Teacher background information

Introduction to states of matter

Matter

All matter is made up of very small particles called atoms. These atoms can join with other atoms to form molecules. While some atoms, such as silver, gold and metals, exist as material entities, the overwhelming components of matter are molecules. Water is made up of water molecules, a combination of hydrogen and oxygen atoms. The way the atoms or molecules are arranged in a material will affect its state of matter.

States of matter

A material might be found in different states. The most familiar states are solid, liquid or gas. Other states of matter are now recognised, such as plasma and liquid crystal, but these will not be dealt with in this unit.

The amount of energy the atoms or molecules of a material possess determines its state of matter. A substance will exist as a particular state of matter in particular temperature and pressure conditions. These are specific to the substance, for example, at room temperature and normal air pressure water can be found as a liquid and iron is found as a solid. Increasing the temperature eventually changes solids to liquids (the iron will melt) and liquids to gas (the water will become vapour).

- **Solids** have atoms or molecules that are held together with rigid bonds. The atoms vibrate in place but they do not change position. This means that a solid holds its shape and does not flow, nor can it be significantly compressed.

- ** Liquids** have atoms or molecules that are held together with looser bonds that allow atoms or molecules to slide past each other. They stay close together and so occupy a constant volume of space. Thus a liquid can only be compressed a little bit, if at all. Due to the force of gravity a liquid flows and takes the shape of the container into which it is poured.

- **Gases** have particles that are not held together with bonds. In the right conditions they can spread out and fill any available container. They can also be compressed.
Properties of materials

The Australian Curriculum: Science defines 'material' as a substance with particular qualities or that is used for specific purposes. As such, the term 'material' will be used in this unit to define what substances objects are made of. For example, a window (object) is made from glass (material) and a soft drink bottle (object) is made from plastic (material).

Materials have properties that can be used to describe and classify them. The properties of materials come from the chemical and physical nature of the molecules that are used to make them. Scientists use properties such as fluidity and compressibility to distinguish between solids, liquids and gases, however there are many other properties that can be studied, such as the absorbency, elasticity, strength and transparency of solid materials or the viscosity of liquids.

Some materials are composite materials, that is they are made of several different substances or materials. For example, foam rubber is made of polyurethane (a solid material) which is wrapped around pockets of air (a gas). The composite materials might have properties that come from their different materials, for example, foam rubber keeps its shape like a solid and is elastic (returns to its original shape after deformation) because of the polyurethane and it is compressible because of the gas trapped inside it.

Students' conceptions

Taking account of students’ existing ideas is important in planning effective teaching approaches that help students develop understandings in science. Students develop their own ideas during their experiences in everyday life and might hold more than one idea about an event or phenomenon.

Students are strongly influenced by everyday language, and can use the term 'solid' to denote something as hard or large. They tend to use it as an adjective rather than to describe a set of substances. They might have difficulty understanding that a rubber ball or a thin plastic sheet is solid in terms of how scientists use this word. 'Solid' is also recognised as an adjective denoting something 'good' or 'great' in some Australian English dialects.
Students might have difficulty recognising crushed or powdered solids as being solids, particularly since they might identify liquids through their ability to pour. Pouring is a consequence of flowing, which is the property of a fluid, but it is also possible to ‘pour’ small solids (beans) or powders. The difference is that when powders are poured they land in a heap and need to be shaken to settle, whereas liquids flow under the effect of gravity to take on the shape of the container.

Some students identify all liquids with water, and the most common liquids identified by students are water-based, including dishwashing liquid, milk, seawater, cordial and lemonade. Viscous liquids, such as oil, paraffin and honey, are less commonly identified as liquid. Students might also assume that all liquids contain water and that melting involves a substance turning to water.

Students might not have many conceptions about gas. When asked about gases they might provide examples of uses of gas, for example, ‘gas flame’, rather than examples of gases, for example, methane. Some students identify gas as dangerous or flammable and do not recognise that air is a gas.

References

Note: This background information is intended for the teacher only.
Key lesson outcomes

Science
Students will be able to:

• observe the properties of liquids
• identify that liquid materials flow and take the shape of their container
• identify the features of a fair test and predict which liquid is the most viscous
• work in teams to explore the viscosity of liquid materials
• review the investigation.

Literacy
Students will be able to:

• understand the purpose and features of a science journal
• record their observations of the properties in a table
• discuss and compare results to form common understandings.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 5).

