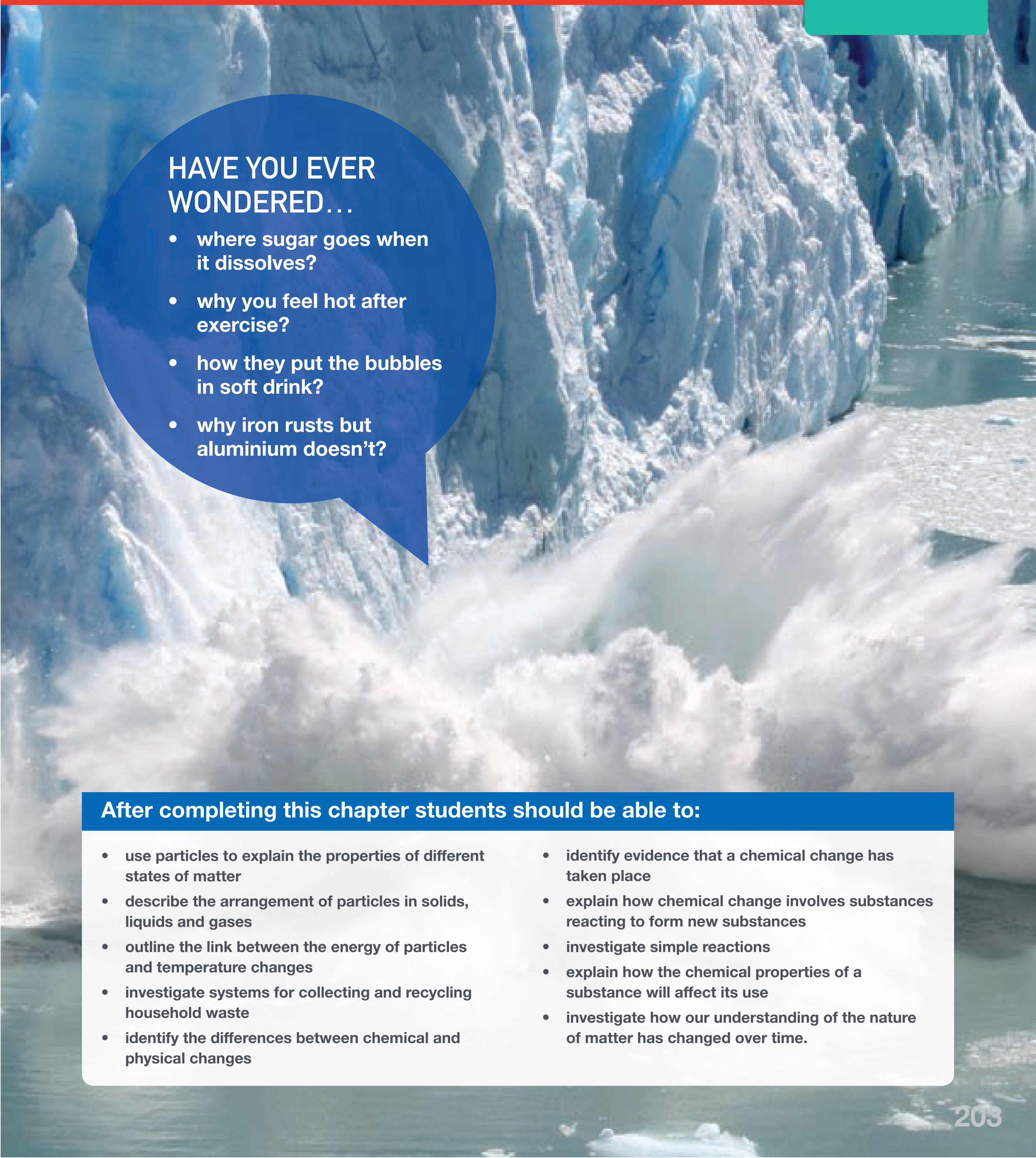
Physical and chemical change

6



HAVE YOU EVER WONDERED…

- where sugar goes when it dissolves?
- why you feel hot after exercise?
- how they put the bubbles in soft drink?
- why iron rusts but aluminium doesn't?

