PEARSON

Science

STUDENT BOOK | 3RD EDITION

8

TOPIC 3

Classifying matter: Elements, compounds and mixtures

Everything is made of matter. Matter is anything that takes up space and has mass. All matter is made from tiny particles called atoms. Sometimes an atom can join with other atoms to make a molecule.

There are 118 known types of atoms. Elements are made of just one type of atom. These elements make up all matter in the universe. Two or more elements combine to make a compound.

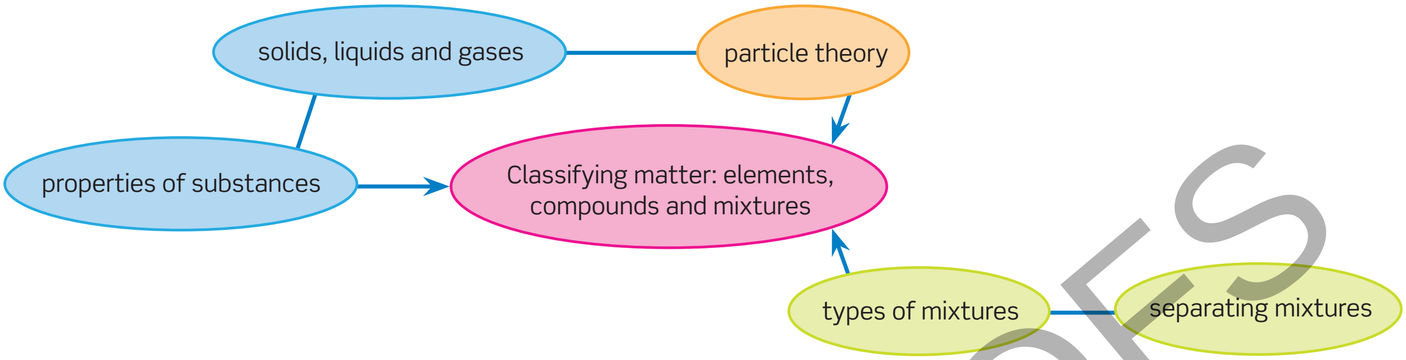
In this topic you will learn about atoms, molecules, elements and compounds. You will also study mixtures and alloys and learn how to read chemical formulas. You will learn how to name molecular compounds and how to draw particle diagrams.

Learning intentions

- ☐ To understand that elements are made up of only one type of atom **xx**
- ☐ To be able to observe, record and organise information of elements **xx**
- ☐ To understand the differences between elements and compounds **xx**
- ☐ To understand how some gases present in the air were discovered, how they have been used and the implications of their use in society **xx**
- ☐ To be able to compare the properties of elements to the properties of compounds **xx**
- ☐ To understand the differences between mixtures and pure substances (elements and compounds) **xx**
- ☐ To be able to use observable properties to classify elements as metals or non-metals **xx**
- ☐ To be able to conduct an experiment that involves the production of a metallic element from a compound **xx**
- ☐ To understand that the particles in matter can have different arrangements **xx**
- ☐ To understand how chemical formulas of compounds are written **xx**
- ☐ To be able to compare information provided in symbols, formulas, two-dimensional models and three-dimensional models of substances **xx**
- ☐ To be able to relate the structure of substances to their observable properties **xx**

3 Classifying matter: Elements, compounds and mixtures

The key concepts that you will use in this topic:



The following questions will help to support your learning in the topic and can be attempted before the first lesson.

Properties of solids, liquids and gases

1 The three key states of matter are solids, liquids and gases. Name the state(s) that:

- **a** have a fixed shape
- **b** have a definite boundary
- **c** can diffuse quickly
- **d** cannot be compressed.

2 When a ballon is filled with helium gas, it can float upwards in the air. A student suggested that this must be because the helium makes the balloon lighter. State whether you agree with this, explaining the reasons for your answer.

Particle theory

3 All materials are made up of particles. Describe the behaviour of particles in a liquid in terms of their movement, spacing and attractions between particles.

4 Liquified petroleum gas (LPG) is a fuel used for barbeques and some cars. When released from the cylinder it turns into a gas. Explain, using the ideas of particle theory, why it is in liquid form when contained in the cylinder.

5 Describe what happens to the particles in a solid when the solid is heated.

Types of mixtures and separating mixtures

6 When salt is added to water and stirred, the salt appears to disappear.

- **a** Using the terms solute, solvent, dissolves and solution, describe what has happened to the salt.
- **b** Describe a way to recover the salt from the water.

7 Air in the atmosphere contains a number of gases including oxygen, nitrogen, carbon dioxide and helium.

- **a** Which one of these gases do you think is the most abundant in our atmosphere?
- **b** State whether you think the amounts of each gas in the atmosphere is fixed or can change. Explain the reasons for your answer.

3.1 Elements, atoms and symbols

Lesson overview

The desk you are sitting at, the pen you are holding, and the clothes you are wearing are all made of matter. Chemistry is the study of matter, and all matter is made up of atoms. Gold, silver, neon and tin are probably all terms you have heard of before. Each of these substances is an element. An element is a substance made entirely of one type of atom.

There are 118 elements that have been identified and named, and each has its own unique symbol. Sometimes these symbols are obvious, like Ne for neon; other times they are less obvious, like Au for gold. All known elements are represented and organised in the periodic table.

In this lesson you will learn about atoms and elements. You will learn that atoms make up all matter, that an element is a collection of one type of atom, and that each element has a unique symbol represented on a periodic table.

Learning intention

To understand that elements are made up of only one type of atom

Success criteria

SC 1: I can explain what an atom is.

SC 2: I can recall that elements are made up of only one type of atom.

SC 3: I can state a range of elements and represent them with their symbols.

SC 1 I can explain what an atom is

Atoms

Imagine small building blocks making up everything around you. You cannot see them, but they make up all **matter**. Previously, you have learned that matter is anything that has a mass and takes up space. This could be something solid, like a piece of wood or it could be the air around you.

All matter is made up of **atoms** (Figure 3.1.1). Atom comes from the ancient Greek word 'atomos', which means indivisible. Atoms are the smallest individual pieces of matter that can exist by themselves. Think of an atom like a grape: there are parts that make up grape (the skin, the flesh, the seed) but for it to be a grape you need all the parts.

You will learn more about the structure and parts of an atom later. Atoms are very small and cannot be seen, even under a microscope. For example, a human hair could fit approximately a million carbon atoms across it.

One way to think about the idea of an atom is to carry out a 'thought experiment'. Imagine a solid, such as a piece of gold, then imagine cutting it in half, then in half again, and again, and again and so on. Eventually you would get to the point that you cannot divide the gold anymore.

This is the point that you have reached one atom of gold.

KEY TERMS

matter a physical substance; anything that has mass and volume

atom the smallest piece of individual matter that can exist by itself

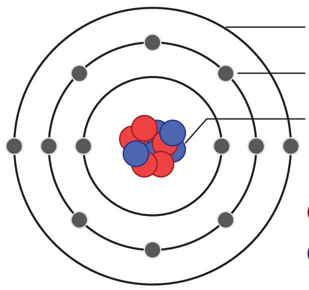


FIGURE 3.1.1 Atoms are too small to see; this is a representation of an atom

SC 1 CHECK YOUR UNDERSTANDING

The word atom is derived from the Greek word *atomos* which was used to describe something that cannot be cut up into smaller pieces (is indivisible).

a Explain why this word was chosen to describe the idea of atoms.

b Describe two other characteristics of atoms.

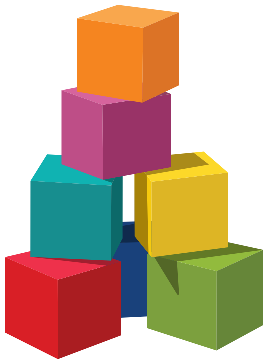


FIGURE 3.1.2 Atoms are like small building blocks that make up all matter

KEY TERMS

element a substance made up of only one type of atom

allotrope different form of the same element

SC 2 I can recall that elements are made up of only one type of atom

Atoms and elements

There are different types of atoms. There could be a silver atom, an oxygen atom or a calcium atom. Silver, oxygen and calcium are all examples of elements. An **element** is made up of one type of atom. An element cannot be broken down into other substances. Using the analogy of building blocks, each element is a like a different coloured block (Figure 3.1.2). A big block of red is only made of red 'atoms'.

There are now 118 identified elements. Some elements are common on Earth (for example oxygen and carbon), while others only exist in a laboratory. For example, meitnerium is an element with the symbol Mt. It is a synthesised element (which means it is not found in nature). It is named after the Austrian female physicist Lise Meitner.

The element carbon

Carbon is an element. Diamond and graphite look very different but are both made entirely of carbon. In diamond and graphite, the atoms are arranged differently.

The arrangement of carbon in diamond and graphite is shown below (Figure 3.1.3). Both are made entirely of carbon atoms, but in each one the carbon atoms are arranged differently. The lines represent links (or bonds) between the atoms.

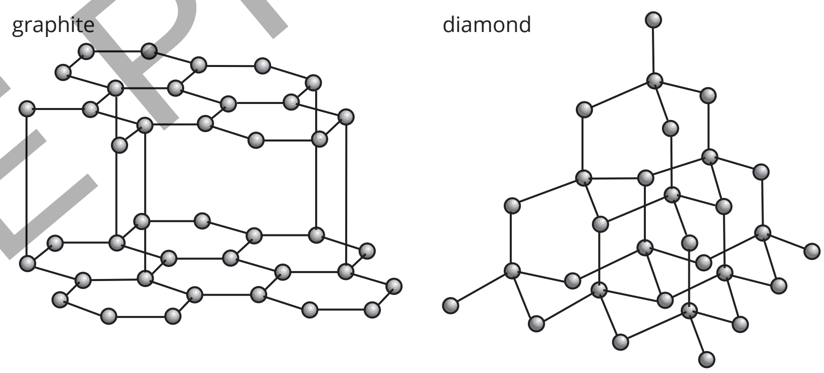


FIGURE 3.1.3 Arrangements of carbon atoms in diamond and graphite

Diamond and graphite are **allotropes**. Allotropes are different forms of the same element (Figure 3.1.4). Both diamond and graphite are carbon, but with the atoms arranged differently.

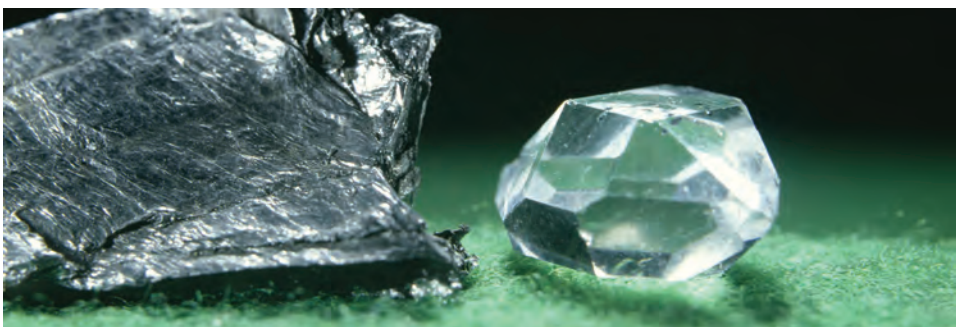


FIGURE 3.1.4 Graphite (left) has very different properties to diamond (right)

Scifile

The element lithium

The element lithium (Li) is sometimes called white gold due its silvery-white colour and its high value. Lithium is used in batteries that will be essential for a successful transition away from the burning of fossil fuels to sustainable energy supplies, such as solar and wind power.

SCIENCE IN SOCIETY

The value of gold (Au)

You may wonder why the price of gold is so important. In 2024 the price of pure gold (described as 24 carat gold) was around $3600 Australian dollars per once (1 once = 26 grams).

There are many reasons why gold has value.

- Gold has a distinct appearance so it is recognised by many different peoples and cultures around the world.
- Gold can be produced in a very pure form which means that gold produced in Australia is the same as gold produced anywhere around the world.
- Gold is relatively rare, and expensive to extract from Earth.
- Gold is an unreactive metal which means it will last for a very long time.
- Gold can be melted and formed into small units, such as ingots and coins without losing any of the gold itself (Figure 3.1.5).

For these reasons, gold has been used as currency for thousands of years, and continues to be used as a form of 'wealth storage'. The Reserve Bank of Australia for example owns around 80 tonnes (80 000 kg) of gold.

Despite Australia's strong link with gold mining, the name is not connected. The name Australia is derived from the Latin Terra Australis meaning southern land. The symbol Au for gold comes from *aurum*, the Latin name for gold.

FIGURE 3.1.5 The biggest and heaviest gold coin in the world at the Perth Mint, Western Australia, made from one tonne of 99.99 per cent pure gold

SC 2 CHECK YOUR UNDERSTANDING

There are thousands of different substances in the world, but only 118 different elements have been discovered. Explain, using the idea of atoms, why this is.

SC 3 I can state a range of elements and represent them with their symbols

Elements and their symbols

All elements have a unique symbol, some of them seem obvious, like H for hydrogen. Others are not obvious, for example, Na for sodium. Some have been named after a place (e.g. Americium), some have been named after a famous scientist (e.g. Mendelevium – Dmitri Mendeleev developed the first periodic table) and some are named from ancient languages (e.g. helium is from the Greek word for sun, *helios*).

Only elements are found on the periodic table.

DISCOVER MORE

A Russian scientist named Dmitri Mendeleev developed an outline of the periodic table in the 1800s. He left gaps where he thought an element would be discovered, and remarkably, those elements were discovered later. This supported his way of organising the elements.

The periodic table

All elements are listed on a periodic table (Figure 3.1.6). Vertical columns are called groups, and horizontal rows are called periods. Periodic means repeating, and each row has similarities to the other rows, which is why the name 'periodic' table is used.