Teacher background information

Properties of liquids
All liquids flow; under the influence of gravity they will spread out and take the shape of the container that they are in or spread out on a flat surface. However, not all liquids flow the same way. The viscosity of a liquid is a measure of its resistance to flowing. A liquid with a high viscosity, for example, cold honey will flow slowly. A liquid with low viscosity, for example, cooking oil will flow quickly and easily. How easily a liquid flows is related to its chemical structure, including the size and shape of the atoms or molecules and the strength of the bonds between them. The viscosity of a liquid is also affected by the temperature. Most liquids will flow more easily at higher temperatures than lower temperatures.

All liquids occupy a definite volume of space. The density of atoms can vary and therefore liquids have different weights for the same volume (density). Oil is less dense than water, which is why it floats on the surface of the ocean during oil spills.

Students' conceptions
Students might think that all liquids are water or contain water. Many common liquids, such as cordials and milk are suspensions of particles in water and behave similarly to water. However, the term 'liquid' applies to all materials that flow while keeping a specific volume, therefore oil, paraffin and honey are classified by scientists as liquids.
Key lesson outcomes

Science

Students will be able to:

- observe the properties of solids
- review the investigation and identify further questions for investigation
- work in teams to safely use appropriate equipment
- identify that powders are solids using evidence-based claims.

Literacy

Students will be able to:

- record their observations of the properties of solids in a table
- discuss and compare results.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 5).

Teacher background information

Properties of solid materials

In this lesson, students will be examine the materials from which several different objects are made. These materials are all classified as solids by scientists. Students will subject the objects to some tests in order to explore the properties (physical characteristics or attributes) of the solid materials. Properties that students might explore include:

Strength: a material's ability to resist forces applied to it. The more force a material can resist, the stronger it is. Tensile strength refers to a material's ability to withstand being pulled end from end, while compressive strength refers to a material's ability to withstand being compressed or squashed. Examples of strong materials include: steel, concrete.

Hardness: how easily the substance is worn away or scratched. Diamond is the hardest naturally occurring substance known, and can only be scratched by another diamond. Examples of hard materials include: diamonds, ceramic, concrete, steel, tusks, teeth.

Brittleness: a material is brittle if it is hard but breaks easily (like glass). Examples of brittle materials include: polystyrene, glass, ceramic, crystal.

Elasticity: a material is elastic if it changes shape when a force is applied to it and recovers its original shape when the force is removed. Rubber and many types of plastics are very elastic.

Malleability: how easily a material can be bent or shaped. A material that can be deformed or reshaped easily is said to be malleable. Examples of malleable materials include: gold, aluminium foil, play-doh, clay, brass.

Note: These terms are for teacher information only. Students are only required to use descriptions, such as squash, scratch, break, stretch, reshape.
**Powders**

Scientists classify materials as solids or liquids, not objects. Size is a characteristic of an object; it does not depend on the material that it was made from. For example, a ball can be the same shape and size irrespective of whether it is made from lead or leather.

Powders are made from solid materials; however, the objects themselves (the grains of powder) are very small. Each grain of powder keeps its shape, but as a group they behave like liquids because they can pour and fill containers. Powders do not spread out under the force of gravity; when poured they form heaps and often have to be shaken to take on the form of the container they are in.

Students might know a range of meanings for the word ‘material’, such as fabric or written information, and for the term ‘property’, such as land, real estate or possessions. For this unit, the term ‘material’ refers to what an object is made of, and ‘properties’ are qualities or attributes.

**Students’ conceptions**

The word ‘solid’ is used differently in everyday language from the way it is used in science. This might cause some confusion for students. For example, in everyday language ‘solid’ is often used to mean the opposite of ‘hollow’, however, hollow objects, for example, tennis balls, are classified as solids by scientists. Similarly, some students might believe that solids must be rigid and hard whereas scientists classify materials, such as paper and sponges, as solids. This is because ‘solid’ describes properties at the molecular level.

Students often find granular substances, such as sand and sugar, difficult to classify, particularly since they rarely examine individual grains. Some students refer to the size of the object when deciding if something is a solid or a liquid.

**Equipment**

**FOR THE CLASS**
- class science journal
- class science chat-board
- team skills chart
- team roles chart
- word wall
- 1 enlarged copy of ‘Solid science’ (Resource sheet 3)

**FOR EACH TEAM**
- each team member’s science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of ‘Solid science’ (Resource sheet 3)
- magnifying glass
- selection of solids (eg, soap, chalk, play-doh, a stone, a block of wood, a sponge, jelly snake, elastic band, marbles, flour, laundry powder, rice) (see ‘Preparation’)

---

_Lesson 3 Solid studies_ 27
Key lesson outcomes

Science
Students will be able to:

- make predictions, provide evidence for their predictions and compare them with results
- identify the features of a fair test and choose which variable to change
- work in teams to safely use appropriate equipment to complete an investigation
- identify that gases take up space and fill the container they are in using evidence-based claims.

