7 Is the breakdown of fructose an exothermic or endothermic reaction? Explain.

8 Describe a hydrogen fuel cell.

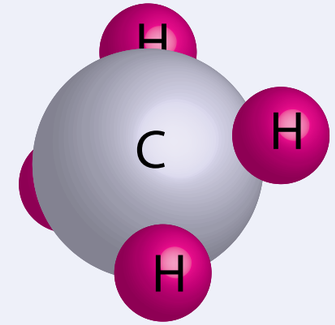
9 The net chemical reaction in a hydrogen fuel cell is:

$H_2 + O_2 \rightarrow H_2O$

Is this a combination reaction or a decomposition reaction?

10 What are three advantages and three disadvantages of hydrogen fuel cells?

Competition Questions



A catalyst is a substance that speeds up a chemical reaction. A catalyst is not used in the reaction and only needs to be present in small quantities.

1 In the example shown on the immediate right, which substance is the catalyst?

a) Steam (H_2O).
b) Methane (CH_4).
c) Nickel (Ni).
d) Carbon dioxide (CO_2).

The major source of hydrogen is from the steam treatment of natural gas. High temperature steam reacts with methane to produce carbon dioxide and hydrogen.

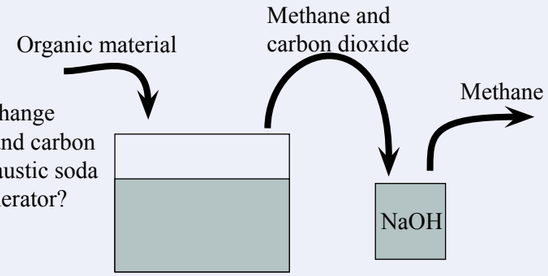
$H_2O + CH_4 \xrightarrow{Ni} H_2 + CO_2$

2 At the top right of this page is an atomic model of one of the compounds involved in the steam treatment of methane. Which compound is represented by the atomic model?

a) Steam (H_2O).
b) Methane (CH_4).
c) Nickel (Ni).
d) Carbon dioxide (CO_2).

3 A biogas generator is essentially the chemical change (breakdown) of organic material into methane and carbon dioxide. What is probably the purpose of the caustic soda (NaOH) solution in the diagram of a biogas generator?

a) Take the moisture out of the biogas.
b) Take the methane out of the biogas.
c) Take the carbon dioxide out of the biogas.
d) Take any microorganisms out of the biogas.



Rough sketch of a biogas generator

4 What could you probably conclude about the physical properties of methane and carbon dioxide?

a) Both methane and carbon dioxide are soluble in a caustic soda (NaOH) solution.
b) Methane is soluble in a caustic soda (NaOH) solution.
c) Carbon dioxide is soluble in a caustic soda (NaOH) solution.
d) Neither methane nor carbon dioxide is soluble in a caustic soda (NaOH) solution.

Harder Test Questions

1 When sugar and yeast are mixed together, the yeast, a fungus, feeds on the sugar. This is described as fermentation because alcohol and bubbles of carbon dioxide are produced.

Sugar ➔ ethanol + carbon dioxide + energy

$C_6H_{12}O_6$ ➔ $2CH_3CH_2OH + 2CO_2$ + energy

a) Give two pieces of evidence that suggest that this is a chemical reaction.

b) Is the feeding of yeast on sugar a combination reaction or a decomposition reaction?

c) What is the evidence that fermentation is an exothermic reaction?

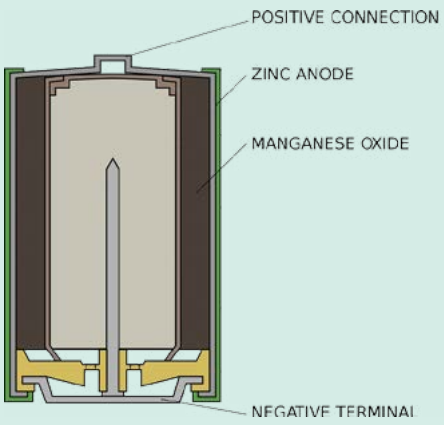
2 A student investigated the question 'What is the effect of temperature on the feeding of yeast on sugar?'. Using the same quantities of yeast, sugar, and water at different water temperatures in a thin measuring tube, the following data was obtained:

Temperature	Bubble height
5°C	60 mm
25°C	100 mm
40°C	160 mm
80°C	70 mm

a) Draw a graph of temperature vs height.

b) Write an answer to the question 'What is the effect of temperature on the feeding of yeast on sugar'?

c) Would you be able to write an answer to the question 'Which temperature does yeast prefer'?



3 The above battery essentially consists of a carbon rod, negative terminal, a zinc casing, positive terminal, and a manganese oxide paste in between the carbon and the zinc.

a) Is the anode positive or negative?

b) When used, why does the battery eventually become flat?

4 Natural gas mostly consists of mixtures of methane and ethane with small amounts of propane, butane, and pentane.
Each of these gases are compounds of carbon and hydrogen.

a) Copy and complete the following table:

Gas	Formula
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	
Pentane	

b) Combustion is the burning of a fuel and an oxidant, such as oxygen, producing heat. Symbolic chemical equations are given for the burning of methane and ethane. Attempt to write the chemical equations for the burning of propane.

$CH_4 + O_2$ ➔ $CO_2 + H_2O$

$C_2H_6 + O_2$ ➔ $CO_2 + H_2O$