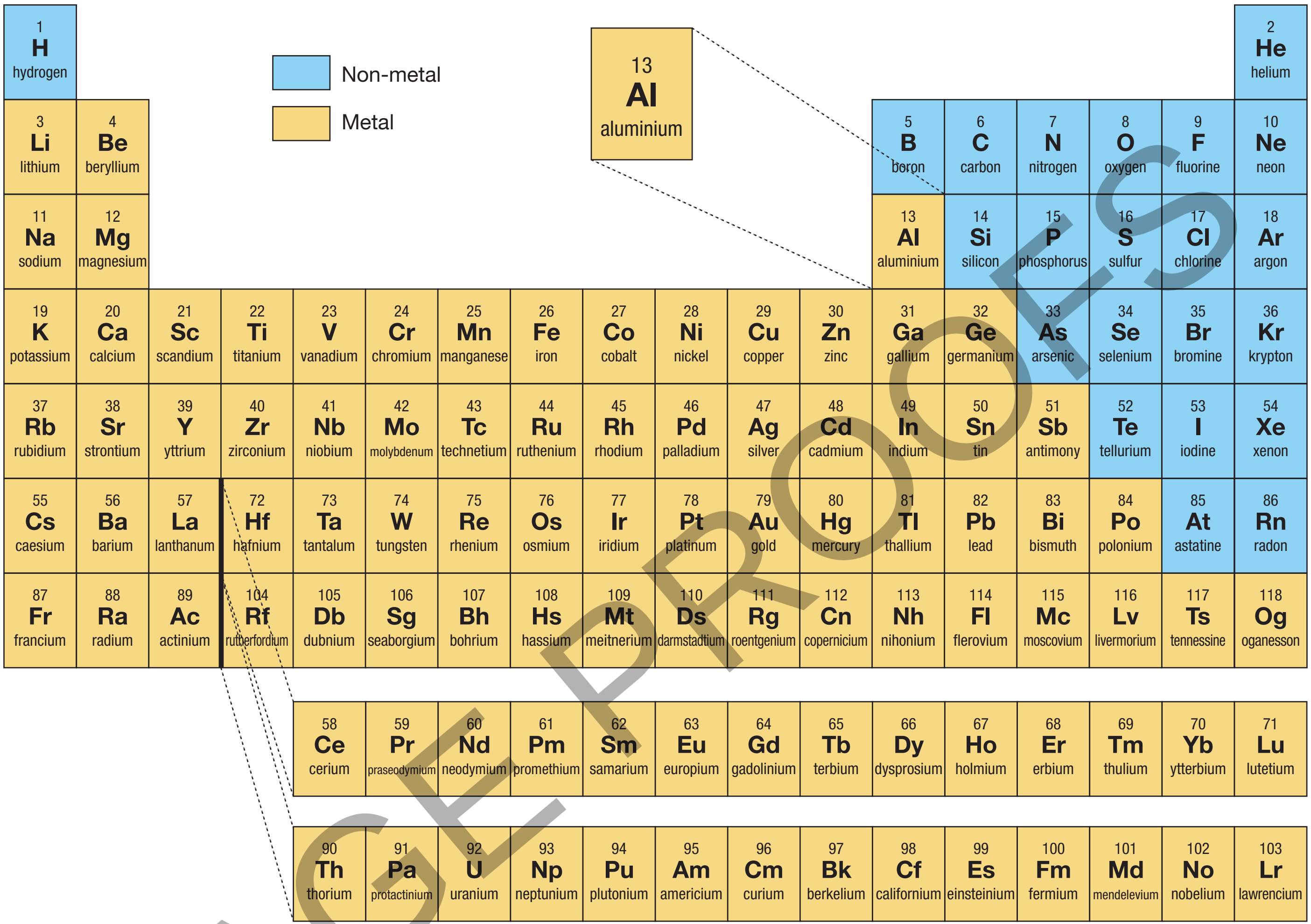


FIGURE 3.1.6 The modern periodic table

Element symbols

Writing element symbols is an important skill that helps you communicate information. Consider the example of the symbol for magnesium here.

1. Identify the element on the periodic table. The element is magnesium (Mg).
2. The first letter (M) must be in upper case.
3. If there is more than one letter, the rest must be in lower case.

For magnesium, write Mg (never MG or mg).

New elements

When new elements are discovered in a laboratory they are given a temporary three-letter symbol. Once the discovery has been confirmed, the element is given its official name and symbol (usually two letters). For example, element 117, previously known as ununseptium (Uus), is now called tennessine (Ts) after the American state of Tennessee (Figure 3.1.7).

What would you name an element if you discovered one?

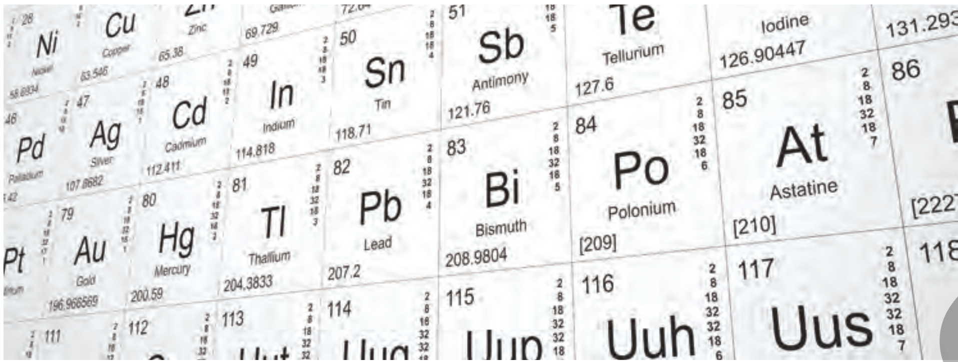


FIGURE 3.1.7 Section of a version of the periodic table showing some three-letter symbols, including ununseptium (element 117)

More elements

Table 3.1.1 provides information about four more common elements: sodium, nickel, iron and copper

TABLE 3.1.1 Four common elements

Element	Symbol	Origin
sodium	Na	Latin (*natrium*) – soda in English
nickel	Ni	From German word *kupfernickel*, meaning devil's copper
iron	Fe	Latin (*ferrum*)
copper	Cu	The Romans first obtained copper on the island of Cyprus. The Latin word for Cyprus is *cuprum*.

SC 3 CHECK YOUR UNDERSTANDING

State the symbols for the following elements.

a helium
b mercury
c gold
d magnesium
e manganese
f iron
g sodium
h chlorine

Lesson review

Use these questions to check your understanding of the learning intention and success criteria for this lesson.

1 Carbon is the element upon which life on Earth is based. Compounds such as DNA, proteins and sugars (a type of carbohydrate) all contain carbon.
- **a** State the chemical symbol of carbon.
- **b** Elements can sometimes exist in forms called allotropes. Use the example of carbon to explain the meaning of the term allotrope.
- **c** Find out what two other elements are present in all carbohydrates.

2 The element Mendelevium has the symbol Md and was discovered in 1955.
- **a** Explain why Md was used as the symbol for Mendelevium and not Mn.
- **b** Name the scientist that this element was named after.
- **c** Describe how this scientist contributed to our understanding of atoms and elements.

3 The following words can be spelt by combining chemical symbols. For each word identify the symbols of the names of the elements used. It would help to have a periodic table to refer to for this question. For example: band = Ba (barium) Nd (neodymium)
- **a** flame
- **b** aspirin
- **c** dynamite

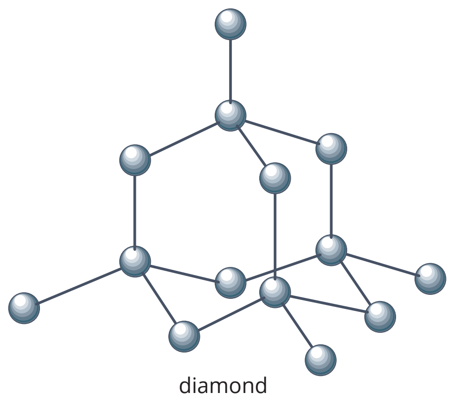
4 Describe the difference between the meanings of the words atom and element.

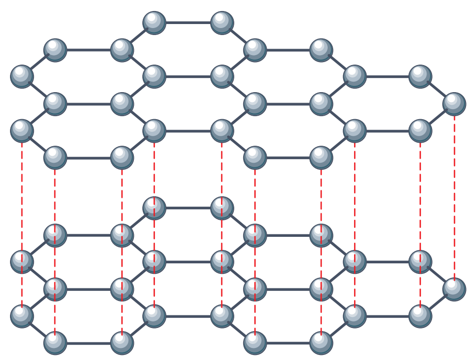
5 Consider the table below that shows a range of elements and their chemical symbols.

Name	Symbol
Copper	Cu
Americium	Am
Curium	Cm
Francium	Fr
Sodium	Na
Mendelevium	Md

From these elements:
- **a** state two that are named after places
- **b** state two that are named after people
- **c** state two which have their symbols derived from the Latin names of the elements.

6 Consider the diagram of the structures of diamond and graphite.
- **a** What do the round grey objects represent?
- **b** What do the lines in the diagrams represent?
- **c** Suggest one reason why a different arrangement of particles results in different properties in the two allotropes.


diamond


graphite

3.2 Observing and describing elements

Introduction

All elements have properties. Maybe they have a high melting point, are a solid at room temperature or conduct electricity. These are some properties of elements (Figure 3.2.1). Elements with similar properties are grouped (vertical columns) in the periodic table.

In this practical investigation you will investigate physical and chemical properties of some common elements.

Background

This investigation examines some of the physical and chemical properties of some common elements. A property is a characteristic that can be observed.

Physical properties to be observed

- State: is it a solid, a liquid or a gas?
- Colour: does it have a distinctive colour?
- Solubility: does it dissolve in water?
- Density: does it sink or float in water?

Chemical property to be observed

Reaction with acid (hydrochloric acid): Is hydrogen gas produced? (Bubbles indicate gas has been produced.)

Aim

To investigate the physical and chemical properties of some common elements

Materials

- two small pieces of the following elements: copper, iron, aluminium, zinc, tin, magnesium
- matches
- splint
- 12 test tubes and test-tube rack
- hydrochloric acid (1.0 M)
- sandpaper

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Learning intention

To be able to observe, record and organise information about elements

Success criteria

SC 1: I can describe the observable properties of a range of elements.

SC 2: I can create a table or spreadsheet that organises observations collected from an investigation.

FIGURE 3.2.1 Copper is ductile, which means it can be drawn into a wire; this is one of its properties

SAFETY NOTES

- Wear safety glasses and lab coats/aprons as directed by the teacher.
- Avoid skin contact with acid.
- Take care with sharp edges on the samples of metals.
- Take care with matches because of the possibility of burns.
- Never tip samples down the sink. Follow your teacher's instructions to dispose of them safely.

Method

Read through the method below and then create a suitable results table before conducting the investigation.

1. Put on safety glasses and any other protective equipment as directed by your teacher.
2. Collect all equipment.
3. Rub each piece of metal with sandpaper (this is to remove any oxide coating).
4. Record the colour of each element in the results table.
5. Label six test tubes and place one piece of each element in each of the test tubes.
6. Cover each sample with 2 cm depth of water and record observations.
7. Record its density (does it float or sink?).
8. Place a second piece of each sample in a clean test tube.
9. Cover with a 2 cm depth of hydrochloric acid and record your observations in the results table.
10. If any bubbles are observed, place another empty test tube over the opening for 10 seconds and collect any gas produced.
11. Remove the second test tube and trap any gas collected using your thumb, holding the test tube at a 45° angle with the top of the test tube point upwards and away from you.
12. Light a splint and hold it to the opening of the upper test tube and record what happens (Figure 3.2.2). If you hear a squeaky 'pop', this indicates hydrogen gas has been produced.
13. Repeat steps 8–12 for the other five elements.

FIGURE 3.2.2 Testing for hydrogen gas – a 'squeaky' pop indicates the presence of hydrogen gas

Results

Design a suitable table for the experiment and record your results. Alternatively, you can create a spreadsheet for your results.

Conclusion

Write your conclusion by answering the following questions.

1. What did all the samples have in common?
2. Why did you rub the samples with sandpaper?
3. How did you know a gas was produced when a sample was placed in hydrochloric acid? How could you determine what gas it was?

Evaluation

Evaluate your practical investigation by answering the following questions.

1. What could you have improved?
2. What other elements would you like to test?
3. For the element(s) you chose for question 2, research their properties. Could they be tested in a school laboratory? Why or why not?

3.3 Elements and compounds

Lesson overview

There are 118 known elements listed on the periodic table but there are millions of different substances which are made from these elements.

A **compound** is a substance made with more than one element. That means it is made of two or more types of atoms. There are many different combinations of elements to make many different compounds.

In this lesson you will learn about the differences between elements and compounds. You will also learn about compounds that are found in everyday items and how to draw particles in elements and compounds (Figure 3.3.1).

Learning intention

To understand the differences between elements and compounds

Success criteria

SC 1: I can describe differences between elements and compounds.

SC 2: I can list many different types of elements and compounds found in everyday items.

SC 3: I can draw diagrams that demonstrate the differences in particle arrangement between elements and compounds.

SC 1 I can describe differences between elements and compounds

An element is made of one type of atom, and each type of atom has a symbol represented on the periodic table. When more than one atom joins together, they create a **molecule**. Oxygen in the air you breathe contains molecules of oxygen, which are two atoms of oxygen joined together.

Often different elements (and, therefore, different types of atoms) are combined together to make a compound. That is, compounds always contain more than one type of atom. The acid in your stomach is hydrochloric acid and it contains hydrogen and chlorine.

Many compounds are made from molecules, where the atoms are joined together to make the particle that is called a molecule. Sugar, for example, contains atoms of carbon, hydrogen and oxygen joined together to form molecules of sugar. Water is a simpler example, containing just the elements hydrogen and oxygen (Figure 3.3.2).

Elements and compounds are both **pure substances**.

KEY TERMS

compound a pure substance that is made up of two or more different types of atom chemically joined

molecule a group of atoms joined together with chemical bonds

pure substance a material that is made up of only one type of substance

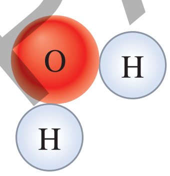


FIGURE 3.3.1 Water is a compound. It contains molecules that consist of two hydrogen atoms and one oxygen atom.

FIGURE 3.3.2 Water is one of the most common compounds. It is made up of hydrogen and oxygen. Its formula is H_2O

SC 1 CHECK YOUR UNDERSTANDING

A student said that carbon dioxide and oxygen must both be compounds as they contain molecules. Explain why this is incorrect.

KEY TERMS

formula a representation of a substance that uses chemical symbols and numbers to show the relative numbers of the atoms present in the substance

inert gases elements in Group 18 of the periodic table that do not easily react because they have a full outer electron shell

SC 2 I can list many different types of elements and compounds found in everyday items

Many everyday substances are elements (for example copper, tin, neon and oxygen). Elements are made of one type of atom.

Other substances might be compounds. Table salt, sugar, water and ammonia are all examples of compounds. This means they are made of two or more elements. Compounds have a definite formula (this is important when you compare them to mixtures) and are pure substances. Different compounds have different properties and can be represented by a **formula**.

There are 118 elements, and these can combine in different combinations to make compounds. Some elements do not combine with others; they are called **inert gases**. They are listed in the far-right hand column of the periodic table. Some examples include neon (Ne) and argon (Ar).

