7.2 Compounds

The billions of substances in the universe are all made up of just 100 or so elements. By understanding how the elements combine to form new substances, scientists can develop useful materials such as plastics, perfumes and medicines. Scientists can also synthesise natural materials such as vitamins, flavours and even blood in the laboratory.

Compounds

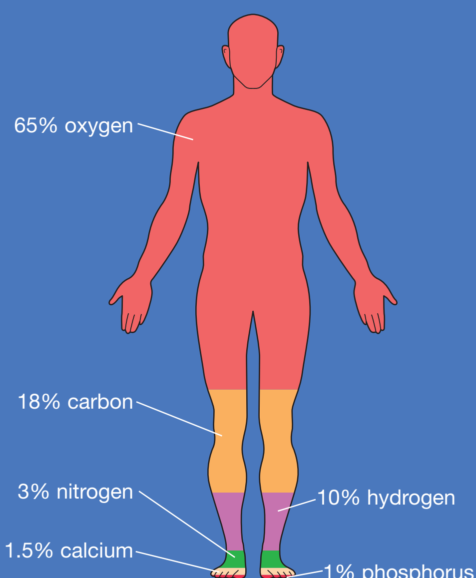
Most substances you encounter every day are made up of more than one type of atom. These forms of matter are known as **compounds**. Like elements, every compound has a unique set of characteristics that scientists call its *properties*. However, the properties of compounds are usually very different from the properties of the elements that make them up. Some compounds found around your home are shown in Figure 7.2.1.

Some compounds are made up of molecules—such as water, wax and vegetable oil. The molecules in these compounds each contain two or more types of atoms. Other compounds form crystal lattices. For example, table salt is made of a lattice of sodium and chlorine atoms while beach sand is a lattice of silicon and oxygen.

Figure 7.2.1 Common compounds seen around the home. Water is a clear liquid, table salt is a white, crystalline solid, candle wax is a soft solid that melts easily and vegetable oil is a thick, yellow liquid.

What are you made of?

The human body is made up of just 16 elements. However, 98.5% of the body is made up of just six! These are oxygen (65%), carbon (18%), hydrogen (10%), nitrogen (3%), calcium (1.5%) and phosphorus (1%).



SciFile

Molecular compounds

The molecules in many compounds are small and contain just a few atoms. Carbon monoxide (formula CO), for example, has just one carbon (C) atom and one oxygen (O) atom. The molecules in other compounds, such as some plastics, contain thousands of atoms. However, all the molecules in any compound are all identical in size, shape and number of atoms. Figure 7.2.2 shows molecules of three common compounds—carbon monoxide, water and glucose (a type of sugar). Despite all having very different properties, each molecule is made by combining different numbers of the same elements, oxygen, hydrogen and carbon.

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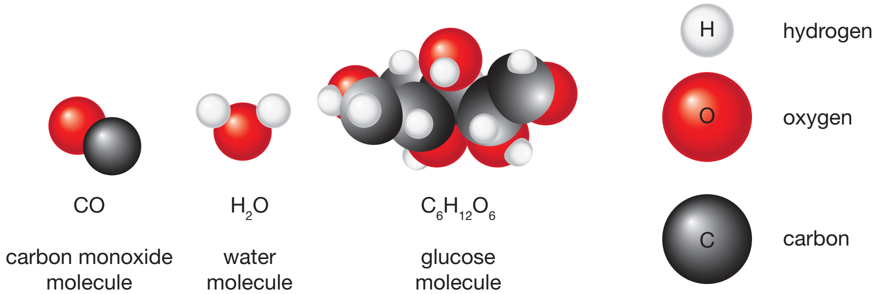


Figure 7.2.2 Molecules of three common compounds. All of these compounds are made of just three elements—oxygen, hydrogen and carbon.