Literacy
Students will be able to:

- discuss and compare results to form common understandings.

This lesson also provides opportunities to monitor the development of students’ general capabilities (highlighted through icons, see page 5).

Teacher background information

Gases
When a liquid is heated sufficiently, its atoms or molecules are so energised that they separate from each other and only have weak interactions. Gases have much more space between their atoms or molecules and are therefore generally hard to see, although a few can have a slight coloured tinge. It is easier to see the effects of a gas, for example, by looking at the movements of tiny ash particles in smoke as they float in the air.

Because the atoms or molecules are not bound strongly together, gases spread out and fill the container that they are in. They have comparably low viscosity and density and can be compressed, unlike solids and liquids. Gases vary in how much they can be compressed, the property of compressibility. If the compression from external pressure is strong enough and/or the temperature is low enough, gases will revert to liquid form.

Air
Air is the name we give to gases that surround the Earth and are kept close to the surface by Earth’s gravity. Air primarily contains nitrogen (78.1%), oxygen (20.9%) and argon (0.9%). It also contains trace amounts if other gases, such as water vapour, carbon dioxide, methane and ozone, which are gases that contribute significantly to the greenhouse effect (keeping some of the heat from Earth from dissipating into space). There might also be trace elements from industrial manufacturing, such as chlorine and fluorine compounds, mercury or sulphur dioxide. The relative concentrations of these pollutants determine air quality. There might also be fine particle of solids floating in the air, such as dust or pollen.
States of matter

Everything around us that takes up space is called matter. ‘States of matter’ means the form that matter takes. The states of matter that we mostly come across are solids, liquids and gases. Another state of matter is plasma. The Sun is mostly made of plasma.

**Solids**

Some solids are **hard**, such as stone and wood, some are **soft**, such as sponges and wool, and others are **powders**, such as flour and coffee, where each particle is a tiny solid. Solids keep their shape. In a solid, it is the particles that maintain its rigid structure. Heating some solids can turn them into liquids. For example, heating butter turns it into a liquid.

**Liquids**

Liquids flow and will spread out when poured. The shape of a liquid depends on the container it is in. Even when liquids change their shape, they always take up the same amount of space. Heating a liquid can turn it into a gas, for example, boiling water turns it into water vapour. Cooling a liquid can turn it into a solid, for example, freezing water turns it into ice.

**Gases**

Gases can be compressed. They are floating around us or are trapped inside a solid. They spread out and fill up the size or shape of the container they are in. Gases are often invisible. Cooling a gas can turn it into a liquid, for example, water vapour turns into water as it cools.
Key lesson outcomes

Science
Students will be able to:

- make predictions, provide evidence for their predictions and compare them with results
- identify the features of a fair test and choose which variable to change
- work in teams to safely use appropriate equipment to complete an investigation
- review the investigation and identify further questions for investigation
- identify that the volume of gases depends on their temperature.

Literacy
Students will be able to:

- discuss and compare results.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 5).

Teacher background information

Hot solids
Many materials become weaker at high temperatures, that is they become less resistant to forces exerted on them. They might also become more malleable and less elastic (less able to return to their original form after a deformation). Materials which retain their strength at high temperatures, in particular despite repeated and quick temperature changes, are useful for many purposes; for example, glass-ceramics have become extremely useful in the home.

Metallic materials that conduct electricity are better conductors at cooler temperatures. Some materials can become superconductors at low temperatures, for example, tin and aluminium, having almost no resistance to electrical current below their critical temperatures.

Solids can expand when heated and contract when cooled. This is one of the reasons houses creak in the evening. Different materials expand to different extents under the same temperature, which is why running hot water over a glass container can help loosen the metal lid (metal expands more than glass).

Hot liquids
When most liquids are heated their viscosity (flow) can change. Warm honey is much easier to spread on bread than cold honey, because the heat has decreased its viscosity. This effect is most noticeable on liquids that are very viscous at room temperature, such as honey or syrup. Liquids expand slightly as they heat and contract slightly as they cool. A notable exception to that rule is liquid water between 0 and 4°C.
Hot air

Gases expand when heated and spread out far more than liquids or solids since the interactions between their atoms or molecules are far weaker. This means that the density (mass per unit of volume) of a gas at a certain pressure can vary significantly depending on the temperature.