After completing this chapter students should be able to:

- use particles to explain the properties of different states of matter
- describe the arrangement of particles in solids, liquids and gases
- outline the link between the energy of particles and temperature changes
- investigate systems for collecting and recycling household waste
- identify the differences between chemical and physical changes
- identify evidence that a chemical change has taken place
- explain how chemical change involves substances reacting to form new substances
- investigate simple reactions
- explain how the chemical properties of a substance will affect its use
- investigate how our understanding of the nature of matter has changed over time.

6.1 When substances change

The world around you is constantly changing. Whether it is the passing of the seasons, a cool breeze or ice blocks melting in a drink, changes are occurring. Most of these changes can be classified as physical or chemical changes depending on whether any new substances are produced.

Identifying physical change

The key feature of a **physical change** is that no new substance is produced during the change. Physical changes include a change in shape or form, expansion and contraction, a change of state (solid, liquid or gas) or mixing substances together. The physical properties of the substance may change but no new substance is formed. For this reason, physical changes are often reversible. Figure 6.1.1 shows four types of physical change.

Figure 6.1.1 During these physical changes, no new substances are produced.

Changing shape or form

The simplest example of a physical change is one that changes the shape or form of a substance. In this case, a force is applied to break, bend, stretch, crush, twist or compress the object. These changes do not produce new substances. For example, when you crush an aluminium can, its shape changes but it is still made of the same aluminium as before. Similarly, if you crush an aspirin tablet into a powder, it is still aspirin but in a different form.

Expansion and contraction

Physical changes also occur when the temperature of a substance increases or decreases. When solids, liquids and gases are heated, they expand and take up more space. When **expansion** occurs, the volume of the object increases and its density decreases but no new substances are formed. When a solid, liquid or gas is cooled, it contracts (takes up less space). When **contraction** occurs, the volume of an object decreases and its density increases.

Thermometers use expansion and contraction of liquids such as ethanol and mercury to measure temperature. When the temperature increases, the liquid in the thermometer expands and moves up the thermometer. When the temperature decreases, the liquid contracts and moves down.

Hot-air balloons use the expansion of heated air to lift off the ground. Figure 6.1.2 shows how hot-air balloons use a burner to heat the air inside. As the air heats, it expands to fill the balloon. The hot air inside is much less dense than the cooler air outside so the balloon floats and lifts off the ground.

Figure 6.1.2 Heating the air inside the balloon causes it to expand and become less dense than the air outside. As a result, the balloon floats.

Changes of state

If enough heat is applied to a substance, then it will not only expand but will also change state from a solid to a liquid (**melting**) or from a liquid to a gas (**evaporation**). Likewise, if a substance is cooled enough, it will not just contract but change state from a gas to a liquid (**condensation**) or from a liquid to a solid (**freezing** or **solidification**). A few substances change directly from a solid to a gas (**sublimation**) or a gas to a solid (**deposition**).

Melting and freezing

When a solid is heated enough, it will melt and change into a liquid. For example, when you place an ice cube in your mouth, the heat from your mouth melts it into liquid water. Also, when butter is spread on hot toast, the butter melts and soaks into the bread. The physical properties of the solid and liquid may be very different. However, they are both made from the same substance and therefore melting is a physical change.

Freezing is the reverse of melting. When a liquid is cooled enough, it will form a solid. This is what happens when liquid water is put in the freezer to form ice cubes. Solidification can also be seen when drops of liquid candle wax cool and become solid again.

Evaporation and condensation

Evaporation occurs when a liquid is warmed and becomes a gas. Evaporation occurs at the surface of a liquid at all temperatures but becomes faster as the temperature of the liquid increases. This is the reason that puddles of water dry faster in hot weather. It is also why tumble-driers heat clothes to dry them more quickly. If the liquid is heated above a certain temperature, known as the **boiling** point, then bubbles of gas will form within the liquid and the liquid is said to boil.