Scifile

Formulas

Elements in a compound are held together by chemical bonds. Every element has a unique symbol. In a compound, when the symbols are written together it is called a formula.

For example, table salt (also known as sodium chloride) is made up of sodium (Na) and chlorine (Cl) atoms. The chemical formula for table salt is NaCl. This means each molecule of sodium chloride contains one sodium atom and one chlorine atom.

Everyday elements

Uranium

Uranium is an element. Its symbol is 'U'. It is mined in Australia for use as a fuel for nuclear energy production in other countries (Figure 3.3.3).

Chlorine

Chlorine is an element. Its symbol is Cl, however in chlorine gas there are molecules of chlorine which have the formula Cl_2. Chlorine is a poisonous gas that is yellow-green in colour.

Neon

Neon is an element. It is an inert gas, which means it does not combine with other elements to make a compound (Figure 3.3.4).

FIGURE 3.3.3 Uranium mine in the Northern Territory

FIGURE 3.3.4 The neon atoms in this sign cause it to glow when electricity is passed through the neon

Everyday compounds

Sulfuric acid

Sulfuric acid is a compound (Figure 3.3.5). It contains the elements hydrogen, sulfur and oxygen. Sulfuric acid is a strong acid; it is the acid used in some batteries. Its formula is H_2SO_4.

FIGURE 3.3.5 Huge quantities of sulfuric acid are produced and used in Australia every year

Carbon dioxide

Carbon dioxide is a compound. It contains the elements carbon (C) and oxygen (O). It's formula is CO_2. Every time you breathe out, you exhale carbon dioxide. It can also be found in some fire extinguishers, and is also what gives fizzy drinks their fizz.

Chlorophyll

Chlorophyll (Figure 3.3.6) is the pigment that makes plants green. It contains a large molecule made with carbon, hydrogen, magnesium, nitrogen and oxygen. Its formula is $C_{55}H_{72}Mg_4O_5$.

FIGURE 3.3.6 Chlorophyll is a compound that gives plants their green colour

What are you made of?

Approximately 99% of the human body is made of just six elements: oxygen, hydrogen, nitrogen, carbon, calcium and phosphorus, with 65% being oxygen (Figure 3.3.7).

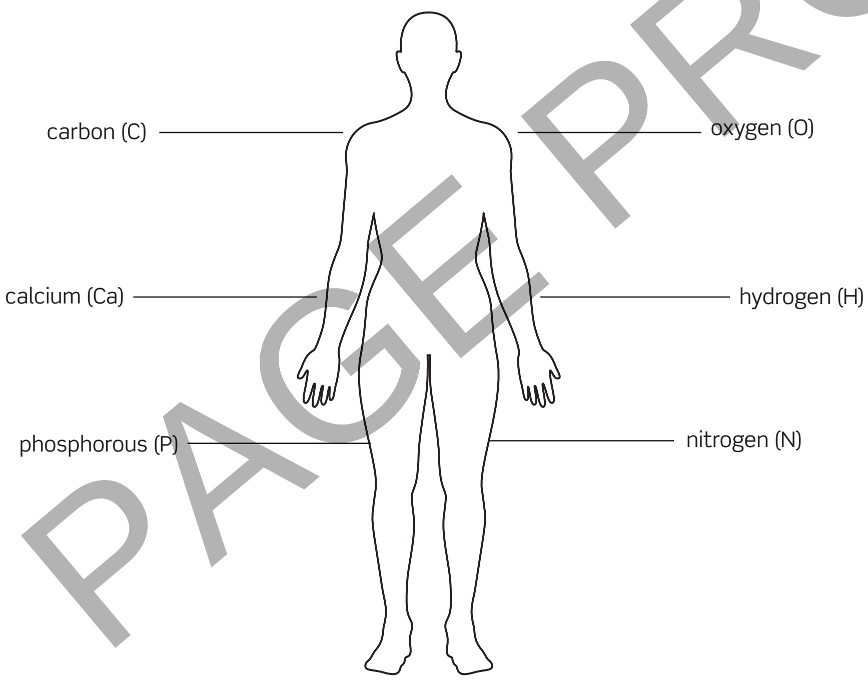


FIGURE 3.3.7 The six main elements in the human body

SC 2 CHECK YOUR UNDERSTANDING

Argon gas is an element that can be used for the packaging of food which stops the food from going bad.

a Suggest why argon can be used for this purpose.

b Name two other elements that will behave in a similar way to argon. You may need to use a periodic table to help with this question.

SC 3 I can draw diagrams that demonstrate the differences in particle arrangement between elements and compounds

Representing atoms and molecules

An element is made of one type of atom and may be made up of single atoms or molecules (two or more atoms joined together). A compound is made of two or more different elements joined together and often contains molecules. Diagrams can represent the differences between atoms and molecules and whether the substance containing these particles is an element or a compound.

SkillBuilder

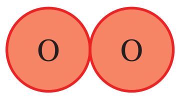
Drawing elements and compounds

Atoms and molecules can be represented with diagrams.

- Each atom can be a circle.
- Every element will have its own colour/shading to distinguish it from other elements.
- Atoms that are joined (bonded) together should be shown as touching each other.
- Use a key or labels to identify the different elements.

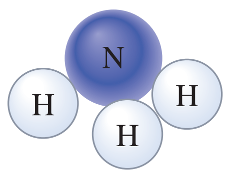
Examples:

1 Noah knows that a molecule of oxygen contains two oxygen atoms bonded together. He represents this as shown here, with each atom labelled with the symbol 'O':



As there are two atoms in contact with each other, Noah can see it is a molecule.

2 Lottie is asked to draw ammonia; she sees it has one nitrogen and three hydrogens. She represents this as one nitrogen atom coloured blue (labelled with an 'N'), in contact with three hydrogen atoms coloured white (each labelled with 'H').



SC 3 CHECK YOUR UNDERSTANDING

Methane has the formula CH_4. Carbon can bond with four other atoms, but hydrogen can only bond with one other atom. Draw a labelled representation of a molecule of methane.

Lesson review

Use these questions to check your understanding of the learning intention and success criteria for this lesson.

1 Read the following statements about elements and compounds. Rewrite any that are wrong to make them correct.
  - **a** Compounds are not pure substances because they contain more than one element.
  - **b** Compounds do not contain atoms.
  - **c** All elements are made up of individual atoms that are not joined together.

2 Oxygen gas has the formula O_2.
  - **a** Describe the particles that exist in a sample of pure oxygen.
  - **b** Water is a compound that contains oxygen. Describe the particles present in pure water.
  - **c** Name three other compounds that contain oxygen.

3 Carbon tetrachloride is a compound that is made of molecules that each contain one carbon atom and four chlorine (Cl) atoms atoms. Draw a labelled representation of a molecule of carbon tetrachloride.

4 Air is a mixture that contains a number of gases, including O_2, N_2, CO_2 and Ar.
  - **a** Using these examples, explain the difference between elements and compounds.
  - **b** Using Ar and N_2 explain the difference between atoms and molecules.
  - **c** Explain why air cannot be described as a compound.

3.4 The use of gases from the air

Learning intention

To understand how some gases present in the air were discovered, how they have been used and the implications of their use in society

Success criteria

SC 1: I can describe how the understanding of gases in the air changed as a result of scientific investigation.

SC 2: I can describe how carbon dioxide is used to carbonate water and how this has influenced society.

SC 3: I can describe how oxygen can be separated from air and how oxygen can be used in a range of situations.

Lesson overview

Air is a mixture of gases. Some of these gases are elements, such as oxygen (O_2) and nitrogen (N_2), and some are compounds, such as carbon dioxide (CO_2). Air is around 78% nitrogen and 21% oxygen (Figure 3.4.1). Carbon dioxide is a tiny percentage of the air (0.04%), but changes to the percentage of carbon dioxide in the air are having major effects on the climate.

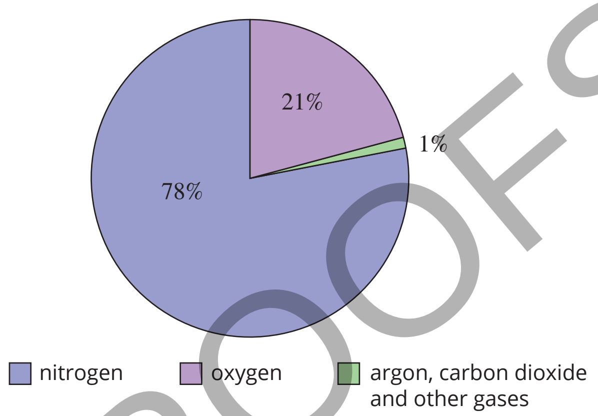


FIGURE 3.4.1 The approximate composition of air in the atmosphere

Gases

Gases such as oxygen and carbon dioxide have a wide range of uses in areas such as food and drink, and health care.

In this lesson you will learn about how scientists, including Joseph Priestley, discovered more about the gases in the air. You will learn about how some of these gases have been used, and how they have affected society.

SC 1	I can describe how the understanding of gases in the air changed as a result of scientific investigation

Gases in the air

In many ancient cultures, air was considered one of the key 'elements' of the world.

Hindu teachings include the five elements of earth (prithi), water (ap), air (vãyu), fire (agni) and aether (akasha) (Figure 3.4.2).

FIGURE 3.4.2 The vãyu mudrã hand gesture, used in yoga to regulate the 'air element' of the body

Ancient Japanese culture also had five basic substances that were thought to make up everything: earth, water, wind, fire and heaven (Figure 3.4.3).

FIGURE 3.4.3 The Japanese kanji character for wind

Today, the word element is used in science to describe substances that contain only one type of atom. Air is a mixture of compounds such as carbon dioxide (CO_2) and water vapour (H_2O) and elements such as oxygen (O_2) nitrogen (N_2) and argon (Ar).

Investigating the nature of air

The nature of air and the gases that it contains has only really been fully understood in the last few hundred years. In the seventeenth century, all substances that burned in air were thought to contain an element called phlogiston, and it was thought when a substance burned it released this 'element' into the air (Figure 3.4.4). When the air was full of phlogiston, it became phlogisticated, and could no longer allow things to burn in it. Phlogiston was given a symbol by alchemists, scientists who aimed to purify certain materials.

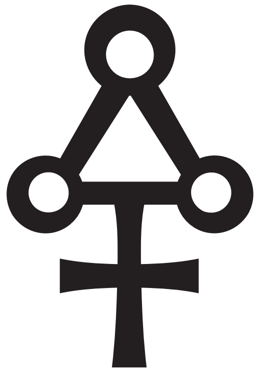


FIGURE 3.4.4 The symbol used for phlogiston in the alchemy alphabet

This theory matched observations at the time, because when objects burned in a fixed amount of air, the material stopped burning after a while, even though there was still plenty of air present.

As more was known about the components of the air, the phlogiston theory was challenged, and eventually replaced with better theories around the composition of the air. The practice of alchemy also evolved and played an important role in the development of modern chemistry and medicine.

Discovering gases in the air

Carbon dioxide

Carbon dioxide was discovered by chemist Jan Baptist van Helmont in 1640. The investigation tested the hypothesis that the products of combustion (burning) would not weigh the same as the starting materials. When he weighed the ash produced from burning charcoal, he discovered that it weighed less than the original charcoal (Figure 3.4.5).

He proposed that this missing mass was because an invisible substance had been produced.

FIGURE 3.4.5 Burning charcoal (an impure form of carbon) produces a gas, now known as carbon dioxide

FIGURE 3.4.6 The gas left over when a candle has burned in a bell jar is mainly nitrogen

Nitrogen

The Scottish scientist Daniel Rutherford is credited with the discovery of nitrogen in 1772, but at the time he did not recognise it to be an element. He investigated air that had a candle burning in it (Figure 3.4.6). (Scientists now know that this would have removed all the oxygen.)

He removed the carbon dioxide from the remaining air and the gas left was nitrogen, although the word nitrogen was not used for another 20 years. Many other scientists were also working on isolating this gas including Joseph Priestley, who called it phlogisticated air.

Oxygen

There are many competing claims between scientists for the discovery of oxygen, including Swedish pharmacist Carl Wilhelm Scheele and French chemist Antoine Laurent Lavoisier. But Englishman Joseph Priestley is normally credited for the discovery, partly because his scientific papers were published in 1775 before Scheele's findings were made public.

Priestly was investigating the substances produced when he focused beams of sunlight on solid mercury oxide and collected the gas produced.

He found that the gas produced made things burn brighter, that mice lived longer in it, and he even felt he had more energy when he breathed the new gas himself (Figure 3.4.7).

FIGURE 3.4.7 Charcoal burning brightly in a flow of oxygen gas

FIGURE 3.4.8 Argon is the gas used inside incandescent light globes because it does not react with the hot, glowing element

Argon

In 1785, Henry Cavendish suspected that there was an inactive gas that made up a small proportion of the air. In 1894, Lord Rayleigh and Sir William Ramsay (using some of Cavendish's old equipment) successfully removed oxygen, water vapour, nitrogen and carbon dioxide from the air. After this there was still some gas remaining, which was named argon, from a Greek word meaning 'inactive' or 'lazy' (Figure 3.4.8).

SC 1 CHECK YOUR UNDERSTANDING

To identify the gases in air, some gases need to be removed. Suggest why it is easier to remove oxygen from air than argon.

SC 2 I can describe how carbon dioxide is used to carbonate water and how this has influenced society

Carbon dioxide and carbonated water

The history of carbonated water goes back to ancient times when natural mineral springs containing carbon dioxide were discovered (Figure 3.4.9). These springs were known for their therapeutic properties, and people believed that drinking the water from these springs could cure a variety of illnesses.

However, it wasn't until the late 1700s that scientists began to understand the science behind carbonation.

FIGURE 3.4.9 Naturally carbonated mineral water rising from the ground in the mountains

Joseph Priestley and gases

Joseph Priestley was an eighteenth-century English scientist and theologian who is credited with discovering the method of infusing water with carbon dioxide (Figure 3.4.10). In the 1700s, people knew that there was gas in the air, but they did not yet understand what it was or how to use it.

Priestley became interested in this gas and conducted a series of experiments to investigate its properties.

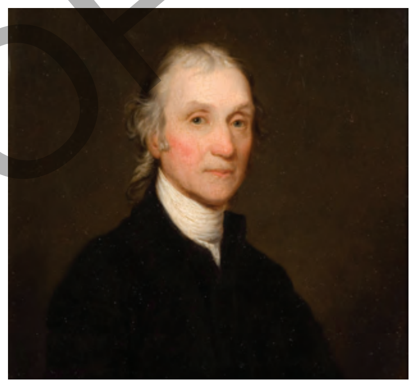


FIGURE 3.4.10 Portrait of Dr Joseph Priestley 1733-1804—English chemist, natural philosopher and political writer

The chemistry of carbonated water

Joseph Priestley's discovery of the method of infusing water with carbon dioxide was significant for several reasons. Water with carbon dioxide dissolved in it is not only 'fizzy' but is also more **acidic** than pure water.