Hot air balloons use this principle to rise above the ground. The air they contain is much less dense than the surrounding air, which is therefore pushed upwards. This is the same principle as when objects less dense than water are pushed to the surface of bodies of water (Archimedes’ principle).

Hot changes

When most solid materials are heated sufficiently they reach their melting point and change into liquid materials. The material has the same atoms or molecules, but their interactions are different and so the properties of the material change significantly. When most liquids are heated sufficiently their atoms or molecules separate from each other and form a gas. These are known as physical changes.

Some solids, liquids or gases, when heated to a specific temperature, reach their burning point and might combust under certain conditions. This is a chemical change. In this lesson students are testing heat-dependent variations in the properties of solids, liquids or gases. They explore physical and chemical changes to materials in other units.

Equipment

**FOR THE CLASS**
- class science journal
- class science chat-board
- team skills chart
- team roles chart
- word wall
- 1 enlarged copy of ‘Balloon investigation planner’ (Resource sheet 6)
- 2 x 500 mL bottles
- 2 balloons
- 1 bucket
- water (~50°C) to ¾ fill the bucket
- extra equipment for conducting fair tests (eg, different-sized bottles, different-shaped balloons, different-shaped containers) (see ‘Preparation’)

**FOR EACH TEAM**
- each team member’s science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of ‘Balloon investigation planner’ (Resource sheet 6)
- 2 x 250 mL bottles
- 2 balloons
- 1 container deep enough to submerge a 250 mL bottle
- water (~50°C) to ¾ fill the container
Teacher background information

Changes to objects can include changes to the size, shape, smell and appearance. For example, a rock crumbles, a teapot breaks, and a steak changes colour, odour and texture when cooked.

Objects have characteristics such as size, weight and appearance, which are determined by the materials that are used to make them. Materials can be made of several different substances, for example, air is a material made of many different gases. Substances are made of particles, atoms or ions.

Physical change is a change to the physical properties of an object or material where the substances remain the same. The object itself might not remain the same, for example, a rock could be ground to powder or a mug be smashed to pieces, but the substances are still present. There is still rock and porcelain. Physical change occurs when an object receives or loses energy. This might be from a force, for example, by being hit, or when a substance gains or loses heat energy, for example, when an ice cube melts or liquid water freezes.

A chemical change is where a substance is transformed into a new substance (or substances) at the molecular level. The new chemical substances may be in the form of a gas, liquid or solid. For example, it is easily seen that charcoal is created when toast burns, but the combustion of the cellulose in the bread also produces invisible carbon dioxide and gaseous water. When a substance undergoes a physical change, however, its chemical composition does not change – water is H₂O whether it is in the form of a gas (steam), liquid (water), or solid (ice). Common salt, solid sodium chloride, can be recovered from salty water by evaporation and dissolved again to form salty water in which the two components of salt are still present. Sugar crystals can similarly be recovered from sugar-sweetened water without chemical change.

When some substances undergo physical changes, there can also be some minute chemical changes occurring at the molecular level. These changes are only detectable through scientific testing. For example, when sodium bicarbonate dissolves in water the majority of the change is physical. At the molecular level, some of the sodium bicarbonate and water react to produce a slightly alkaline solution.

For further information about physical and chemical changes see the PrimaryConnections Science Background CD and the PrimaryConnections website. www.science.org.au/primaryconnections

Students’ conceptions

Taking account of students’ existing ideas is important in planning effective teaching approaches which help students learn science. Students develop their own ideas during their experiences in everyday life and might hold more than one idea about an event or phenomenon.

Many students might hold non-scientific conceptions about physical and chemical changes because the changes that occur at a particle level are not observable. In physical changes such as freezing, melting, evaporation and boiling that bring about a change of state, students might believe that substances which evaporate simply disappear and no longer exist and that heat and cold are actual substances involved in these changes.

Students might not realise that the substances produced by a chemical reaction are new substances, different from the original substances. For example, rust is not iron—it is something new created when iron reacts with oxygen in the presence of water. Students might think that the
same materials or substances are still present after a chemical change. A chemical change produces new substances by consuming the original ones.

Many students do not believe that mass is conserved in a chemical change, that is, the mass of substances before and after the change are the same. Many students believe that the mass of exhaust gases is less than the mass of liquid petrol burnt in the car's engine. This is related to the misconception that gases have no weight. Many students also believe that air or oxygen plays no active role in combustion reactions.

Students sometimes confuse substances and energy. For example, they might think that heat and light are substances whereas they are forms of energy, not substances made of particles.