High and dry

SciFile

Australia has recently experienced one of the worst droughts in recorded history. This has had devastating effects, forcing many farmers to leave their homes. It has also cost the Federal Government billions of dollars in the form of drought assistance. Unfortunately, drought may be a fact of life for many Australians in the future and we may need to access alternative supplies of fresh water such as desalination and water recycling.

The opposite of evaporation is condensation. Condensation is when a gas cools and becomes a liquid. When you leave a cold can of soft drink out of the fridge, it develops moisture on the outside, as shown in Figure 6.1.3. This is because water vapour in the air condenses on the cold outside of the can to form liquid water. Similarly, when you breathe out on a cold day, 'fog' may come out of your mouth. This 'fog' is water vapour in your breath condensing to form a mist of tiny liquid water droplets.

Figure 6.1.3 When a cold can is left out of the refrigerator, water vapour from the air will condense as liquid water on the outside.

Sublimation

In some cases, a substance can change from a solid directly into a gas. This change of state is called sublimation. Dry ice is an example of a substance that sublimes. Dry ice is solid carbon dioxide. At temperatures above –78.5°C, dry ice sublimes to form carbon dioxide gas. This makes dry ice perfect for use in smoke machines in theatres and concerts as it produces a thick, white fog without leaving behind any liquid. Other substances that sublime are iodine, graphite and naphthalene (mothballs).

Mixing

Mixing two substances represents another type of physical change. Figure 6.1.4 shows a bucket of different coloured balls. It is an example of a mixture that can be seen by eye. The different coloured balls mix but no new balls are formed.

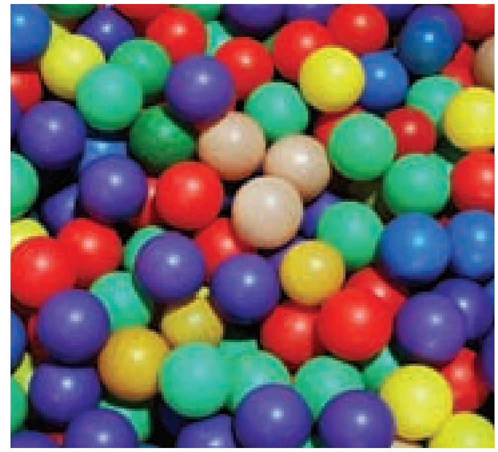


Figure 6.1.4 Although the different coloured balls may spread evenly through this mixture, the balls do not change or form new colours.

Dissolving

When a solid (solute) is dissolved in a liquid (solvent), they form a **solution**. A solution is a mixture. The smallest particles of the solute mix and spread evenly throughout the smallest particles of the solvent—just like a mixture of balls but invisible to the naked eye.

In a solution, the solute seems to disappear. In reality, the solute is broken down into such small particles that they are invisible. If the solvent is removed by boiling or evaporation, then the solute particles join together again to form crystals.

For example, when sugar is dissolved in water, the sugar particles spread evenly throughout the water to form a sugar solution. However, the sugar particles remain sugar particles and the water particles remain water particles—a physical change has occurred. If the water is boiled off or left to evaporate, then sugar crystals are left behind. Liquids and gases can also be dissolved. Figure 6.1.5 shows liquid food colouring dissolving in water.

1 p212

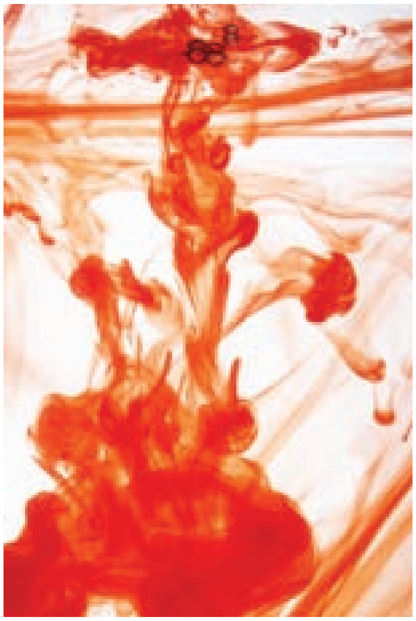


Figure 6.1.5 When two substances mix, one substance is spread evenly through the other but no new substances are formed.