This process is an example of a chemical change, where the carbon dioxide gas dissolves in the water and creates to create a new compound with different properties. The acid that is formed is called carbonic acid.

The development and use of carbonated water

The history of carbonated water can be traced back almost 400 years (Figure 3.4.11).

KEY TERMS

acidic having the properties of an acid, or containing acid; having a pH of less than 7

fermentation the chemical process in which carbohydrate or sugar is broken down into a simpler substance, such as alcohol or an acid

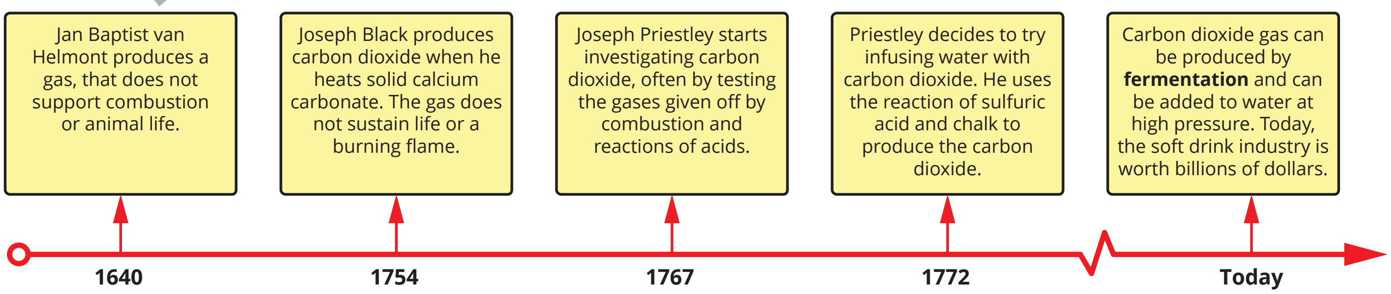


FIGURE 3.4.11 Timeline of the development and use of carbonated water

FIGURE 3.4.12 The addition of carbon dioxide changes the properties of the water

The modern process of dissolving carbon dioxide into water is similar to the technique used by Joseph Priestley in 1772. However, by increasing the pressure, more carbon dioxide can be absorbed by the water more quickly (Figure 3.4.12). The carbon dioxide is produced, normally as a product of burning fuels, and stored in pressurised cylinders until used. In Priestley's experiment, the carbon dioxide was produced using a chemical reaction between sulfuric acid and chalk (calcium carbonate).

SCIENCE IN SOCIETY

The impacts of carbonated water

The discovery of carbonated water had an effect in the scientific world, but it also had significant impacts on the behaviour of people in society.

Soda

The production of soft drinks using carbonated water started around 250 years ago. Many versions of carbonated water drinks contained sodium compounds such as sodium chloride (table salt), sodium bicarbonate (bicarbonate of soda) and sodium citrate. This is why these drinks were referred to, especially in America, as 'soda' (Figure 3.4.13).

FIGURE 3.4.13 Club soda—carbonated water with additional minerals added

These substances were added as preservatives and to also balance the acidity of the drink, therefore improving the taste. Most soft drinks contain carbonated water, a sweetener and a flavouring, depending on the drink.

The soft drink industry

Today the global soft drink industry makes a profit of $50 billion dollars each year (Figure 3.4.14). The average yearly consumption of soft drinks in Australia is around 100 litres per person. (In the USA it is around 200 litres, and in Japan it is around 20 litres.) In most places in the world the consumption of carbonated soft drinks is decreasing.

FIGURE 3.4.14 Coca Cola is the highest selling soft drink in the world.

These numbers have implications for society. In the United Kingdom, it has been estimated that around 5% of all litter is Coca-Cola cans. Health risks of soft drinks are well known, including increased occurrence of obesity, tooth decay and raising the risk of individuals contracting cancer.

SC 2 CHECK YOUR UNDERSTANDING

Carbonated water is produced by combining carbon dioxide gas with water.

a State three ways that carbon dioxide can be produced for this process.

b Describe how the carbon dioxide is combined with the water.

c Explain how the properties of water are affected by the addition of carbon dioxide.

SC 3 I can describe how oxygen can be separated from air and how oxygen can be used in a range of situations

Oxygen gas

Oxygen is the most abundant element on Earth and the third most abundant element in the universe. It is a reactive gas that allows things to burn and is essential for animal life on Earth. Oxygen was discovered by Carl Wilhelm Scheele and Joseph Priestley around 1773–1775, but it was Antoine Lavoiser, the person often described as the founder of modern chemistry, who first recognised it as an element and gave it the name oxygen. The name came from the Greek '*oxy-gene*', meaning 'acid-producer', which was a misconception. At the time Lavoisier thought that the element oxygen was present in all acids, which is now known not to be true.

FIGURE 3.4.15 Oxygen is a vital component of the atmosphere

Oxygen in the environment

Oxygen makes up just under 21% of the air. The air that people breathe out only contains 17% oxygen because some of the oxygen has been converted to carbon dioxide by the process of **cellular respiration**.

Plants convert carbon dioxide into oxygen through a process called **photosynthesis**.

Before life evolved on Earth, there was virtually no oxygen in the atmosphere (Figure 3.4.15). It was only the presence of plants that increased the amount of oxygen. This includes plants that live in rivers and oceans.

Oxygen is **soluble** in water so some of the oxygen on Earth is dissolved in oceans. 1000 L of seawater will contain around 8 grams of oxygen.

KEY TERMS

cellular respiration a set of processes in the cells that convert chemical energy from nutrients into energy used by cells

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun

soluble able to dissolve in a particular solvent

distillation a process that uses evaporation followed by condensation to recover solvents from mixtures

Producing oxygen

The main way of producing oxygen used today is by a form of **distillation**. Air, which is a mixture of gases, is cooled to extremely low temperatures (around –200°C) to produce liquid air.

The air is then allowed to warm up and the liquified gases will turn back into gas as they evaporate. Boiling points of the three main components of air are:

oxygen (–183°C) argon (–186°C) nitrogen (–196°C)

Because nitrogen and argon have lower boiling points than oxygen, they will turn to a gas first, so they can be separated from the liquid oxygen.

Oxygen is normally stored as a liquid (in pressurised cylinders) because it takes up less space as a liquid than as a gas (Figure 3.4.16).

FIGURE 3.4.16 Oxygen stored as a liquid in pressurised cylinders

SCIENCE IN SOCIETY

Oxygen changing lives

Here are some examples of the uses of oxygen.

Medicine

Oxygen-based therapies are used to treat diseases such as asthma and pneumonia (Figure 3.4.17). Oxygen is also used in emergency situations such as respiratory failure or carbon monoxide poisoning. The oxygen is delivered through a face mask. Some of these treatments occur in a patient's home due to improvements in technology that have reduced the size and cost of the equipment.

FIGURE 3.4.17 A patient at home with an oxygen supply to aid with breathing

Exploration

Oxygen is used in space exploration to improve the power in a rocket engine as the rocket fuel will burn more violently in pure oxygen compared to air. It is also used to provide life support for astronauts in space. Scuba divers use oxygen-rich air in scuba tanks that enable them to explore oceans (Figure 3.4.18).

FIGURE 3.4.18 Oxygen in scuba tanks allow divers to spend extended times underwater

Environmental management

Aerobic bacteria require oxygen to survive. Some can be used to break down organic pollutants, such as sewage, in the environment (Figure 3.4.19). Oxygen is supplied to the bacteria to speed up their growth and reproduction rate which improves the effectiveness of the waste treatment process. Oxygen is also used to produce ozone (O_3) which has a wide variety of uses, including water purification.

FIGURE 3.4.19 Scientists checking oxygen content in waste water

SC 3 CHECK YOUR UNDERSTANDING

Oxygen is used in the process of cellular respiration.

- **a** Describe what happens during cellular respiration.
- **b** State two applications of oxygen that rely on its role in the process of respiration.
- **c** For one of the situations stated in part (b), explain why oxygen is required.

Lesson review

1 When Joseph Priestly produced a new gas by heating solid mercury oxide, mice were found to live longer in an atmosphere rich in this new gas. Explain this finding.

2 Describe how adding carbon dioxide to water changed the drinks industry.

3 Describe how modern methods enable carbon dioxide to be combined with drinks quickly to increase the rate of production of soft drinks.

4 Oxygen can be used to treat a range of diseases and emergency situations.

- **a** Explain why asthma sufferers might sometimes need to breathe pure oxygen or air rich in oxygen to reduce their symptoms of the disease.
- **b** Explain why firefighters might need to use oxygen breathing apparatus when tackling an intense fire.

5 The boiling point of oxygen is −183°C and the boiling point for nitrogen is −196°C. Use this information to explain, using correct scientific terms, why distillation can be used to separate oxygen from nitrogen in a sample of air that has been cooled to −200°C.

6 The table below shows the approximate relative amounts of different gases in the atmosphere today compared to Earth's early atmosphere.

	Today	Early atmosphere
Nitrogen	high (78%)	low
Oxygen	moderate (21%)	very low
Argon	low (1%)	low
Carbon dioxide	very low (0.04%)	high
Methane	minimal (0.000 17%)	high

- **a** Briefly summarise the key changes to the atmosphere over time.
- **b** Explain why the amount of oxygen has increased over time.
- **c** Suggest why carbon dioxide is an important part of the atmosphere even though the concentration in air is very low.

3.5 Properties of elements and compounds

Learning intention

To be able to compare the properties of elements to the properties of compounds

Success criteria

SC 1: I can identify the elements present in a range of compounds.

SC 2: I can compare the properties of elements with the properties of the compounds made from those elements.

KEY TERMS

formula A representation of a substance that uses chemical symbols and numbers to show the relative numbers of the atoms present in the substance

property the observable characteristics of a substance; what a substance looks like and how it behaves

SAFETY NOTES

- Do not taste any of the substances.
- Be careful with sharp ends of nails.
- Wear safety glasses when testing the solubility of the substances.

Introduction

Today we know about the existence of almost 120 chemical elements. Combinations of these make up millions of different compounds. Each element has its own properties. When an element exists in a compound it can have very different properties.

In this practical investigation you will identify the elements in compounds by examining their formulas and investigate the properties of the elements and the properties of compounds made from those elements.

Background

Every element has a symbol represented on the periodic table. Compounds are made of two or more elements chemically combined and are represented by a **formula**. Every element has physical and chemical **properties**.

Every compound also has properties that may be very different from the properties of the elements in it.

Aim

To compare the properties of elements with the properties of compounds that contain these elements

Materials

For observation:

- clean iron nail (not galvanised), graphite (carbon) rod, rusty iron nails, photograph of sodium metal, photograph of chlorine gas

For experimentation:

- table sugar (sucrose), table salt (sodium chloride), iron(III) oxide
- sandpaper
- 250 mL beaker
- spatula
- stirring rod

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

1. Add the names of the elements in each compound to your results tables.
2. Collect all materials and equipment required.
3. Record the state, colour and texture of all substances in your results tables. Some have been completed for you as they are difficult to observe directly.
4. Place the graphite rod and the iron nail in some water in a beaker to see if they dissolve.

5 Place a small spatula of sugar in 100 mL of water in the beaker and stir with stirring rod. Record the solubility of the sugar.
6 Repeat step 5 with the salt and then the iron oxide (rust).

Results

Create two results tables like these shown in your notebook.

Compounds

Substance	Formula	Elements present	State	Colour	Texture	Solubility (does it dissolve in water)
sugar (sucrose)	$C_{12}H_{22}O_{11}$					
table salt (sodium chloride)	NaCl					
rust (iron oxide)	Fe_2O_3					

Elements

Substance	Symbol	State	Colour	Texture	Solubility (how well it dissolves in water)
carbon (graphite)					
hydrogen					insoluble
oxygen					slightly soluble
sodium				soft metal	reacts violently with water (to produce hydrogen gas)
chlorine					slightly soluble
iron					

Conclusion

1 Using an example from this experiment, define a compound.
2 Using specific examples from your observations, describe the differences between properties of the three compounds in this experiment and the properties of the elements that make up the compounds.
3 Suggest a reason why the properties of an element change when it forms into compounds.
4 Describe another example where an element's properties vary greatly from a compound that contains that element.

Evaluation

Evaluate your practical investigation by answering the following questions.

1 What did you find challenging about this practical investigation?
2 Describe two ways that practical investigation could be improved.

3.6 Mixtures and compounds

Learning intention

To understand the differences between mixtures and pure substances (elements and compounds)

Success criteria

SC 1: I can describe mixtures as substances that can be separated into pure substances.

SC 2: I can list a range of different types of mixtures and pure substances found in everyday items.

SC 3: I can draw diagrams that demonstrate the differences in particle arrangement between mixtures and pure substances.

KEY TERM

pure substance a material that is made up of only one type of substance

Lesson overview

Mixtures are combinations of different pure substances. These substances can be either elements or compounds. As you have learnt, mixtures can be separated back into **pure substances**.

In science, 'pure' means that only one thing, or substance, is present. This is true for elements and compounds, so these are called pure substances.

In this lesson you will re-visit mixtures and how they can be separated into pure substances. You will learn how to tell the difference between mixtures and pure substances. This will include comparing particle diagrams that represent mixtures to particle diagrams that represent elements and compounds.

FIGURE 3.6.1 Cement is an example of a mixture

SC 1	I can describe mixtures as substances that can be separated into pure substances

Mixtures

Orange juice, muesli and strawberry jam all have something in common. They can all be eaten for breakfast, but they are also all examples of mixtures (Figure 3.6.2). While a compound is two or more elements chemically combined, a mixture contains two or more substances that are not chemically combined.

A mixture can be separated into two more pure substances with different separation techniques.

FIGURE 3.6.2 Muesli is an example of a mixture; it contains more than one substance, but they are not chemically combined

Separating mixtures

Filtration

Filtration uses a filter to separate different substances based on particle size (Figure 3.6.3).

Magnets

A magnet can be used to separate magnetic substances from non-magnetic ones (Figure 3.6.4).

Chromatography

Chromatography is used to separates liquids with different levels of solubility, for example to separate mixtures of coloured substances (Figure 3.6.5).

Evaporation

Evaporation separates a solute from a solution by boiling or evaporating the solvent (often water) until only the solute remains. For example, salt water can be evaporated until only the salt crystals remain (Figure 3.6.6).