Safety

This unit uses some common household items and chemicals. Each Australian state and territory has specific health and safety requirements. You need to comply with any requirements of your state and school regarding health and safety in the classroom, particularly with restrictions on using aspirin and aspirin derivatives in the classroom.

Check local jurisdiction requirements before teaching this unit.
Key lesson outcomes

Science

Students will be able to
• plan an investigation, with teacher support
• make predictions about what factors will make an ice cube melt fastest and a liquid evaporate fastest
• observe, record and interpret the results of their investigation
• describe the effect of temperature on phase change
• explain that the same substance can change state and be a liquid, a solid, or a gas
• explain why they can smell evaporated liquids.

Literacy

Students will be able to
• understand the purpose and features of a table
• use oral, written and visual language to record and discuss investigation results
• engage in a discussion to compare ideas, and use evidence from an investigation to explain that temperature has an effect on phase change
• role-play their understanding of the effect of temperature on phase change by using representational models of particles.

Teacher background information

An object can be changed by external forces, for example, it can be dented, scratched or broken. An object can also change because the substances the object is made of change. For example, a full, sealed bottle of water placed in the freezer can change shape, or even explode, because the water in the bottle expands as it freezes. A chocolate rabbit left in the Sun will change shape because the heat from the Sun melts the chocolate.

States of matter

All substances are made of particles. A substance might be found in different states. The traditional ones are solid, liquid or gas. The difference between them is the amount of energy the particles of the substance have, for example, the difference between solid chocolate and melted chocolate is the amount of energy their particles have. Other states of matter are now often recognised, for example, plasma and liquid crystal.

**Solids** have a fixed shape and volume at the particle level. For example, an ice cube has a certain shape and space it takes up. The particles of solids are all tightly packed together; however, the particles vibrate about a fixed point.

**Liquids** have a fixed volume but their shape depends on their container. One litre of water takes up the same amount of space in any container, but will take the shape of its container (for example, the shape of a bottle, glass or bowl). The particles of liquids are packed together but can slide over each other enabling liquids to change their shape.

**Gases** have no fixed shape or volume, and assume the shape of the space in which they are contained. The particles of gases bounce around, into each other and off the sides of the container. The gases of the atmosphere are retained around the Earth because of the Earth's gravity.
Changing states

Substances change state when they gain or lose heat energy. For example, frozen water that gains heat energy will start changing into liquid water at 0°C, and liquid water will start changing into water vapour (gas) at 100°C. When a saucepan of water is placed on a stove, the heat energy initially goes into warming the water. When all the water has reached 100°C then the heat energy will go into turning the water into vapour (rather than heating the water). The liquid water will remain at 100°C and bubbles of water vapour will form. The heat energy makes the particles vibrate and move more energetically. Some particles move so fast they escape from the surface of the liquid water and become water vapour.

Whether a substance is a solid, a liquid or a gas depends on the pressure and temperature of the substance’s environment. Pressure tends to keep particles together. When heat provides energy causing a substance to change state, adding pressure can prevent this from occurring. For example, the liquid water in a pressure cooker can reach temperatures above 100°C.

When melting a solid or evaporating a liquid, the faster heat is gained by the substance, the quicker it will change state. Heat enters through the surface, therefore the larger the surface available, the faster heat will be absorbed. Heating an ice cube in a frying pan only warms one side and takes longer than immersing an ice cube in hot water. Smashing an ice cube increases the available surface area, and so it will melt faster.

When a substance changes state, the particles do not change, it is the way the particles are spaced that changes. This is known as a physical change, and it is easily reversible. However, when a non-pure solid (mixture) melts and becomes liquid, sometimes the components can separate. Therefore when the liquids are put back into the freezer, the original solid might not be re-created. For example, melted and refrozen ice-cream becomes two separate solids: ice and frozen cream.

Students’ conceptions

Students have difficulty classifying soft, malleable and granular solids as solids in the way they are defined by scientists. This is reinforced by the common use of ‘solid’ as an adjective meaning hard, heavy, not flexible or in one big piece. Granular solids, such as powders, might behave like liquids because they take the shape of the container they are in. However the particles in each grain of a powder have a definite shape and volume, and powders can form mounds when poured whereas liquids can not. Some solids such as jelly are considered to be non-rigid solids to distinguish them from solids that are rigid and have a fixed shape.

Some students might associate melting with ‘turning to water’. When an ice cube melts it is not turning into water, it is solid water changing into liquid water. The water is changing state. All substances remain the same substance when they melt.