Scientists represent the molecules of compounds in a similar way to the molecules of elements. Water is a molecular compound with the molecular formula H_2O. The chemical formula indicates that there are two hydrogen (H) atoms and one oxygen (O) atom in each water molecule. Carbon dioxide has the molecular formula CO_2 (representing one carbon and two oxygen atoms) and glucose is $C_6H_{12}O_6$ (six carbon atoms, twelve hydrogens and six oxygen atoms).

WORKED EXAMPLE
Constructing molecular formulas

Problem

Determine the chemical formula for the sulfuric acid molecule shown in Figure 7.2.3.

Solution

1. Identify the atomic symbol of each type of element contained in the molecule: hydrogen, H; sulfur, S; oxygen, O.
2. Identify the number of each type of element: 2 hydrogens; 1 sulfur; 4 oxygens.
3. Write the atomic symbols for each element with the numbers below (as subscripts) to construct the formula: H_2SO_4.

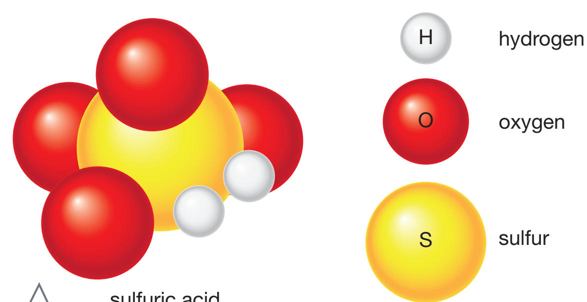
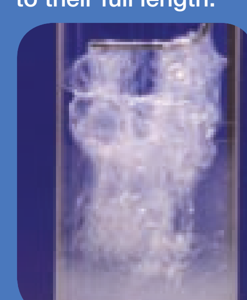


Figure 7.2.3

DNA

The DNA in each of your body cells is an extremely long molecule. The fine threads of DNA shown below would be 2–3 metres long if stretched to their full length.



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Compound lattices

Compounds can also form crystal lattices. In these lattices, the atoms are bonded very strongly to each other so they tend to be very hard solids at room temperature. Two common examples of compound lattices are table salt and beach sand.

The lattice for table salt is shown in Figure 7.2.4. The scientific name for table salt is sodium chloride and its chemical formula is NaCl. From the chemical formula, you can see that table salt is made from sodium (Na) and chlorine (Cl). However, NaCl is not a molecular formula because it does not contain molecules. Instead the formula tells you that in the crystal lattice there is one sodium for every chlorine.

2 p264

Beach sand has the scientific name silica or silicon dioxide. Its chemical formula is SiO_2. This formula indicates that in a grain of beach sand, there is one silicon atom for every two oxygen atoms.

3 p265

7.6

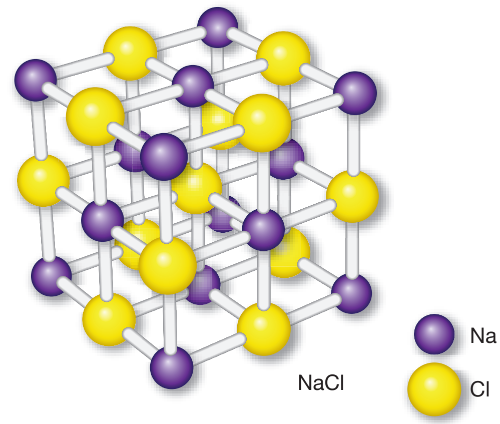


Figure 7.2.4 In a lattice of sodium chloride, sodium and chlorine atoms form a grid-like structure with one sodium atom for every chlorine atom.