Identifying chemical change

To distinguish between a **chemical change** and a physical change, you need to determine if a new substance has formed. If a new substance has been produced, then a chemical change has occurred.

The new substance formed in a chemical change could be a solid, liquid or gas. You can detect its presence by:

- seeing a change in colour
- smelling a gas or seeing bubbles
- seeing a new solid (known as a **precipitate**) forming in a clear solution
- observing that energy is produced or absorbed in the form of heat or light.

2 p212

These indications of chemical changes are shown in Figure 6.1.6. However, these are just guidelines. Identifying chemical change also requires a good understanding of physical changes to know when there may be exceptions to these rules.

Permanent colour change

When you observe something changing colour, it is very likely that a chemical change has occurred. This happens because the new substance produced by the chemical reaction has a different colour to what you started with. Burning a match, paper or a piece of toast produces a black powder, which is carbon. If iron is left in the rain, then it turns orange-brown because iron oxide (rust) is produced.

Other examples include green apples ripening to turn red, the changing colour of leaves in autumn, bleaching or dyeing clothes or hair (as shown in Figure 6.1.7) and a bruised leg turning purple.

Figure 6.1.7 Dyeing hair is an example of a permanent colour change caused by a chemical reaction.

Figure 6.1.6 Some indications of a chemical change

INQUIRY
science 4 fun

Invisible ink

Yes

Can you use a chemical change to write a secret message?

Collect this ...

- lemon juice
- paper
- fine paint brush
- warm light globe or hairdryer

Do this ...

1. Use the paint brush to write a secret message on the paper in lemon juice.
2. Let the paper dry and then give the secret message to a friend.
3. To read the message, tell your friend to hold the message up to a warm light globe or use a hairdryer to heat the paper.

Record this ...

Describe what happened.

Explain why you think this happened.

Sometimes a physical change can also cause a colour change. For example, when snow melts to form liquid water it turns from white to colourless. This is not a chemical change because snow and liquid water are both made of water.

Mixing paint is also an example of a physical change that causes a colour change. Figure 6.1.8 shows yellow and blue paint being mixed together. They produce green paint. However, no new substances are formed. The yellow and blue particles are mixed so closely together that they give the illusion of green paint.

Figure 6.1.8

Although mixing paint causes a colour change, it is still a physical change because no new substance has been formed.

A gas is given off

The production of a gas also indicates a chemical change. A gas produced during a chemical change may be observed as bubbles, a new smell or perhaps smoke. When vinegar is added to bicarbonate of soda, many bubbles of carbon dioxide (chemical formula CO_2) are formed. Carbon dioxide is also formed by chemical changes in soft drink to create fizz or when Alka-Seltzer tablets are dissolved in water.

SciFile: Life-saving gases

A chemical reaction that has already saved many lives is the one used to inflate car airbags. In a car accident, an electrical current ignites a small pellet of sodium azide. The sodium azide burns very rapidly, producing enough nitrogen gas to fill the airbag in just 0.03 second.

Rotten eggs are well known for their pungent smell. This smell is the gas hydrogen sulfide (chemical formula H_2S), which is produced when eggs rot. Therefore, rotting is another example of a chemical change. Often when something is burning, the first thing you notice is the smell. This is because burning causes a chemical change that also produces smelly gases.

An exception to this rule is in the case of boiling or sublimation. In these cases, a solid or a liquid becomes a gas but no new substance is produced.

A precipitate forms

Occasionally, when two solutions are mixed a new solid is produced, indicating that a chemical change has occurred. The solid precipitates (falls) out of the solution and sinks to the bottom. The new solid is known as the precipitate. Precipitation occurs in pipes and drains when scale or lime deposits inside, as shown in Figure 6.1.9. Crystals can also precipitate inside the body. Some collect in the kidneys and can cause very painful kidney stones.

A precipitate can also form when a gas is bubbled through a liquid. This type of precipitation is the basis of a simple test for carbon dioxide gas. When carbon dioxide gas is bubbled through a solution of calcium hydroxide (limewater), it precipitates solid calcium carbonate that turns the clear solution milky white.