Students might think that a thick cloth or aluminium will melt an ice cube, because they associate these materials with warmth. These materials help keep our body (or food) warm because they are effective insulators—they insulate the warmth produced by our bodies. However they will also slow the rate at which heat energy moves from the surrounding air or surfaces to the ice cube.
Session 3  Evocative evaporation

Teacher background information

The particles of a gas are widely separated, move around freely, and move at high speeds. A gas therefore takes up more space than the same amount of matter in a liquid form. The hotter a gas is, the more energy the particles have and the greater the space it takes up.

Air is a mixture of different gases. Air generally contains nitrogen, oxygen and carbon dioxide, as well as many other particles such as water vapour. If the air contains particles that react with the smell receptors in our nose, then we sense these as smells. For example, perfumes contain particles that react with our smell receptors, but water particles and oxygen particles do not—they are odourless.

When our nose is blocked, the particles cannot reach the receptors and we cannot smell. Some particles need to be present in large quantities in order for the receptors to send a ‘smell’ message to the brain. This is why we smell better by putting our nose close to where the substances are evaporating, before the particles disperse widely in the air.

Students’ conceptions

Students have various understandings of what happens when a puddle evaporates. This is due to confusion between the substance water (in one of its three states) and liquid water (that they can see and recognise as water). This is reinforced by common language—we say we drink water, rather than drinking liquid water, and we refer to solid water as ‘ice’. For example, students might think the water disappears, or ‘dries up’. However, the liquid water changes state into gaseous water (turns into water vapour). The particles of water are still present (matter does not disappear). Students often do not imagine that particles go into the air, so they might mention the water ‘going into the Sun’ or ‘going into the table’.

Students might not associate the smell of liquids, such as perfume, with a physical substance. They might think of it as a property of the object, rather than the particles from the object reaching their nose.
Session 1 Delightful dissolving

Teacher background information

Dissolving

When a solid, for example, in a powder form, is added to a liquid, it might dissolve. When this happens the particles of the solid completely disperse in the liquid so that they are no longer visible (not to be confused with a suspension of a solid in a liquid). For example, when table salt is dissolved in water, a liquid solution is formed that contains a dissolved salt. The salt is not changed into another chemical substance: the salt remains as salt but is now dissolved in water.

Not all substances will dissolve in water, for example, nail polish dissolves in acetone. Some solids will dissolve in water but not in other liquids, for example, aspirin tablets will not dissolve in oil. Whether or not things dissolve depends on the properties of the liquids and the solids, for example, hydrophobic (‘fears water’) substances, such as fats, will not dissolve in water—that is why detergents are used to remove grease.

If the powdered solid does not dissolve in the liquid, the liquid will appear cloudy when it is stirred (and will become clear again when the powder resettles at the bottom). This is because the solid particles block light more effectively than the liquid does. After adding a soluble powder, a liquid might become cloudy when it is first mixed. This is because it takes time for solids to dissolve. Stirring helps the process by allowing the water to reach as much of the solid as possible.

Liquids such as liquid water can only dissolve a certain amount of a solid at room temperature and pressure. That is why some solid might remain undissolved if too much of a solid is added to the water. The salt or sugar dissolves until the ‘solution is saturated’. You can increase the amount of substance that dissolves in a liquid by increasing the temperature or pressure. Water can dissolve more sugar crystals when it is hot. If the sugar solution is ‘saturated’ when it is hot, sugar will crystallise from the solution when it cools.

Gases can also dissolve in liquids. ‘Carbonated water’ used for soft drinks is water in which carbon dioxide gas has been dissolved. The water and gas are put under pressure so more gas is dissolved in the water than would be the case under normal atmospheric conditions. When the pressure is released by opening a bottle or can, the excess carbon dioxide escapes from the water as bubbles.

Students’ conceptions

Students might confuse dissolving with melting. Melting is a change of state—a solid substance becomes liquid through a change of pressure or heat. Dissolving is when one substance (solid or gas) combines with a liquid substance.

Students might say that the ‘sugar has disappeared’ when sugar has dissolved in water. This statement might mean that students believe that the sugar is no longer present, or it might mean that they are simply remarking that they can no longer see the sugar. The sugar is still present, although it is no longer visible, and can be retrieved if the water evaporates from the solution.
Session 2 Gas bags

Teacher background information

Sodium bicarbonate (NaHCO₃) is a common chemical used in the kitchen. It has many other common names, including sodium hydrogen carbonate, sodium bicarb, baking soda, bread soda, cooking soda, bicarbonate soda or bicarbonate of soda. It is used in baking because when it comes in contact with an acid, carbon dioxide gas is formed. When the gas is produced it is trapped in bubbles in the material. Gases expand when they are heated, so the cake mixture (with bubbles of gas trapped in it) rises.