Mixtures

Many of the substances used every day are not simply elements or compounds but are **mixtures** of elements and compounds. Air, for example, is a mixture of the elements oxygen (O_2) and nitrogen (N_2) with compounds such as water vapour (H_2O), carbon dioxide (CO_2) and

INQUIRY science 4 fun

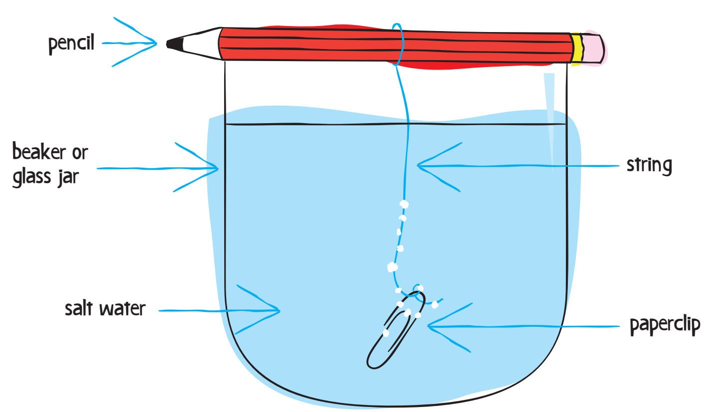
Stringy crystals

Can you grow crystals on a string?

Collect this …

Yes

- beaker or glass jar
- water
- string (15–20 cm)
- paperclip
- pencil
- table salt
- teaspoon
- kettle



Do this …

1. Boil water in the kettle and leave it to stand for a minute.
2. Pour the hot water into the beaker or jar. Take care not to spill the water or touch the sides.
3. Dissolve salt in the water one teaspoon at a time until no more salt will dissolve. Stirring will help to dissolve the salt.
4. Tie one end of the string to the paper clip and one end to the middle of the pencil.
5. Drop the paperclip into the salt water and suspend the string by sitting the pencil across the top of the beaker.
6. Crystals should begin to form within 24 hours and continue to grow for a week.

Record this …

Describe what you saw.

Explain why you think this happened.

carbon monoxide (CO). The water from the tap is also not pure H_2O but a mixture including chlorine, fluorine and many other trace elements. Anything that has a list of ingredients, such as shampoo or soft drink, is a mixture. Figure 7.2.5 shows the ingredients of a typical mixture

The main difference between a mixture and elements or compounds is that the molecules in a mixture are not identical. As a result, no chemical formula can be written for a mixture.

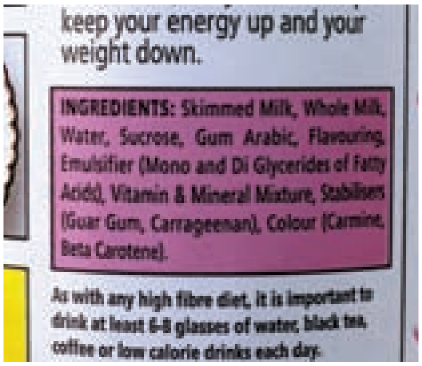


Figure 7.2.5

Any substance made up of two or more ingredients is a mixture.

Gaseous mixtures

Any two gases can be easily mixed together because the particles of a gas are separated by large distances. The air you are breathing right now is a mixture of nitrogen (78%), oxygen (21%) and carbon dioxide (less than 1%). The air you breathe out is about 78% nitrogen, 17% oxygen and 4% carbon dioxide.

Solids and liquids can also be mixed into gases. When small solid particles are mixed with a gas, it is usually referred to as a smoke or dust. Examples include ash particles floating out from a chimney or fine sand particles in a dust storm.

When small liquid particles are mixed into a gas, it is referred to as a mist or fog. Clouds are a mixture of tiny liquid water droplets suspended in the air.

7.7

Liquid mixtures

Not all liquids can be mixed together. Liquids that can be mixed, such as water and food colouring, are said to be **miscible**. Liquids that do not mix, such as oil and water, are said to be **immiscible**.

Gases and solids can also be mixed into liquids. When gases are mixed into liquids, they may dissolve to form a solution such as the carbon dioxide gas dissolved in soft drinks. Alternatively, the gases may remain within the liquid as bubbles, such as in shaving cream (Figure 7.2.6) or beaten egg whites. In these cases, the mixture is called a foam.