Note that salt water made of two pure substances: salt (sodium chloride, NaCl) and water (H_2O). In salt water the salt and water are not chemically combined so the water can be evaporated leaving the salt crystals. Salt water does not have a fixed amount of salt in it whereas Pure substances like salt (NaCl) and water (H_2O) have fixed ratios of the numbers of each type of atom.

Distillation

Distillation separates liquids based on difference in boiling points. For example, different fuels such as petrol and diesel may be separated from crude oil in oil refineries (Figure 3.6.7).

FIGURE 3.6.7 An oil refinery separates crude oil into products such as petrol and diesel using distillation

FIGURE 3.6.3 Filtration separates solid particles from a liquid

FIGURE 3.6.4 A magnet being used to separate iron filings from yellow solid sulfur

FIGURE 3.6.5 Chromatography can be used to separate different coloured pigments that make up the ink in a marker

FIGURE 3.6.6 Evaporation of salt water leaves the salt crystals behind

SCIENCE IN SOCIETY

'Pure' drinking water and LifeStraw®

Drinking water is not a pure substance. It contains a range of minerals and other dissolved substances. But when those substances are potentially toxic, such as bacteria and parasites, the water becomes unsafe to drink.

This often what happens in the aftermath of a natural disaster such as an earthquake or extreme weather events.

LifeStraw® is a water filtration device designed to make contaminated water safe to drink (Figure 3.6.8).

FIGURE 3.6.8 LifeStraw® is a portable water purifier that removes almost all bacteria from water

The LifeStraw® works by using advanced microfiltration technology to remove bacteria, parasites, and other harmful contaminants from water.

LifeStraw® filters are lightweight, portable, and require no batteries or electricity.

Lifestraw® was originally created for use in emergencies and by people in developing countries who don't have access to clean water (Figure 3.6.9).

FIGURE 3.6.9 A Lifestraw® (the blue component) used in a system that provides safe drinking water in a remote area, such as here in Swaziland, Africa, away from any power supply

After a devastating earthquake in Haiti in 2010, clean drinking water became scarce. LifeStraw® filters were distributed to help prevent waterborne diseases like cholera. These filters provided immediate access to safe drinking water for thousands of affected individuals.

The 2015 Nepal earthquakes left many communities without access to clean water. LifeStraw® filters were deployed to provide safe drinking water to those living in temporary shelters and remote areas, ensuring they had a reliable source of clean water (Figure 3.6.10).

FIGURE 3.6.10 The supply of safe drinking water was a major problem following the 2015 Nepal earthquake

SC 1 CHECK YOUR UNDERSTANDING

Explain how a mixture of sand and salt can be separated into its pure substances.

SC 2 I can list a range of different types of mixtures and pure substances found in everyday items

Types of mixtures

Sugar, muddy water, copper and apple juice are all examples of **matter**. All matter is either a pure substance or a mixture.

Pure substances can then be categorised into compounds or elements. Sugar (compound) and copper (element) are examples of pure substances. Muddy water and apple juice are examples of mixtures.

Mixtures can then be categorised into **homogenous mixtures** (or solutions) or **heterogenous mixtures** (Figure 3.6.11).

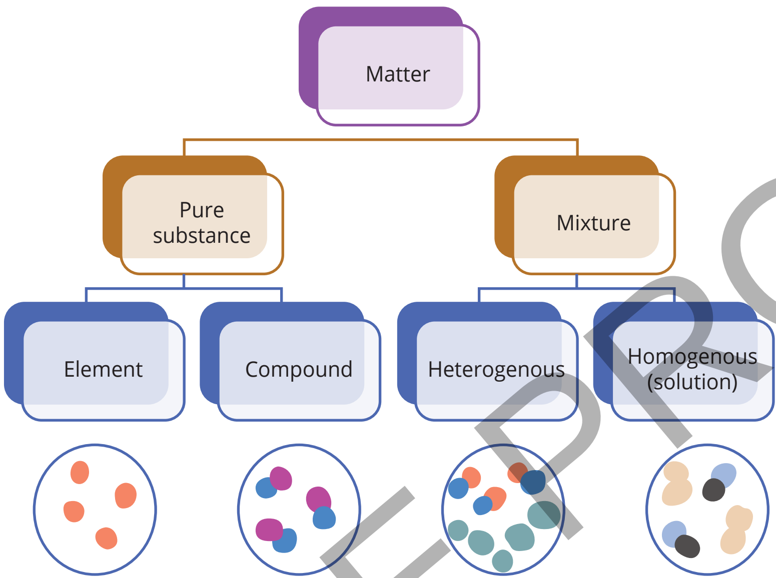


FIGURE 3.6.11 A flow chart for classifying matter

Homogenous mixtures

A homogenous mixture is one in which the different parts (such as salt dissolved in water) have been uniformly combined (salt water).

This means that a homogenous mixture appears the same throughout the substance, like clear apple juice (Figure 3.6.12).

Heterogenous mixtures

In a heterogenous mixture, the parts are not uniformly combined, and the amount of each substance might be different throughout. Think of a chocolate chip biscuit, one part of the biscuit might have lots of chocolate chips while another part might not. A chocolate chip biscuit is an example of a heterogenous mixture.

KEY TERMS

matter a physical substance; anything that has mass and volume
homogenous mixture a mixture that has uniform composition and properties through the mixture
heterogenous mixture a mixture that varies in composition and properties through the mixture

DISCOVER MORE

Look at the start of each word. In homogeneous, homo- means same. In heterogeneous, hetero- means different or other.

FIGURE 3.6.12 This apple juice is an example of a homogenous mixture

Scifile

Alloys: Solutions of metals

When you melt metals, they can dissolve into each other. The mixture that is made is called an alloy. When metal atoms in an alloy have a similar size, such as zinc and copper, they pack together to form a malleable alloy, which are relatively soft, such as brass. When the atoms are a lot smaller, such as carbon, they can fit into gaps between the larger metal atoms. These types of alloys, such as steel are much harder.

This means that a heterogenous mixture is not the same throughout, like muddy water (Figure 3.6.13).

FIGURE 3.6.13 Muddy water in a river is a heterogenous mixture

SC 2 CHECK YOUR UNDERSTANDING

List three examples of mixtures and three examples of pure substances that you might find in a kitchen.

SC 3 I can draw diagrams that demonstrate the differences in particle arrangement between mixtures and pure substances

Comparing particle arrangements of mixtures and pure substances

Particle diagrams can be used to represent state of matter of substances (solids, liquids and gases) (Figure 3.6.14).

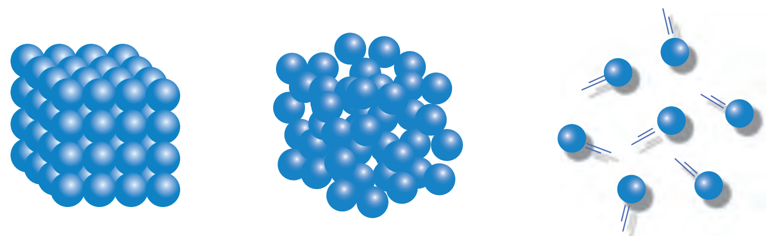


FIGURE 3.6.14 Particle diagram showing the three states of matter

Particle diagrams can also be used to represent elements, compounds and mixtures.

Pure substances

Pure substances (elements and compounds) have definite compositions. For example, water (H_2O), a compound, always has two hydrogen atoms and one oxygen atom. Carbon monoxide (CO) always has one carbon and one oxygen atom (Figure 3.6.15).

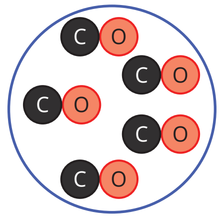


FIGURE 3.6.15 Carbon monoxide is a compound and, therefore, a pure substance; a molecule of carbon monoxide is one atom of carbon and one atom of oxygen joined together

Mixtures

Mixtures on the other hand do not have a definite composition as seen in these examples.

Air

Air is a mixture of nitrogen gas 78%, oxygen gas 21%, argon 0.9%, carbon dioxide 0.04% and traces of water.

If there is more pollution from burning fossil fuels, there may be more carbon dioxide. The air that you breathe out contains more carbon dioxide and less oxygen compared to the air that you breathe in. Air is a mixture and does not have a fixed composition.

Salt water

Another example is a glass of salt water. There may be one spoonful of salt in the water or there might be three. Both examples are still salt water but there is no set composition for how much salt must be in the water.

Water has a set composition and so does salt (one sodium and one chlorine atom). Water and salt are examples of pure substances. Salt water is a mixture and, with the correct separation techniques, it can be separated into water and salt.

Particle diagrams summary

The diagrams in Figure 3.6.16 summarise ways to represent elements, compounds and mixtures using particle diagrams.

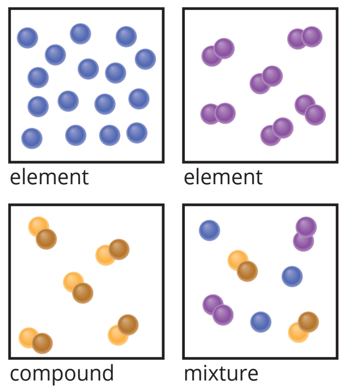


FIGURE 3.6.16 Different ways to represent elements, compounds and mixtures

SC 3 CHECK YOUR UNDERSTANDING

Draw three labelled particle diagrams that represent:

a pure water (H_2O)
b pure oxygen (O_2) gas
c oxygen dissolved in water.

Lesson review

1 Describe and explain the process of separating a mixture of iron filings and sulfur powder.

2 Identify the following as a mixture or a pure substance.
  a air
  b gold (Au)
  c muddy water
  d baking soda ($NaHCO_3$)

3 Explain why apple juice can be considered a mixture while copper wire is considered a pure substance.

4 Draw and compare particle diagrams for pure water and a solution of sugar. Explain the differences in particle arrangements. You can use a simple representation of the molecules without showing individual atoms.

3.7 Metals and non-metals

Learning intention

To be able to use observable properties to classify elements as metals or non-metals

Success criteria

SC 1: I can identify substances as metals based on their observable physical properties.

SC 2: I can use the names and the position of elements in the periodic table to predict whether they are metals or non-metals.

SC 3: I can explain, with an example, the difference between a pure metal and an alloy.

KEY TERMS

metal an element that is shiny, conducts heat and electricity, and can be hammered into sheets and drawn into wires
malleable able to be hammered or bent into new shapes
ductile able to be stretched to form a wire
lustrous shines when polished or freshly cut
corrosion the breakdown of metals due to their reaction with other chemicals

Introduction

Why do you think electrical wires are made of copper? What about a saucepan being made of stainless steel or aluminium?

What it is about these substances that make them suitable for these uses?

The answer to the last question is based on what properties the substances have. Some groups of substances, such as **metals**, have special properties that only they have.

In this practical investigation you will observe some chemical and physical properties of various materials that include elements, mixtures and compounds and use this to help classify them as metals or non-metals.

Background

Metals

Metals have certain properties. They are **malleable**, **ductile**, can conduct electricity, and are **lustrous**.

This practical investigation will examine a range of materials (metals and non-metals) and test their properties.

Alloys

An alloy is a homogenous mixture of substances including at least one metal. For example, stainless steel is a mixture of iron, carbon and chromium, and bronze is a mixture of copper and tin.

Alloys have similar properties to metals. By combining the metals, the properties can be changed to make the alloy better for a particular use. For example, to make the metal solid softer, or harder (for example in coins) or to make the substance more resistant to **corrosion** (for example in saucepans).

Alloys are not compounds. A compound has a fixed ratio of elements, but an alloy does not, which makes it a mixture. An example of an alloy is brass (Figure 3.7.1).

FIGURE 3.7.1 A brass trumpet. Brass is an alloy of copper and zinc

Aim

To investigate common properties of various substances and classify them as metals or non-metals

Materials

- alligator clips
- electric leads
- sandpaper
- battery pack or power pack
- globe (or ammeter/multimeter)
- copy of the periodic table
- samples to test: iron nail, stainless steel nail, copper strip, magnesium strip, piece of chalk, plastic, brass tacks, wood, graphite rod

SAFETY NOTES

- Keep any electrical equipment away from water.

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

Use this method for each sample.

1. Record the appearance of the sample, including its lustre, in a table like the one shown in the Results section. Lustre is the shine given off from a material. A highly polished metal has high lustre (or is lustrous), while a piece of unvarnished wood might be dull (not lustrous).
2. Record whether you think the substance is malleable. A substance is malleable if it can be moulded into shape. If you were to hit the substance with a hammer, would it flatten or would it break?
3. Record whether you think the substance is ductile. A substance is ductile if it can be stretched into a wire. Do you think the substance could be pulled to make a thin wire?
4. Use sandpaper to scratch the surface of the material. If the fresh surface that you have uncovered is a different colour to the old surface, it is likely that the old surface had reacted with the air. This suggests that the material is **reactive**.
5. Check each of your samples for its **conductivity**:
   - Use the battery pack (or power pack) to set up the electrical circuit as shown in Figure 3.7.2.
   - The lightbulb (which can be replaced by an ammeter or multimeter) will indicate whether a current is passing through the material and around the circuit.
   - Record the brightness of the lightbulb or the current measured with the ammeter/multimeter.

KEY TERMS

reactive a description of a substance that readily undergoes chemical reactions

conductivity a measure of the ability of a material to conduct heat, sound or electrical energy

FIGURE 3.7.2 Using the equipment to test the conductivity of the iron nail

Results

Copy this table into your workbook and record your results in the table.

	Appearance	Malleable (yes/no?)	Ductile (yes/no?)	Reactive (yes/no?)	Conducts electricity (yes/no?)
Iron nail					
Stainless steel nail*					
Copper strip					
Magnesium strip					
Chalk					
Plastic					
Brass tack*					
Wood					
Graphite					

*Note that brass and stainless steel are alloys.

Conclusion

Write a conclusion to your experiment by answering the following questions.

1 Metals are shiny, malleable, ductile and can conduct electricity. Non-metals are usually dull, brittle (break easily) and do not conduct electricity. Look at the substances you tested and classify them as metals or non-metals. (You can include the alloys as metals.)

2 Find the position of the pure metals used in this experiment on the periodic table. What do you notice about where they are?

3 Name the metals used to make brass and suggest why alloys like brass are normally shiny, malleable, ductile and can conduct electricity.

4 Iron is a fairly reactive metal (it forms rust when in contact with oxygen and water). Chromium is very resistant to corrosion. Suggest why stainless steel contains chromium.

5 Suggest why stainless steel is used instead of iron on boats.

6 Suggest why electrical wires are often coated with a plastic layer.

Evaluation

Evaluate your practical investigation by answering the following questions.