When tartaric acid and sodium bicarbonate are mixed in powder form the particles are not free to react with each other, so there is no chemical reaction. When each is dissolved in water separately there is no carbon dioxide gas formed since only one of the necessary particles is present each time. It is only when the substances are combined in their dissolved form that the reaction takes place. The two original substances sodium bicarbonate and tartaric acid (the reactants) react with each other and are changed into new substances which are formed by the chemical reaction (carbon dioxide, water and sodium tartrate).

Sodium bicarbonate is a chemical salt, which means it is a solid made of two particles (Na⁺ and HCO₃⁻). These two particles separate in the water. Acids such as tartaric acid are substances that release particles of hydrogen (H⁺) when they are dissolved.

The reaction occurs between the HCO₃⁻ particles from the sodium bicarbonate and the hydrogen (H⁺) particles from an acid. These react together and form carbon dioxide (CO₂) and water (H₂O). The carbon dioxide produced is a gas at room temperature so it forms bubbles in the solution.

Sodium bicarbonate will react with any acid to produce the gas carbon dioxide. Because the reaction changes the acid, sodium bicarbonate is often used to neutralise acids. For example, it is sometimes prescribed to patients with acid indigestion.

Students' conceptions

Students might think that a chemical reaction is not an interaction of ingredients, but one ingredient that plays an active role. For example, when presented with bicarbonate reacting with vinegar (a weak acid in water), they might ascribe the cause of the reaction to be the sodium bicarbonate dissolving in a liquid. Using tartaric acid instead of vinegar will allow students to compare dissolving and reacting.

Most students are familiar with 'fizzy' drinks. Therefore the appearance of bubbles is not necessarily seen as something which needs to be explained. See the 'Teacher background information' in Lesson 3, Session 1 for an explanation of why carbonated drinks have bubbles of carbon dioxide in them. Students might have the misconception that the bubbles formed by a chemical reaction (a chemical change) is the same process by which bubbles are released from solution when the cap is removed from a bottle of fizzy drink (a physical change).
Teacher background information

Fire is what we see in the chemical reaction of combustion. This reaction requires three things: heat, fuel and oxygen. ‘Getting the fire started’ literally means creating enough heat for the fire to self-sustain so long as there is fuel and oxygen. Once started, the reaction produces heat energy.

The fuel provides the chemical energy for the reaction. It is generally carbon-based, for example, wood, coal, natural gas, oil or wax.

Oxygen (from the air) reacts with the fuel in the heat of the reaction. Combustion reactions usually produce carbon dioxide gas and water vapour, for example:

\[ \text{candle wax + oxygen} \rightarrow \text{carbon dioxide + water} \]

Wax and oxygen are combined in the chemical reaction to form carbon dioxide and water vapour as new substances.

Fire blankets are designed to stop oxygen reaching the fuel and therefore stop the reaction. A candle goes out when covered by a jar because the oxygen in the jar is consumed and the flame becomes surrounded with carbon dioxide which does not support combustion.

When a fuel receives enough heat and oxygen it will burst into flame. The temperature at which this occurs is known as the ignition point, and each fuel has its own ignition point. Substances with low ignition points are more likely to burn when heated by a fire and are known as flammable, for example, certain fabrics and paper. Fire starters have a low ignition point, they are therefore easy to light and the heat produced by their burning can cause logs to ignite.

If the temperature drops below ignition point the combustion reaction can no longer occur. Fire fighters douse flames with water because the water absorbs the heat energy to change the liquid water into water vapour, dropping the temperature of the fire. For the same reason, logs that are full of moisture will not burn easily since the initial heat put on them will go into turning the liquid water to water vapour rather than bringing the wood to its ignition point.

The wick of a candle burns long enough for the wax to start melting. The liquid wax is drawn up the wick to the flame where it becomes a gas. As a gas it reacts with the oxygen and creates carbon dioxide and water. This reaction releases energy in the form of heat. The carbon dioxide and water produced are gases; however the water vapour will condense once away from the heat of the candle. Some wax particles begin to react with the oxygen but leave the candle before they are completely changed; these particles create a black smear where they land.

Students’ conceptions

Students might not think that gaseous substances, for example, oxygen, are actively involved in the burning process. Therefore they might not realise that such substances are consumed during the reaction.