Solids may also dissolve in liquids to form solutions. If the solid does not dissolve but the particles are very small, then the solid–liquid mixture is called a colloid. Milk and blood are examples of colloids. If the solid particles are bigger, then mixture is known as a suspension, such as when you throw sand into water. The main difference between a colloid and a suspension is that the particles in a suspension will eventually fall to the bottom of the liquid. In contrast, colloids will never separate out of the liquid.

Figure 7.2.6

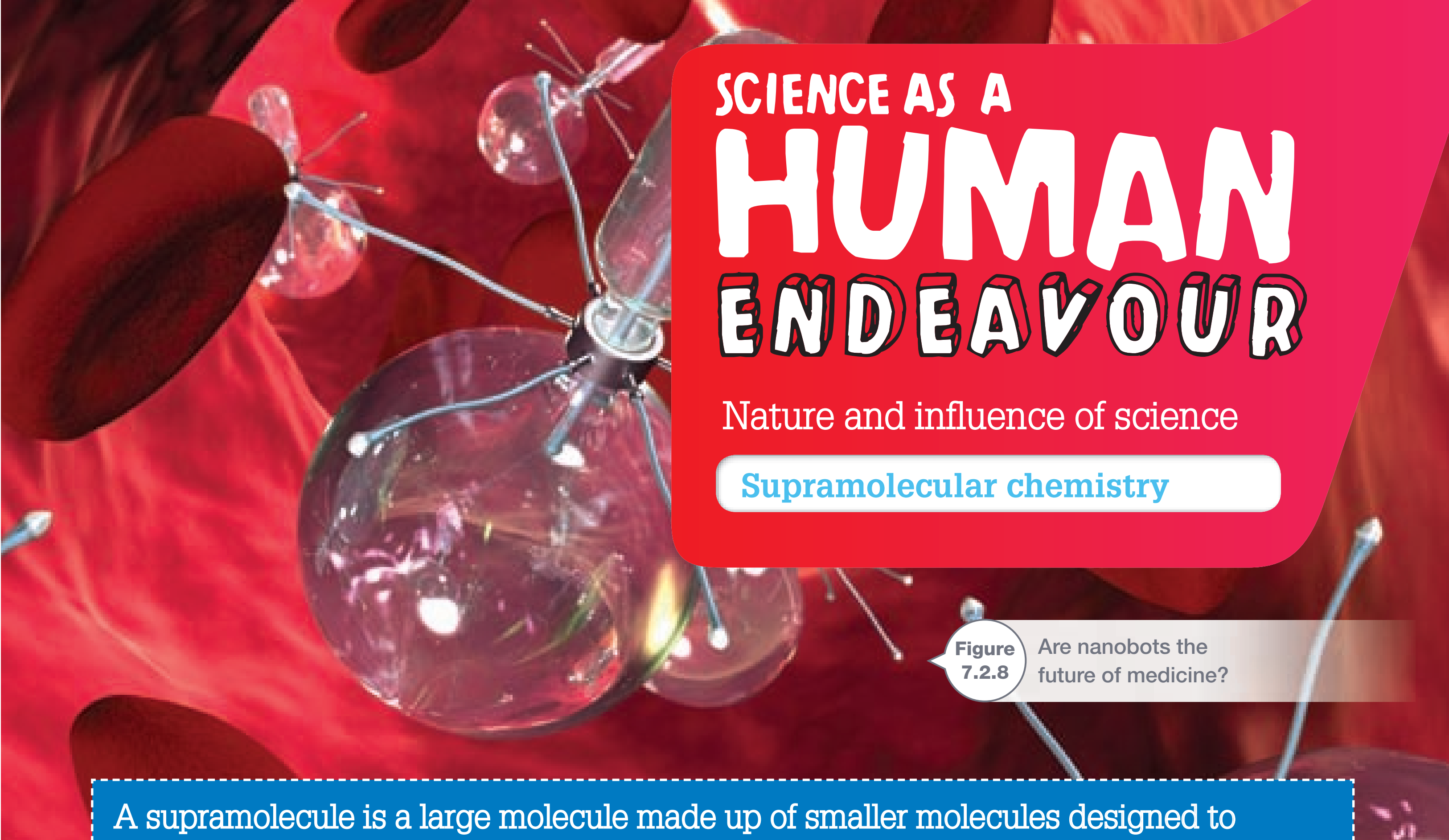
Shaving foam is a mixture of gas bubbles in a liquid.