1 Were there any substances that were difficult to classify as metals? If so, why?

2 Identify any other challenges you encountered during this investigation.

Practical investigation

3.8 Producing a metallic element

Introduction

What do you think would happen if you put a gold ring in a jar of water? What about a piece of iron?

Metals have varying degrees of reactivity. Consider the reactivity series of metals shown here (Figure 3.8.1).

Looking at the list you can see that potassium and sodium are very reactive, and that gold and platinum are less reactive. The reactivity of metals can be used to determine if one metal will replace another one from a solution.

In this practical investigation you will use this idea to obtain copper metal from a solution of copper sulfate, using just a piece of zinc.

Learning intention

To be able to conduct an experiment that involves the production of a metallic element from a compound

Success criteria

SC 1: I can conduct an experiment to investigate how an element is extracted from a solution of a compound.

SC 2: I can describe how copper as an element differs from the copper compound used in the experiment.

SC 3: I can suggest why zinc is used in the experiment.

Background

The reactivity of metals can determine how a metal will react in certain scenarios.

In a displacement reaction one element takes the place of another. For metals, this means that metal A will replace metal B in a solution if metal A is more reactive (higher in the series).

For example, aluminium is higher than lead on the reactivity series of metals. If a piece of aluminium is placed in a solution containing a lead compound, aluminium will take the place of lead in the compound dissolved in the solution. The lead that has been displaced ('pushed out') will form solid crystals of lead metal.

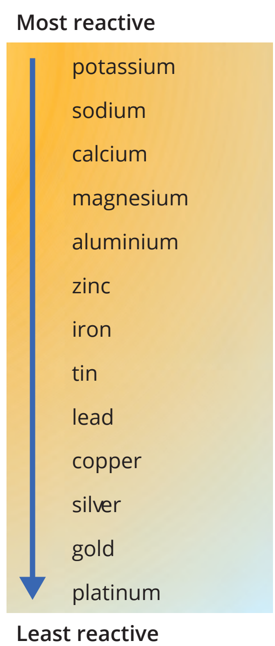


FIGURE 3.8.1 Reactivity series of metals

Aim

To form crystals of metallic copper

Prediction

Predict what will happen when zinc metal is added to a solution of copper sulfate.

Materials

- zinc (Zn) metal strip
- 0.1 M copper sulfate ($CuSO_4$) solution
- 100 mL beaker
- filter paper
- magnifying glass or microscope

SAFETY NOTES

- Copper sulfate is toxic, so wear gloves and safety glasses and avoid contact with eyes, skin and mouth.

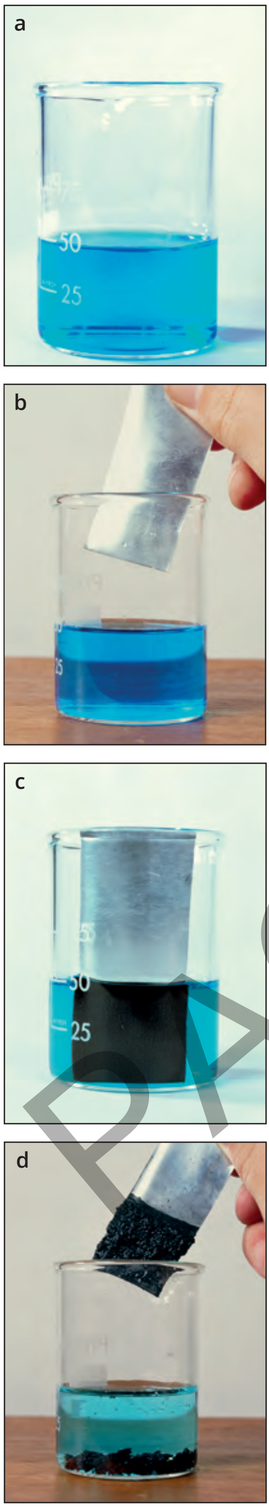


FIGURE 3.8.2 Experimental set-up

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

1 Add copper sulfate solution until it reaches the 50 mL mark on your beaker (step **a** in Figure 3.8.2).

2 Place the zinc metal strip so that it is partly immersed in the copper sulfate solution (steps **b** and **c** in Figure 3.8.2).

3 Observe the copper crystals as they deposit on the zinc strip.

4 Once you have seen a noticeable change, remove the zinc strip and place it on the filter paper (step **d** in Figure 3.8.2).

Results

Record your results using the following prompts.

1 Observations as the copper crystals form.

2 Colour of the copper sulfate solution as the experiment proceeds.

3 Detailed appearance of the copper crystals once you have removed the zinc strip (use a magnifying glass or microscope if possible).

Conclusion

Write a conclusion to your experiment by answering the following questions.

1 What elements, and how many atoms of each, are shown in the formula of copper sulfate?

2 Using evidence from your experiment, describe how copper as an element is different from the copper compound used in the experiment.

3 Explain why, over time, the solution became less blue.

4 Referring to the reactivity series of metals, explain why zinc is used in this experiment.

5 Based on its reactivity, suggest why copper is a good metal for making saucepans.

Evaluation

Evaluate your practical investigation by suggesting how the experiment could be altered or extended.

3.9 Particles in substances

Lesson overview

If you had a piece of aluminium tubing and a rubber tube, which one do you think would be easier to bend (Figure 3.9.1)? Why would this be so? The answer will be linked to the arrangement of atoms in the substance. The way that atoms are arranged and bonded together is called the structure of the substance.

In this lesson you will learn about the arrangement of atoms in different substances and how this contributes to the properties of the substances. You will also compare the key features of some types of structures.

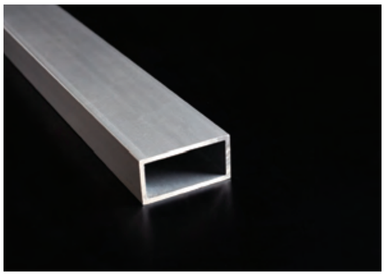
Learning intention

To understand that the particles in matter can have different arrangements

Success criteria

SC 1: I can recall the particle arrangement in elements, molecules, compounds, mixtures and pure substances.

SC 2: I can compare the key features of structures including molecules, metals and non-metallic lattices.



Aluminium steel tube profile for windows and doors manufacturing.

Latex rubber tube for industry and sports

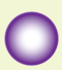
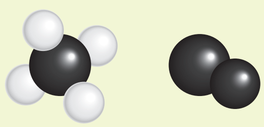
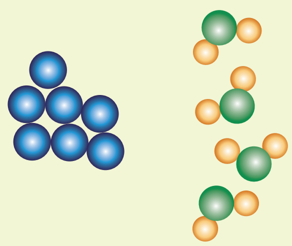
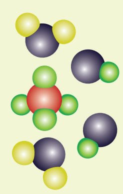
FIGURE 3.9.1 The arrangement of particles in rubber is different from the arrangement in aluminium; this makes rubber easier to bend than aluminium

SC 1	I can recall the particle arrangement in elements, molecules, compounds, mixtures and pure substances

Types of substances

Titanium, carbon dioxide and salt water can be all be classified differently according to the type of substance they are. Titanium is an element, carbon dioxide is a compound and salt water is a mixture. Particle diagrams (Table 3.9.1) show the relationships between these terms (and the terms atom, molecule and pure substance).

TABLE 3.9.1 Examples of particle diagrams

Atoms	Molecules	Pure substances	Mixtures
An atom.  A single atom on its own must be an element.	A molecule is two or more atoms combined.  It can be a compound (left) with more than one type of atom, or an element (right) with only one type of atom.	 A pure substance can be either an element (left) or a compound (right).	A mixture is made up of two or more substances that are not chemically combined.  Mixtures can be separated into pure substances.

SC 1 CHECK YOUR UNDERSTANDING

What is a pure substance, and how can it be identified in terms of particle arrangement?

SC 2 I can compare the key features of structures including molecules, metals and non-metallic lattices

The only elements that exist in nature as single atoms are the inert gases such as neon (Ne) and helium (He). Most elements do not exist as single atoms. Instead, the atoms are bonded together in a molecule or in a lattice structure.

Molecules

Many non-metallic elements exist as molecules (Figure 3.9.2). An example is oxygen (O). It exists as a molecule of two oxygen atoms joined together, which is written as (O_2). Every molecule of oxygen will have the same size and shape. Molecules such as these are sometimes called discrete molecules as each molecule is a separate particle.

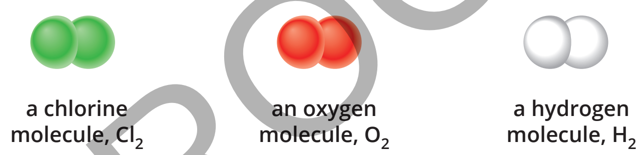


FIGURE 3.9.2 Most non-metallic elements exist as molecules

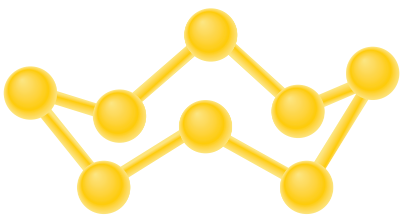


FIGURE 3.9.3 A sulfur molecule in the form of a ring

Diatomic elements

Seven elements exist as diatomic molecules: hydrogen (H_2), nitrogen (N_2), oxygen (O_2), fluorine (F_2), chlorine (Cl_2), bromine (Br_2) and iodine (I_2). The prefix di- in diatomic means two. For example, nitrogen is represented by N_2 where the 2 indicates there are two nitrogen atoms in the molecule.

Some elements have more than two atoms in their molecules. For example, sulfur (S) molecules have with eight atoms in a ring and can be written as S_8 (Figure 3.9.3).

Carbon (C) can form giant molecules. One example is a molecule called buckminsterfullerene. It has 60 carbon atoms (C_{60}) joined together in a ball shape known as a buckyball (Figure 3.9.4).

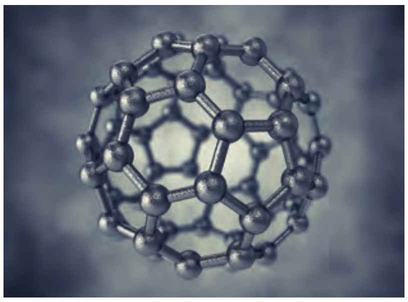


FIGURE 3.9.4 A buckyball is made up of 60 carbon atoms; it gets its name from looking like a soccer ball

Metals

Metals, such as iron, exist as closely packed atoms (Figure 3.9.5). They are held together by metallic bonds, which can act in all directions. Most elements in the periodic table are metals.

Metals are strong because of this arrangement. They are also malleable (able to be moulded into shape) and ductile (able to be drawn into wire) because when a force is applied to the metal, the atoms can ‘slide over’ each other into new positions without breaking the metallic bonds.

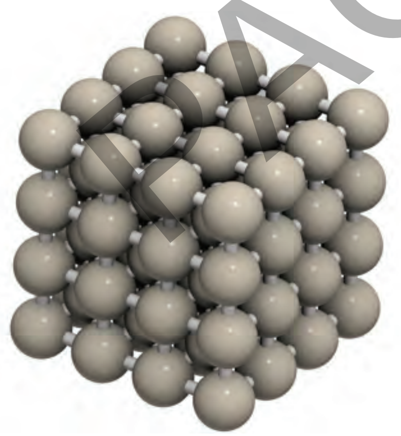


FIGURE 3.9.5 Iron atoms packed closely together

Non-metallic lattices

A lattice is a highly ordered arrangement of atoms in a repeating format. Non-metallic lattices tend to be very hard and strong. They cannot easily change shape, and are more likely to break, crack or shatter if a force is applied to them because the atoms cannot slide past each other.

Diamond

Diamond is one of the hardest materials known and diamonds are prized for their clarity (how clear they are) (Figure 3.9.6). Diamond is made of carbon in a lattice structure which results in the extreme hardness (Figure 3.9.7).

FIGURE 3.9.6 A crystal of pure diamond

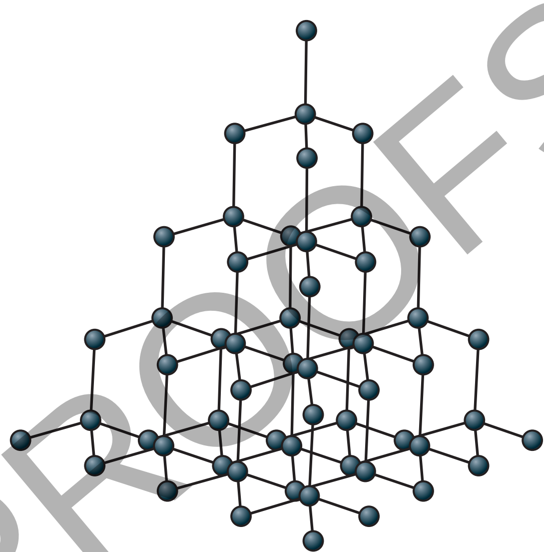


FIGURE 3.9.7 Carbon atoms held in a three-dimensional lattice in diamond

Graphite

Graphite is also a form of carbon but is black solid and much softer than diamond (Figure 3.9.8). This is because the arrangement of the carbon atoms is very different. The structure of graphite allows layers to be easily transferred to a piece of paper because the bonds between the layers are fairly weak (Figure 3.9.9).

FIGURE 3.9.8 Graphite, the form of carbon that can be used for pencils and drawing

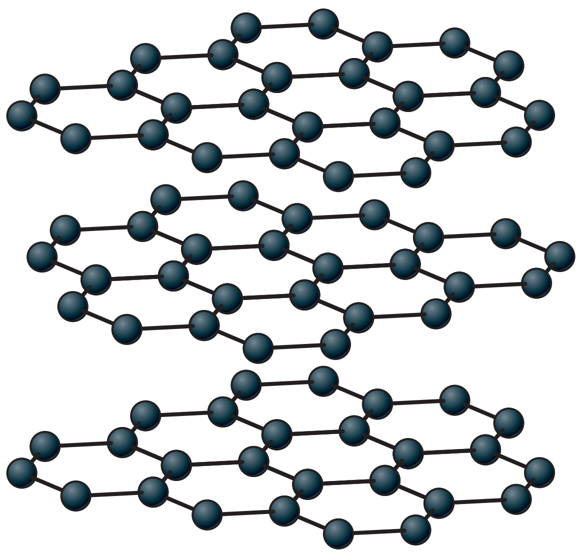


FIGURE 3.9.9 Carbon atoms in graphite with weak bonds between the layers

Silicon dioxide (silica)

Silicon dioxide (SiO_2) is the main compound in sand and is also known as silica (Figure 3.9.10). Its structure is a lattice with repeating atoms of silicon and oxygen joined together (Figure 3.9.11). Like diamond, there are no weak bonds in silicon dioxide.