Figure 6.1.9 Scale or lime can precipitate from water, causing blockages in pipes.

Energy is produced or absorbed

A chemical change is often associated with the production or absorption of energy in the form of heat, light or sound. A chemical change that produces energy is described as **exothermic**, while a chemical change that absorbs energy is described as **endothermic**.

Exothermic chemical change

Exothermic chemical changes give off energy in the form of heat, light and sound. Some exothermic chemical changes include fireworks, sparklers, firing a bullet or burning magnesium ribbon. The explosion in Figure 6.1.10 is a spectacular example. Exothermic change is happening when a match is burnt or natural gas is burnt in a stove or a Bunsen burner. You have an exothermic chemical change going on in your body right now. An exothermic chemical change occurs when your body converts food into energy through the process of respiration. When you exercise, you speed up the process of respiration and may start to feel overheated.

Figure 6.1.10 Fires and explosions are examples of extreme exothermic reactions—they release large amounts of heat and light energy.

Endothermic chemical change

Endothermic reactions absorb energy from the surroundings. If an endothermic reaction occurs in a test-tube, then the test-tube will feel cold because the reaction absorbs the heat energy from your skin. This is how the chemical ice pack shown in Figure 6.1.11 works. When the ammonium nitrate and water inside the ice pack are allowed to mix, an extremely endothermic reaction takes place. This absorbs heat from your skin, making it feel icy cold.

6.1

Physical changes can also be exothermic and endothermic. Evaporation is an endothermic physical change. You feel cooler when you sweat, because the sweat evaporates and absorbs the heat from your skin. Condensation is exothermic. This is why steam is particularly dangerous. It can produce terrible burns as it condenses on the skin and releases heat energy.

Figure 6.1.11 The reaction in a chemical ice pack causes a dramatic drop in temperature as it absorbs heat from the surroundings. It is an example of an extremely endothermic change.

Figure 6.1.12 Aluminium is recycled because it is cheaper than making it from new material.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Recycling

Today, there is a large range of recyclable materials including paper, glass, plastics and aluminium.

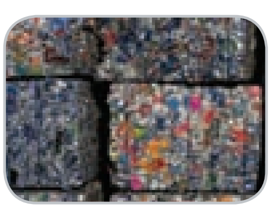
By recycling these materials, society is able to conserve these resources and reduce the cost of producing new materials. In most cases when a material is recycled, the form of the material may change but the material itself stays the same. Therefore, the recycling process is simply a series of physical changes.

6.2

Physical changes when recycling aluminium cans

Crushing: When you finish a can of soft drink you might crush the can before throwing it away.

Mixing: When you throw the can in the rubbish bin it is mixed with all the other materials, creating a mixture of garbage.



Separation: Before the aluminium cans can be recycled, they must be separated out of the garbage and cleaned.

Shredding: Once cleaned, the aluminium cans are shredded into tiny pieces.

Melting: The aluminium pieces are then melted into liquid aluminium, which is then poured into moulds.

Solidification: The liquid aluminium is allowed to cool and solidify, forming blocks of pure aluminium, known as ingots.

Processing: The ingots can then be processed into any aluminium product, including more aluminium cans to start the process all over again.

3 p213

6.1 Unit review

Remembering

1 **List** four examples of physical changes.

2 **List** four indications of a chemical change.

3 **State** an example of a physical change that causes a gas to be produced.

4 **Name** the reverse process for the following changes of state.
   a condensation
   b solidification
   c sublimation

5 **State** the two components of a solution.

6 **List** the physical changes that take place during the recycling of aluminium cans.

Understanding

7 **Explain** why heating the air inside a hot-air balloon allows it to float.

8 **Explain** why mixing paints should be considered a physical change even though there is a colour change.

9 **Define** the term *precipitate*.

10 **Explain** how sweating helps to keep you cool on a hot day.

Applying

11 **Identify** three examples of both physical and chemical changes you might see in the home.

12 **Identify** the missing labels and complete the flow diagram shown in Figure 6.1.13.