Alloys

Alloys are a mixture of a metal with other metals or non-metals. Alloys are particularly important because they often have very different and useful properties compared to the pure metal. For example, iron is cheap to produce but is soft and rusts easily—making it less useful. Adding small amounts of carbon to iron produces steel, which is strong and useful for building skyscrapers, bridges, machinery and cars. Adding chromium and nickel produces stainless steel, which stops it rusting. Some other common alloys are shown in Figure 7.2.7.

Figure 7.2.7

Common alloys



SCIENCE AS A HUMAN ENDEAVOUR

Nature and influence of science

Supramolecular chemistry

Figure 7.2.8 Are nanobots the future of medicine?

A supramolecule is a large molecule made up of smaller molecules designed to perform a specific task. In other words they are molecular machines.

Supramolecular chemistry

Nanobots are miniaturised robots and are a common theme in sci-fi movies. Examples are shown in Figures 7.2.8 and 7.2.9. While nanobots currently exist only in fiction, scientists are creating nano-sized (smaller than micro) machines by using supramolecular chemistry. These 'machines' are 1000 times smaller than a grain of pollen.

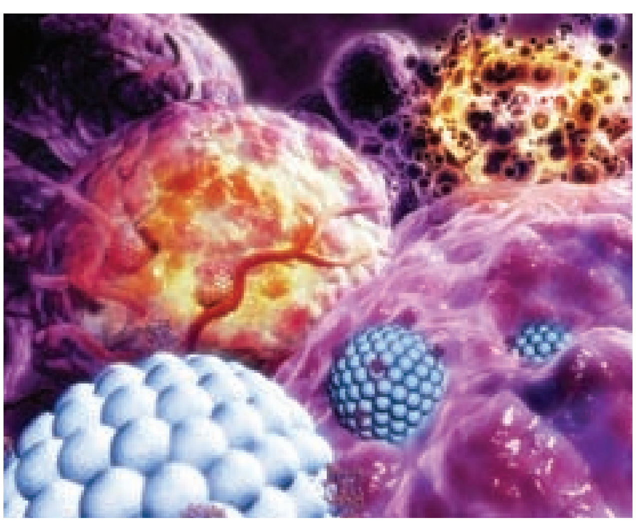


Figure 7.2.9 This artist's impression shows nanobots attacking cancer cells.

Supramolecules in nature

The most complicated supramolecules are found in nature. Chlorophyll is the chemical found inside the chloroplasts in the cells of plants and is what makes leaves green. Chlorophyll is a supramolecule that plays a key role in photosynthesis, the process by which plants make their own food. Photosynthesis does this by converting sunlight into chemical energy.

Haemoglobin is another supramolecule. It makes your blood red and is responsible for transporting oxygen to your cells and removing carbon dioxide. There are many examples of supramolecules in your body but perhaps the most impressive is DNA (Figure 7.2.10). DNA acts like molecular computer software with the program for creating a person and all their physical characteristics.

7.8

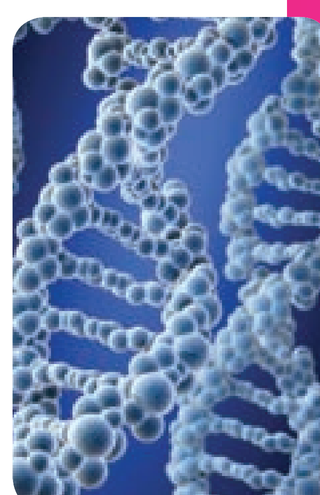


Figure 7.2.10 A DNA molecule is made up of two very long molecules twisted together in a spiral called a double helix.