FIGURE 3.9.10 Sand is a hard substance due to its strong lattice structure

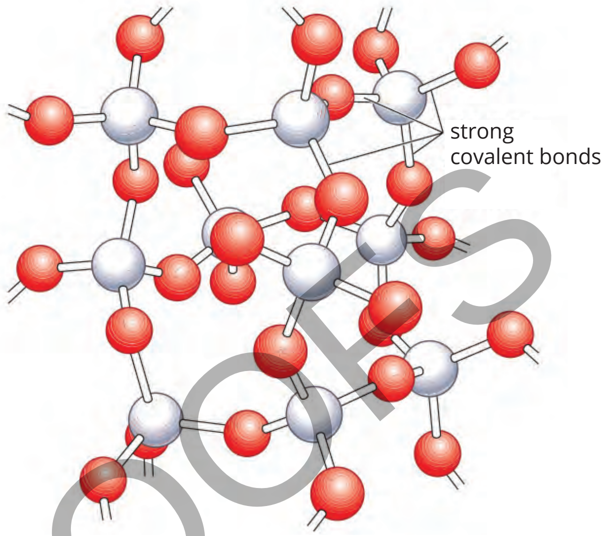


FIGURE 3.9.11 The structure of silica is similar to diamond, but with two types of atoms, silicon (white) and oxygen (red)

SC 2 CHECK YOUR UNDERSTANDING

Metals and some non-metals have lattice structures.

a Describe the key differences between the particle arrangements in metals compared to non-metallic lattices.

b Describe a key difference between the structure of graphite compared to diamond.

Lesson review

1 Compare the particle structures of oxygen (O_2) and diamond.

2 Describe how you would distinguish between a compound and a mixture by looking at a particle diagram.

3 In a metal the bonds between atoms can act in all directions. Explain how this makes a metal difficult to break.

4 Use your understanding of how the atoms are arranged to explain why diamond is much harder than graphite, even though both are made of carbon atoms.

5 Copper (Cu) is an element that can be mixed with other metals to make alloys such as bronze (copper and tin) and brass (copper and zinc).

- **a** Describe the particle arrangement in pure copper.
- **b** Suggest how this arrangement would change if copper were part of a mixture, such as bronze.

3.10 Chemical formulas

Lesson overview

Would you drink dihydrogen monoxide? What if you knew that it is also called H_2O or water? Elements and compounds can be represented by their name or formula or with a diagram (Figure 3.10.1).

In compounds, the name often tells you what atoms are present, and how many there are of each.

In this lesson you will learn about how to read chemical formulas and how to name certain molecular substances when you are given their formula.

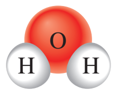
water H_2O 

FIGURE 3.10.1 There are a range of ways to represent compounds such as water

Learning intention

To understand how chemical formulas of compounds are written

Success criteria

SC 1: I can recall the formulas of some familiar chemical compounds.

SC 2: I can identify the types and numbers of atoms from chemical formulas of compounds.

SC 3: I can write the names of some unfamiliar molecular substances from their chemical formulas.

SC 1 I can recall the formulas of some familiar chemical compounds

Chemical formulas of common compounds

Many substances have a common name; for example, water, salt and ammonia, which have the formulas H_2O, $NaCl$ and NH_3. Scientific (or systematic) names of compounds help show the elements they contain. For example, the name copper chloride shows that the compound contains the elements copper and chlorine.

Below are some examples of everyday compounds and their formulas (Table 3.10.1).

TABLE 3.10.1 Everyday compounds

Table salt	Carbon dioxide	Water	Sodium hydroxide (used in drain cleaners)	Ammonia (used in household cleaners)
				
Name: sodium chloride	**Name:** carbon dioxide	**Name:** water	**Name:** sodium hydroxide	**Name:** ammonia
Formula: $NaCl$	**Formula:** CO_2	**Formula:** H_2O	**Formula:** $NaOH$	**Formula:** NH_3

SC 1 CHECK YOUR UNDERSTANDING

State the chemical formula of the following substances.

a sodium hydroxide **b** carbon dioxide **c** sodium chloride

SC 2 I can identify atoms from chemical formulas of compounds

Identifying atoms from chemical formulas of compounds

Every element has a unique symbol. A compound's chemical formula uses these symbols and says what elements it contains. It also uses numbers to show the relative number of atoms of each element there are in the compound.

SkillBuilder

Molecular formulas — what do they represent?

This SkillBuilder and the following Worked Example will help you to:

- Identify elements from their symbols using a periodic table.
- Identify the numbers of atoms in a chemical formula.

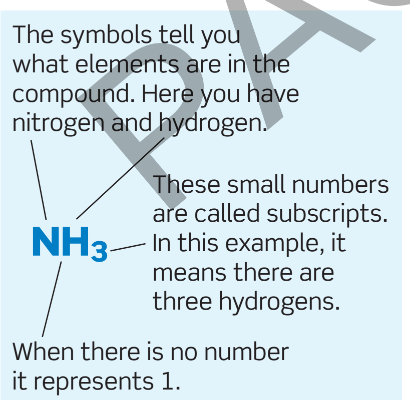
How to determine the elements in a compound formula

1. Identify the symbols (remember that each one starts with a capital letter).
2. Determine the elements by using a periodic table.
3. Look at the small numbers (subscripts). These tell you how many of each atom there are. The subscript is always written on the right side of its element. If there is no number, then there is one atom.
4. If the chemical formula has the same element written more than once, add up all the atoms of each element. (Sometimes longer formulas are used to show how the atoms are joined together in complex molecules.)

Examples

1. Ava was asked to determine the elements in the compound ammonia, which has a formula of NH_3.
   - There are two capital letters so there are two elements.
   - N means there is nitrogen. There is no number, so there is 1 nitrogen atom.
   - H means there is hydrogen. The subscript is 3, so there are 3 hydrogen atoms.
2. Lottie was asked to determine the elements in ethanoic acid (which is present in vinegar). Its formula is often written as CH_3COOH.
   - C means there is carbon. There are 2 letter C's so there are 2 carbon atoms.
   - H means there is hydrogen. H appears as H_3 and H so in total there are 4 hydrogen atoms.
   - O means there is oxygen. There are 2 letter O's so there are 2 oxygen atoms.
   - In total there are 2 carbon atoms, 4 hydrogen atoms and 2 oxygen atoms. Another way to write the formula is $C_2H_4O_2$.

Fertiliser like these white pellets often contains the compound ammonia, NH_3



NH_3 shows that there is 1 nitrogen atom and 3 hydrogen atoms

Worked example

What do molecular formulas represent?

Problem

Phosphoric acid is the main acid present in cola. Identify the types and numbers of atoms in a molecule of phosphoric acid. Its formula is H_3PO_4.

Cola contains the acid H_3PO_4

Solution

Thinking	Working
Identify the elements in the compound by looking at the symbols.	There are three symbols H (hydrogen), P (phosphorus) and O (oxygen).
Use the subscripts to identify the number of each atom.	Hydrogen has a subscript of 3 so there are 3 hydrogen atoms. Phosphorus does not have a subscript so there is 1 phosphorus atom. Oxygen has a subscript of 4 so there are 4 oxygen atoms in the molecule.
Summary	Hydrogen: 3 Phosphorus: 1 Oxygen: 4

Try yourself

Identify the types and numbers of atoms in copper chloride. Its formula is $CuCl_2$.

SC 2 CHECK YOUR UNDERSTANDING

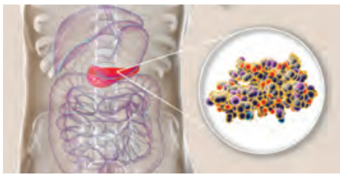
Glucose is a common type of sugar. It has the formula $C_6H_{12}O_6$. State the names of the elements present and the number of each type of atom.

Scifile

Insulin

Insulin is the compound that controls the level of glucose (a sugar) in blood. It is made in the pancreas, as shown in the diagram below. Not enough insulin and the glucose builds up in the blood and cannot be used for energy release in the body's cells.

The formula of insulin is $C_{257}H_{383}N_{65}O_{77}S_6$! It is a type of protein and all proteins contain the elements carbon, oxygen, hydrogen and nitrogen.



Someone with diabetes either does not produce enough insulin or the insulin is not working correctly. In both cases, insulin may need to be injected to manage the persons sugar levels.

SC 3 I can write the names of some unfamiliar molecular substances from their chemical formulas.

Naming molecular compounds

When some pairs of elements combine there may be more than one possible compound formed. In these situations, the names of the compounds indicate the number of atoms of the elements in the compounds. They do this by using prefixes, which are added at the front of a name of an element.

For example, when carbon and oxygen combine, there are two possible products:

- carbon dioxide with two oxygen atoms, and
- carbon monoxide with just one oxygen atom.

Air that is breathed out has carbon dioxide in it. Carbon monoxide is a poisonous gas that is often found around substances that burn. These two gases have names that sound quite similar except for a key difference; one is dioxide, and one is monoxide.

SkillBuilder

Writing a chemical name from a formula

This SkillBuilder will help you to:

- use the correct names to identify the elements present from a chemical formula
- use the correct prefixes at the start of the name to indicate the number of each type of atom in a chemical compound.

Writing the names of the elements

- The names of molecular compounds use the full name of the first element.
- The name of the second element is changed by using the stem of the element name, plus the suffix -ide at the end of the name.

Showing the number of atoms with prefixes

- The prefixes shown in Table 3.10.2 are used to indicate how many of each element are in a molecular compound.

If there is only one atom of the first element, then a prefix is not used.

TABLE 3.10.2 Prefixes used to show the number of atoms in a molecular formula

Number of atoms	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-

Examples

1 Declan was asked to name the substance with the formula CCl_4.

- There is carbon atom, so its name stays as carbon and no prefix is needed.
- The name of the second element, chlorine, is changed to chloride, and tetra- is added before the name because there are 4 atoms of chlorine.

Therefore, the name is 'carbon tetrachloride'.

2 Isabella is asked to work out the systematic name for water H_2O.
She named the water 'dihydrogen monoxide' because there are two hydrogen atoms and only one oxygen atom. She has had to use the prefix mono- because the oxygen is the second element.

Non-systematic names

Many compounds that are used in everyday life, such as water (H_2O), are known by a common name. Other examples are CH_4 (methane) and NH_3 (ammonia).

Their systematic names are carbon tetrahydride (for CH_4) and nitrogen trihydride (for NH_3).

SC 3 CHECK YOUR UNDERSTANDING

Give the scientific names of the following compounds.

a SO_3 **b** SiO_2 **c** PCl_5 **d** CF_4

Lesson review

Use these questions to check your understanding of the learning intention and success criteria for this lesson.

1 The substance ammonia is used for household cleaning.
- **a** Give the formula of ammonia.
- **b** State the types and numbers of atoms present in a molecule of ammonia.
- **c** Ammonia can be reacted with nitric acid to form the substance ammonium nitrate (NH_4NO_3) which can be used as a fertiliser. State the types and numbers of atoms shown in the formula of ammonium nitrate.

2 The compound sodium dichromate is an orange solid with the formula $Na_2Cr_2O_7$. It was used in the past in breathalyser tests to indicate the amount of ethanol (an alcohol with a formula of C_2H_5OH) in the breath of a driver.
State the types and numbers of atoms shown in the formulas of these two compounds.

3 When nitrogen combines with oxygen a range of different compounds can be formed. These include NO, NO_2, N_2O and NO_5. Name these four compounds.

4 Consider the formula and name shown here.
Formula: P_2O_5
Name: phosphorous pentachloride
Rewrite the information so that is correct:
- **a** by changing the name to match the formula
- **b** by changing the formula to match the name.

3.11 Modelling the arrangement of atoms in compounds

Learning intention

To be able to compare information provided in symbols, formulas, two-dimensional models and three-dimensional models of substances

Success criteria

SC 1: I can construct scientific models to show the arrangement of particles in different substances.

SC 2: I can describe the information communicated by two-dimensional and three-dimensional models of substances.

SC 3: I can select an appropriate representation to communicate information to a specific audience.

Introduction

Atoms and molecules can be represented in different ways, including symbols, formulas, 2-dimensional and 3-dimensional models. Models are a great way to visualise molecules. They enable you to see how the atoms join to make up the molecule, as in this model of glucose (Figure 3.11.1).

In this inquiry activity you will use models to represent the arrangement of atoms in substances, and compare the information provided by different representations of compounds.

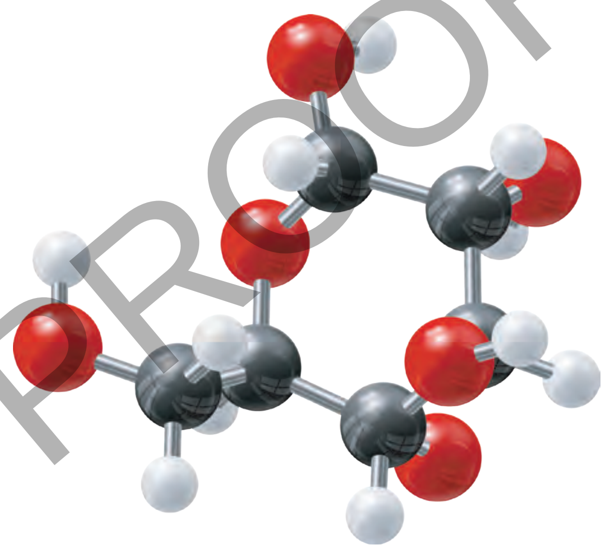


FIGURE 3.11.1 A model of a glucose molecule $C_6H_{12}O_6$, using 6 black balls to represent carbon, 12 white balls for hydrogen, and 6 red balls for oxygen

Background

In this activity you will create models of a range of compounds. Some information is provided in the lesson, but you will also need to conduct research to discover how the atoms are arranged in the compounds.

Aim

To create models of compounds and compare information provided in symbols, formulas, and models of substances

Plan

You are required to create 2-dimensional and 3-dimensional models of the following compounds:

- water molecule (H_2O)
- carbon dioxide molecule (CO_2)
- sulfuric acid molecule (H_2SO_4)
- glucose molecule ($C_6H_{12}O_6$)
- sodium chloride (NaCl) (see hint)

Conduct research to collect any information that you need to complete this task.

Design

Working with other students, decide on your approach to producing the 2-D and 3-D models of the compounds.

Make a list of any materials that you will need to complete the task.

Conduct

1. Use paper, whiteboard or a digital device to create 2-dimensional representations of the compounds. Use colours and labels to show the key aspects of your model.
2. Ensure that your representations are saved so that they can be reviewed and shared later.
3. Use the materials provided to create 3-dimensional models of each of the five compounds.
4. Compare your models to others in the class and encourage feedback from other students.