Analysing

13 **Contrast** the terms *endothermic* and *exothermic* and give examples of each.

14 Write out the steps for your favourite recipe and **classify** them as physical or chemical changes.

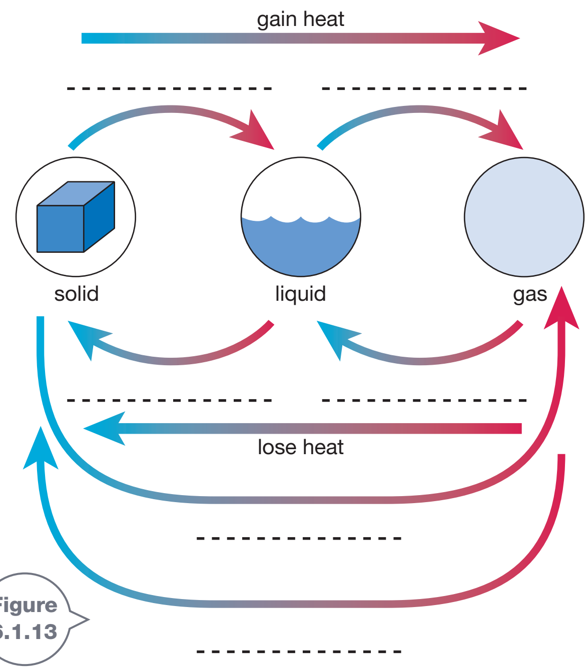


Figure 6.1.13

Evaluating

15 You are performing a chemical reaction and notice condensation on the outside of the test-tube.
   a **Deduce** if the reaction is exothermic or endothermic.
   b **Justify** your answer.

Creating

16 **Construct** a flow diagram of the physical changes that paper goes through when it is recycled.

17 Using pictures from magazines or the internet, **construct** a poster split into two halves. On one half show examples of physical changes and on the other half examples of chemical changes.

Inquiring

1 Research water recycling or desalination. List the purification processes as either physical or chemical processes.

2 Investigate a method for extracting iron, aluminium or gold from its ore. Classify the steps as either physical or chemical changes.

6.1 Practical activities

1 A model thermometer

Purpose
To construct a model thermometer that uses the expansion of gases to measure temperature.

Materials
- conical flask
- rubber stopper with single hole
- glass tubing
- water
- food dye
- retort stand
- bosshead and clamp
- clear plastic tubing
- ice cube

SAFETY
Food dye can stain your clothing or skin.

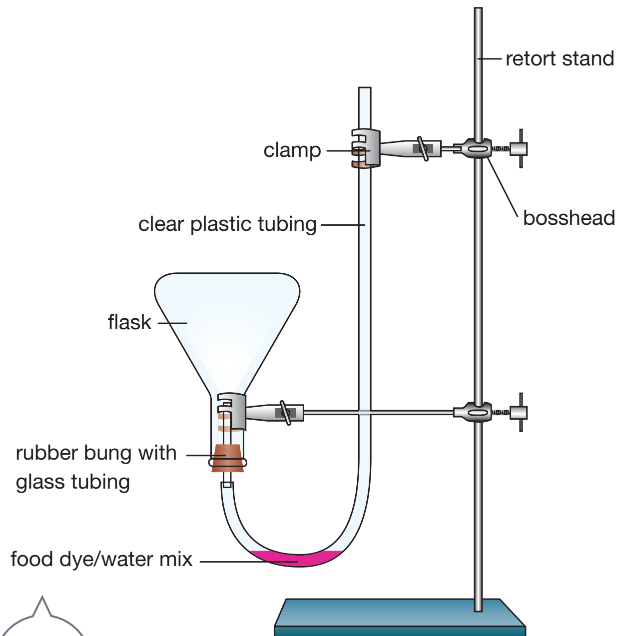


Figure 6.1.14

Procedure
1. Build the model thermometer shown in Figure 6.1.14.
2. When you have built your thermometer, wrap your hands gently around the flask to warm it. Observe what happens to the water in the plastic tubing.
3. Place an ice cube on top of the flask to cool it. Again, observe what happens.