ENDEAVOUR

Imitating nature

Scientists are still learning how to create the extremely complicated supramolecules found in nature. Americans Donald Cram and Charles Pedersen and Frenchman Jean-Marie Lehn (Figure 7.2.11) are considered the pioneers of supramolecular chemistry. In the 1960s, they studied crown ethers, which are large molecules shaped like doughnuts. In 1987, they were awarded the Nobel Prize in Chemistry.

Since then, there have been many other examples of supramolecules made in the laboratory. For example, genetic engineers use special molecules called enzymes to cut the DNA molecule up into pieces. The enzymes used to do this are known as *molecular scissors*. Other useful supramolecules include:

- molecular claws for catching and trapping atoms like the one shown in Figure 7.2.13
- molecular motors that rotate when an electrical current passes through them
- molecular tweezers for clasping other molecules.

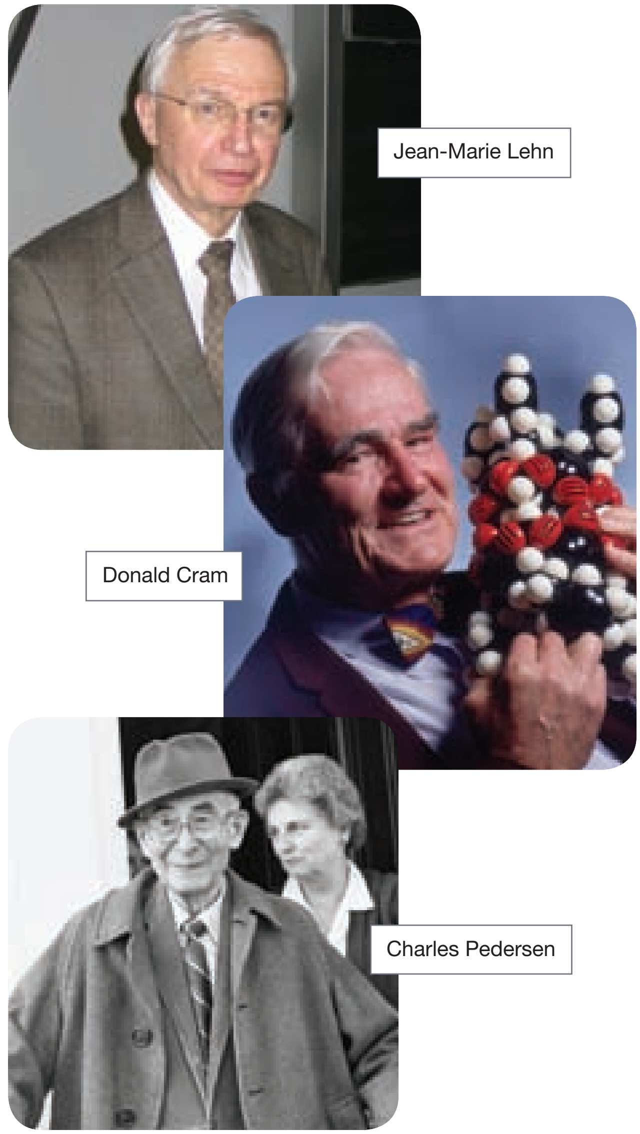


Figure 7.2.11 Donald Cram, Jean-Marie Lehn and Charles Pedersen were jointly awarded the Nobel Prize in Chemistry in 1987 for their work on supramolecules.

SciFile

Getting some perspective

People often use the word *nano* to describe anything that is very small. However, scientists use *nano* in a very specific way. A nanometre (nm) is a measure of length that is a billion times smaller than a metre. To put this in perspective, a human hair is about 50 000 nm wide, a grain of pollen (Figure 7.2.12) is around 30 000 nm wide, blood cells are 5000 nm wide and the holes in filter paper are about 100 nm wide.