Improve

1. Describe how you could improve your 2-dimensional representations.
2. Describe how you could improve your 3-dimensional representations.

Evaluate

1. Describe how models can provide more information about a compound than the formula and compare the effectiveness of 2-dimensional and 3-dimensional models.
2. Scientists can use formulas, 2-dimensional models or 3-dimensional models to communicate information about a compound. Describe one situation where each of these would be the best to use, giving reasons for your answers.

HINTS

There are different ways to model atoms, including plastic models, modelling clay or marshmallows with toothpicks.

When you make your models, try to take photos of them so they can be shared.

HINTS

In your research you might see glucose molecules represented in two different ways, one with the carbon atoms in a ring and one with the carbon atoms in a line. Either can be used for this activity.

HINTS

Note that sodium chloride is different to the other compounds because it is made up of a huge network (or lattice) of atoms and not individual molecules. Consider how you will represent a section of this lattice.

Practical investigation

3.12 Structure and properties of substances

Learning intention

To be able to relate the structure of substances to their observable properties

Success criteria

SC 1: I can record observations of the properties of a range of substances.

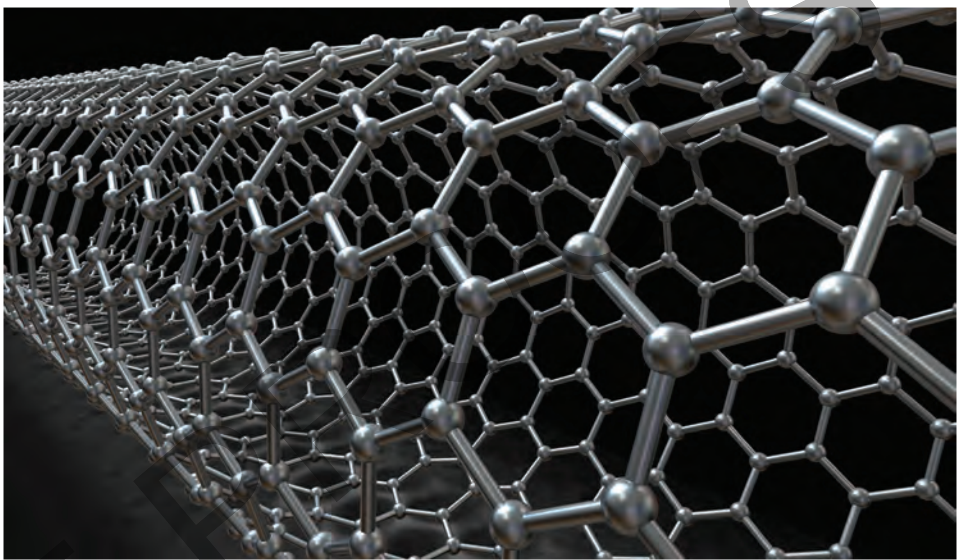
SC 2: I can use knowledge of structures to explain the differences between the hardness and melting points of substances.

SC 3: I can use observations of properties of a substance to predict the type of structure within the material.

Introduction

In this topic different substances and their properties have been investigated. You have also learned about how atoms are arranged into different structures and how those structures can be represented.

In this practical investigation you will observe and test a range of substances and consider how each substance's structure, such as the arrangement of carbon atoms in a nanotube in 3.12.1, contributes to its properties.



3.12.1 A model showing the arrangement of carbon atoms in a nanotube

KEY TERMS

molecule a group of atoms joined together with chemical bonds

metal an element that is shiny, conducts heat and electricity, and can be hammered into sheets and drawn into wires

lattice the structure of non-metallic elements, or compounds that consist of a large network of atoms connected in a three-dimensional arrangement

Background

The arrangement of atoms in substances varies depending on the type of substance. For example, substances can contain **molecules**, they can be **metals**, or they can consist of a **lattice**.

In this practical investigation you will observe the properties of some common substances and consider how their properties can be linked to their structure. The substances are:

Molecular substances	Metals	Substances consisting of lattices
water nitrogen (in air)	copper iron	salt (sodium chloride) sand

Aim

To investigate the properties of various substances and determine the relationship between their properties and their structure

Hypothesis

The properties of a substance are determined by the structure of the substance.

Prediction

Write a testable prediction for your investigation based on the hypothesis.

Materials

- salt (sodium chloride)
- sand
- 2 cm lengths of copper wire
- small iron nails
- sandpaper or emery cloth (to clean the metals)
- 100 mL beakers
- Bunsen burner, tripod and gauze
- matches
- tin lid
- spatula
- tongs

Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

1 Construct a results table to record your observations. An example table is in the Results section.

2 Record the state and the appearance of the substances. For the metals, clean the surface using the sandpaper or emery cloth. For water, use tap water, and for nitrogen, use the air (which is 78% nitrogen).

3 The hardness of the solids can be observed by touching (wash hands afterwards) or using a steel nail.

4 Solubility is tested by placing a small amount of the substance in 50 mL of water and stirring.

5 The melting point of the solids is tested by placing a small amount of the substance on a tin lid and heating for 30 seconds.

SAFETY NOTES

- Bunsen burners must be turned off or switched to a safety flame when not being used.
- Avoid direct contact with any hot objects.
- Safety glasses must be worn at all times.

Results

Record your results in a table like this.

Structure	Substance	State	Appearance	Hardness	Solubility in water (soluble or insoluble)	Melting point (high or low)
Molecular	water			N/A	N/A	
	nitrogen			N/A	N/A	
Metal	copper					
	iron					
Non-metallic lattices	salt					
	sand					

Conclusion

Write a conclusion to your experiment by answering the following questions.

1 For each of the three types of substances, list any similarities of the properties.

2 Using evidence from your experiment, describe how well your observations support the hypothesis.

3 Explain why substances that are made from lattice structures are hard and have high melting points.

4 Predict the type of structures present in diamond, in candle wax and in limestone, giving your reasons for each.

Topic review

3 Classifying matter: Elements, compounds and mixtures

Topic summary

The key concepts included in this topic are:

- Elements are made up of only one type of atom.
- Compounds contain two or more elements combined together and the properties of compounds vary significantly from the properties of these elements.
- Air is a mixture of gases that have been used for a range of applications in society.
- Elements and compounds are pure substances with fixed compositions whereas mixtures contain two or more pure substances that are not in fixed proportions and can be separated.
- Metallic elements have a range of distinctive properties including shiny appearance, malleability, strength, and the ability to conduct electricity.
- Particles in matter can have different arrangements and these affect the properties of the substance.
- The relative numbers of atoms in a compound can be shown using chemical formula and models can be used to show the arrangements of these atoms.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 State the symbols of the following elements. You can use a periodic table to help you answer this question.

a magnesium
b manganese
c mendelevium
d mercury

2 State the names of the elements represented by the following symbols. You can use a periodic table to help you answer this question.

a Au **b** Be **c** Ba **d** As

3 Identify which of the following substances are compounds: seawater, methane, mercury, glucose, germanium.

4 State four properties of metals.

5 Briefly describe how you can prepare hydrogen gas in the laboratory. Include the names of the chemicals required.

Understand

6 Identify which of the following substances do not contain molecules.

neon	sodium chloride	water
oxygen	gold	carbon monoxide

7 The symbol for the element copper is Cu and the symbol for iron is Fe.

a Describe where these symbols have been derived from.
b Explain why Co cannot be used for copper and Ir cannot be used for iron.

8 Using the examples of neon (Ne), nitrogen (N_2) and ammonia (NH_3):

a explain the difference between an atom and a molecule
b explain the difference between an element and a compound
c explain why the formula of nitrogen contains two atoms.

9 The element sodium (Na) is an extremely reactive metal and the element chlorine (Cl_2) is a toxic gas.

a State the common name, the scientific name and the formula of the compound produced when these elements combine.
b Describe the properties of the compound produced.
c Explain why the properties of the compound are so different to the properties of the two elements.

10 Diamond is the hardest known natural substance on earth and tungsten is one of the strongest metals.

- **a** Describe the difference between the terms ‘strong’ and ‘hard’.
- **b** Draw a diagram in your notebook to explain why diamond is so hard.
- **c** Draw a diagram in your notebook to explain why tungsten is so strong.

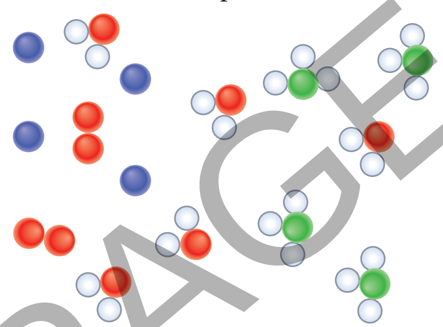
Apply

11 Ashbal was investigating the properties of elements and watched a video about the element potassium (K). He recorded the following observations from the video.

‘The potassium was in a small cube which had a dull grey colour. It was cut in half with a knife and the inside was like silver. When a piece of the potassium was placed in cold water there was lots of fizzing and smoke. Another piece of potassium was heated using a Bunsen burner and it caught fire straight away, with a lilac-coloured flame.’

Using these observations, list four properties of potassium.

12 Consider the particle diagram of a mixture below. Each different colour represents a different element.



- **a** Describe the components of the mixture in terms of elements and compounds.
- **b** State whether you think this diagram represents a homogenous or heterogeneous mixture.
- **c** Explain your answer to part b.

Analyse

14 Read the information about phlogiston and oxygen below.

Before the discovery of oxygen, all substances that burned in air were thought to contain an element called phlogiston. After the substance had burned, it was believed that the phlogiston in the substance was ‘used up’; however, instead of disappearing, it was released into the air. The released phlogiston then prevented other things burning in that air.

Englishman Joseph Priestley is normally credited with the discovery of oxygen gas. He found that this gas made things burn more strongly and allowed some animals to live longer in it.

When a candle burns in a limited supply of air, it will only burn for a short amount of time before going out.

- **a** Describe how this observation supports the theory of phlogiston as described above.
- **b** Describe this observation based on your knowledge of the element oxygen.
- **c** It is now known that when candles burn, the compound carbon dioxide is given off. Use your knowledge of carbon dioxide to suggest why the candle in the description above stops burning.

13 A group of students were investigating the properties of two substances. Their observations are summarised below.

Substance	State	Hardness	Solubility in water	Melting point	Effect when hit with hammer
A	solid	hard	insoluble	very high	changes shape
B	solid	very hard	soluble	very high	shatters

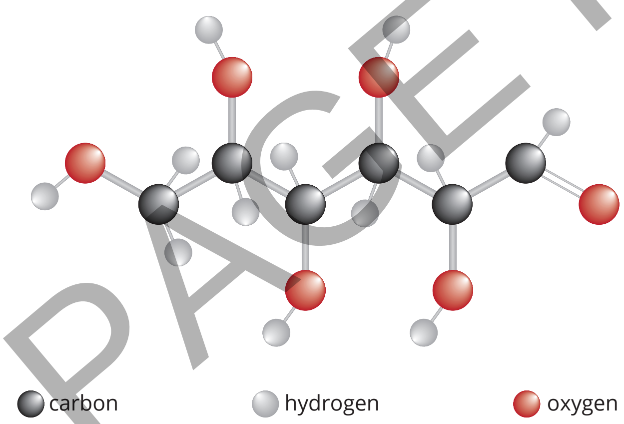
- **a** Identify which substance is a metal.
- **b** Use evidence from the observations to explain your answer.

15 Consider the following observations of the testing of some elements.

Element	Appearance	Effect of hitting with mallet
A	grey solid some red solid on surface	fairly hard to bend
B	smooth yellow shiny solid	shatters
C	brown/orange shiny solid	flattened
D	white solid	no change in shape
E	black solid with smooth surface	cracks when hit
F	silver-like solid	bends a little

a Identify which of the above are likely to be metals.
b Element C changes shape when it is hit. Name the property that allows the substance to do this.
c Describe a test that can be used to confirm which of the elements are metals.
d Suggest the identity of element C.
e Suggest the identity of element E.

16 Consider the model of a glucose molecule below.



a Use the model to write the chemical formula for glucose.
b Describe three things the model shows that cannot be worked out from just seeing the chemical formula.
c In the same style, draw a representation of a methane (CH_4) molecule.

Extension: Research task

17 The energy transition to renewable energy sources relies on the storage of electricity using batteries. This is because energy sources such as wind, solar and tidal power do not generate electricity at all times of the day or every day of the year.

Australia is rich in a number of the elements required for the production of batteries including silver, lead, lithium, cobalt, nickel and copper.

a Write the symbols of these six metals.
b Choose two of these metals and by conducting your own research, describe how they are used in batteries. In your answer you can include where the batteries are used and whether the metals are used in the batteries as elements or as compounds of the element.
c Choose two of the metals, which can be the same or different to those chosen for part b, and briefly describe how they are extracted from the earth. In your answer you can include the name of the compounds found in the earth and their formulas, where they are located in Australia and any risks associated with the extraction process.

Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

3 Glossary

acidic having the properties of an acid, or containing acid; having a pH of less than 7

allotrope different form of the same element

alloy a homogeneous mixture of two or more metals

atom the smallest piece of individual matter that can exist by itself

cellular respiration a set of processes in the cells that convert chemical energy from nutrients into energy used by cells

compound a pure substance that is made up of two or more different types of atom chemically joined

corrosion the breakdown of metals due to their reaction with other chemicals

distillation a process that uses evaporation followed by condensation to recover solvents from mixtures

ductile able to be stretched to form a wire

element a substance made up of only one type of atom

fermentation the chemical process in which carbohydrate or sugar is broken down into a simpler substance, such as alcohol or an acid

formula a representation of a substance that uses chemical symbols and numbers to show the relative numbers of the atoms present in the substance

heterogenous mixture a mixture that varies in composition and properties through the mixture

homogenous mixture a mixture that has uniform composition and properties through the mixture

inert gas element in Group 18 of the periodic table that do not easily react because they have a full outer electron shell

lustrous shines when polished or freshly cut

malleable able to be hammered or bent into new shapes

matter a physical substance; anything that has mass and volume

metal an element that is shiny, conducts heat and electricity, and can be hammered into sheets and drawn into wires

mixture combination of two or more pure substances that can be separated to recover the pure substances

molecule a group of atoms joined together with chemical bonds

lattice the structure of non-metallic elements, or compounds that consist of a large network of atoms connected in a three-dimensional arrangement

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun

property the observable characteristics of a substance; what a substance looks like and how it behaves

soluble able to dissolve in a particular solvent

pure substance a material that is made up of only one type of substance

reactive a description of a substance that readily undergoes chemical reactions