Discussion
1. **Explain** why gases expand when heated and contract when cooled.
2. **Explain** how this model thermometer could be used to measure temperature.

2 Observing chemical reactions

Purpose
To observe different examples of chemical change.

Materials
- 4 large test-tubes and rack
- 3 droppers
- thermometer
- dilute hydrochloric acid
- blue litmus paper
- piece of magnesium metal
- silver nitrate
- sodium hydroxide solution

SAFETY
Silver nitrate stains the skin.
Hydrochloric acid and sodium hydroxide are corrosive and burn.

Procedure
1. Place blue litmus paper in the first test-tube.
2. Use a dropper to place 2 drops of dilute hydrochloric acid on the blue litmus paper. Record your results in the table.
3. Use the dropper to put to 2 cm of dilute hydrochloric acid in each of the next three test-tubes, as shown in Figure 6.1.15.
4. In the second test-tube, add the magnesium metal. Record your results.
5. In the third test-tube, use a separate dropper to add 10 drops of silver nitrate.
6. Use the thermometer to measure the temperature of the hydrochloric acid in the fourth test-tube. Record your results. Rinse the thermometer.

7 Use a separate dropper to add 2 cm of sodium hydroxide solution to the fourth test-tube then remeasure the temperature. Record your results. Rinse the thermometer.

Results

1 Copy and complete this table.

Reaction number	Reaction	Observation
1	Blue litmus and dilute hydrochloric acid	
2	Magnesium metal and hydrochloric acid	
3	Silver nitrate and hydrochloric acid	
4	Sodium hydroxide solution and hydrochloric acid	

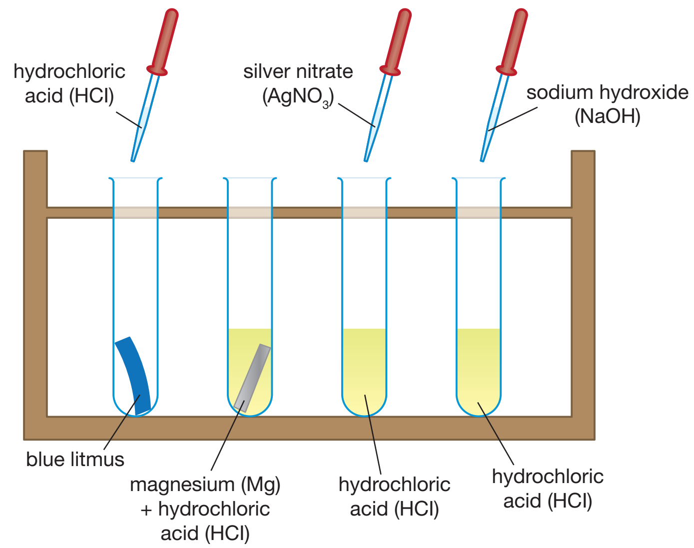


Figure 6.1.15

Discussion

In each case, **identify** the clue(s) that suggests that a chemical change has taken place.

3 Making recycled paper

Purpose

To see how physical changes can be used to process materials into different shapes and different purposes.

Materials

- 4 sheets of newspaper
- warm water
- large bowl or bucket
- absorbent paper towels
- frame with fine mesh stretch across it and stapled in place
- deep tray larger than the frame, blender (optional)

Procedure

1 Cut or shred the newspaper into small pieces.

2 Create a paper pulp either by placing the shredded paper and warm water in a blender and blending until finely chopped or by allowing the paper to soak in the large bowl overnight and mashing it by hand.

3 Place the frame and mesh in the tray with the mesh at the bottom.

4 Pour the paper pulp into the tray

5 Gently lift out the frame and allow the water to drain. Ensure that the mesh is covered evenly by the paper pulp.

6 Place the frame on some paper towel to absorb excess water.

7 Leave in a warm sunny place to dry.

8 Remove the paper from the frame.

Discussion

1 **List** all of the physical changes that occurred during the recycling process.

2 **Describe** how the paper you made was different from the paper you started with.

3 a **Assess** whether this is an efficient method for recycling paper

b **Justify** your answer.