Figure 7.2.12 This grain of pollen is approximately 30 000 nm wide.

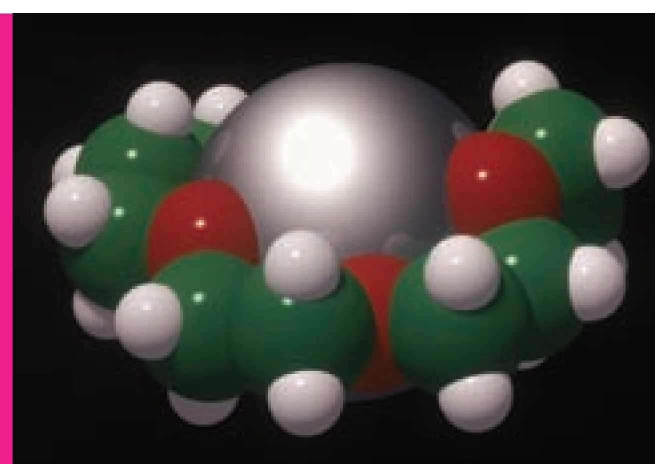


Figure 7.2.13 The first supramolecules could be described as molecular cages or molecular claws. They are like hollow balls that can trap single atoms inside.

7.2 Unit review

Remembering

1 **State** two examples of molecular compounds and two examples of lattice compounds.

2 a **List** three alloys.

b **State** a use for each of the three alloys.

3 **List** three examples of molecular machines made in the laboratory.

4 **State** the ratio of elements in these compound lattices.
- a sodium chloride, $NaCl$
- b magnesium chloride, $MgCl_2$
- c aluminium chloride, $AlCl_3$
- d sodium oxide, Na_2O
- e aluminium oxide, Al_2O_3

Understanding

5 a **Explain** what the chemical formula of a molecular compound tells you about the molecules that make up the compound.

b **Recall** an example of a molecular compound.

6 a **Explain** what the chemical formula for a crystal lattice compound tells you about the atoms in the crystal lattice.

b **Recall** an example of a crystal lattice.

7 **Explain** why a chemical formula cannot be written for a mixture.

8 **Explain** why iron is rarely used in its pure form.

9 **Define** the term *supramolecule*.

Applying

10 **Identify** the number and type of atoms in each of the following molecules.
- a carbon monoxide, CO
- b carbon dioxide, CO_2
- c nitrous oxide, NO_2
- d glucose (sugar), $C_6H_{12}O_6$
- e trinitrotolulene (TNT), $C_7H_5N_3O_6$
- f acetic acid (vinegar), CH_3COOH (Be careful with this one!)

Analysing

11 **Contrast** elements and compounds.

12 **Contrast** mixtures and compounds.

13 **Determine** a chemical formula for the molecule in Figure 7.2.14.

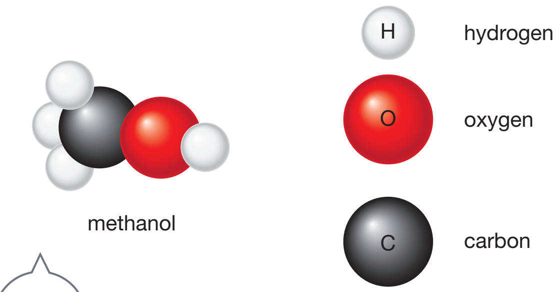


Figure 7.2.14

14 **Classify** the following compounds as either molecular or lattice: water, table salt, carbon monoxide, silicon dioxide, carbon dioxide.

15 **Classify** the following as element, compound or mixture: pool water, helium, air, nitrogen, gold, sugar, salt, cordial, carbon dioxide.

Creating

16 **Construct** diagrams of beakers containing an element, a compound and a mixture. Use labels to show the differences.