Many students think that during burning, a substance called heat is formed and no other substances are formed. Heat is not a substance; it is a form of energy. The two new substances formed (carbon dioxide and water) are both colourless gases.

Students might believe that the wax slows the wick down or holds it up, rather than realising its role as fuel. Similarly students might believe that a candle simply melts or changes to vapour in the air, rather than being consumed by the flames and producing new substances.
Teacher background information

Developing categories helps scientists to organise and make sense of the world around them. Everything in the world is unique, and categories help to identify the similarities and differences between things. Things might be grouped in different ways for different purposes. For example, scientists studying food webs might group animals as herbivores or carnivores whereas an ecologist studying a community of native animals might want to distinguish kangaroos from wallabies.

The following descriptions are used for this unit:

**Physical change** is a change in which no new substance is formed.

**Chemical change** is a change that results in the conversion of the original substances to form new substances.

In this unit a 'new substance' means the formation of new types of particles. Therefore water melting and salt dissolving are physical changes, whereas burning and the sodium bicarbonate reaction are chemical changes. These descriptions are very simple, and some changes seem to fit into both categories. For example, when a candle burns, the wax melts (physical change) and then burns (chemical change). The important thing is for students to give a reasoned argument as to why they chose to classify the changes as physical or chemical.

In this unit students investigate reversible physical changes (melting, evaporating and dissolving) and irreversible chemical changes (burning and the formation of gas). However, some chemical changes are reversible, for example, the chemical reaction which drives rechargeable batteries. Some physical changes are also irreversible, for example, grinding a log into sawdust.

Some other common changes are:

- Rusting iron, which is caused by the iron particles reacting with water and oxygen to form a new substance (rust). The original metal is changed into a new substance. This is a chemical change.
- Cutting wood is a physical change since the wood changes form. However if the friction of the chainsaw produces enough heat some of the wood might reach ignition point, in which case some sawdust might burn and undergo a chemical change.
- Bending wire is a physical change, since the object only changes form.
- A glowing tungsten filament in an incandescent light bulb is not a chemical change. The heat and light produced are forms of energy, not new substances. The filament is heated to its ignition point but as there is no oxygen, the wire does not burn—it glows.
- Bubbles appearing in carbonated drinks is a physical change. Carbon dioxide gas was dissolved in the drink at high pressure, and when the pressure was released, the particles come out of solution, become a gas again, and leave the drink.
Key lesson outcomes

Science

Students will be able to
- formulate a question and make predictions about what factors affect the speed of a chemical reaction
- plan and conduct fair tests of different factors to see if they affect the speed of a chemical reaction
- make and record observations
- construct and identify patterns in a graph
- provide evidence to support their conclusions.

Literacy

Students will be able to
- represent results to decide what factors affect the speed of a chemical reaction
- summarise their findings about what factors affect the speed of a chemical reaction
- engage in discussion to compare ideas and provide relevant arguments to support their conclusions.

Teacher background information

Most fizzy tablets contain sodium bicarbonate and an acid powder, for example, citric acid. As seen in Lesson 3, these two chemicals react when in water together forming bubbles of carbon dioxide. This is a chemical reaction since new substances are formed (water and carbon dioxide) and the original substances are changed. Like most chemical reactions, the speed of this reaction increases at higher temperatures and decreases at lower temperatures. As the reaction depends on the substances being in water, the faster the water has access to the particles, the faster they dissolve and can react with each other. Breaking the tablet in half or crumbling will increase the surface area exposed to water which will increase the speed of the reaction.

Tablets might contain the ingredients to create bubbles for several reasons. It might help increase the rate at which the tablet breaks up and dissolves. Also, fizzy liquids are absorbed by the intestines faster than other liquids. The bubbles tickle the exit valve in your stomach, and it opens. For example, this is why champagne tends to make people more tipsy (the alcohol reaches the bloodstream faster).

Replication and repeat trials

In this investigation, students will focus on variables that influence the speed of the chemical reaction that produces the fizzing effect. The time taken to complete fizzing is a measure of the reaction rate or speed of the reaction.

The speed of the reaction might vary slightly from tablet to tablet because the tablets are not identical (sampling error). Also there might be other sources of error, for example, observation error (for example, a timing error) and manipulation error (for example, the tablets might not all be inserted in the same way). It is best to repeat the test several times to be sure that the average result is a good approximation of the actual time it takes for the reaction to take place. Scientists conduct repeat trials whenever possible. The more sources of error, the more trials are needed to be sure that the results are reliable.