Inquiring

1 Research the properties of an alloy and compare and contrast the alloy with the elements that make it up.

2 Water has the chemical formula H_2O while bleach has the chemical formula H_2O_2.
- a Describe what these formulas tell you about the two molecules.
- b Research, compare and contrast the properties of these two compounds.

3 a Research how table salt is harvested at the Dampier salt mines in Western Australia.

b Construct a diagram to summarise your findings.

7.2 Practical activities

1 Forming carbon dioxide, a molecular compound

Purpose

To form the molecular compound carbon dioxide, CO_2.

Materials

- 0.1 M hydrochloric acid
- sodium carbonate
- test-tube
- spatula
- dropper
- wooden splint
- matches

SAFETY
Hydrochloric acid is corrosive.

Procedure

1. Use the spatula to deposit a small amount of sodium carbonate in the test-tube.
2. Use the dropper to add hydrochloric acid to the sodium carbonate.
3. Light the end of the wooden splint with a match, and then blow out the splint so that the end is glowing red.
4. Place the glowing splint in the test-tube.

Discussion

1. **State** what evidence there is that a new substance is being formed.
2. **State** whether carbon dioxide is a solid, liquid or gas at room temperature.
3. **State** the colour of carbon dioxide.
4. **Explain** why you think the splint glows in air but not in carbon dioxide.

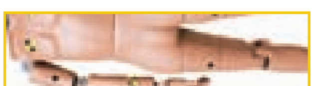
2 Forming alum, a lattice compound

Purpose

To grow crystals of potassium aluminium sulfate, also known as alum.

Materials

- 250 mL beaker
- water
- glass rod
- measuring cylinder
- string
- alum
- filter paper
- spatula
- electronic scales
- hotplate or Bunsen burner, bench mat, tripod and gauze mat
- thermometer
- digital camera (optional)

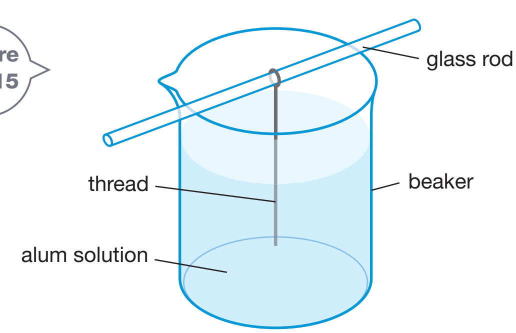


SAFETY
Take care when using Bunsen burners and boiling liquids.
Tie long hair back when using a Bunsen burner.

Procedure

1. Use the electronic balance to measure out 10 g of alum onto the filter paper.
2. Pour the alum into the 250 mL beaker.
3. Add approximately 70 mL of water.
4. Heat the mixture to 60°C and stir with the glass rod until all the alum is dissolved. Then carefully remove it from the heat.
5. Wash the glass rod and tie a string around the middle as shown in Figure 7.2.15.

Figure 7.2.15



6 Lie the glass rod across the top of the beaker so that approximately 3 cm of string is immersed in the solution.

7 Place the beaker in a sunny spot and observe each day for 7 days.

Results

Use diagrams or digital photos to record your observations every day.

Discussion

1 **List** three physical properties of the alum crystals.

2 **Describe** where the crystals initially began to grow and **explain** why you think they grew there first.

3 **Describe** where the biggest crystals were.

4 **Predict** what might happen if you prepared a new solution of potassium aluminium sulfate and deposited these crystals in it.

3 Making models

Purpose

To construct models of different compounds.

Materials

- different-coloured sticks of modelling clay

Procedure

1 Use modelling clay to construct models of the following compounds:

   a carbon monoxide molecule (CO)

   b sulfuric acid (H_2SO_4)

   c water molecule (H_2O)

   d glucose ($C_6H_{12}O_6$)

   e sodium chloride lattice (NaCl).

Results

Copy the table below into your workbook.

Compound name	Chemical formula	Molecule or lattice	Number and type of atoms in each molecule
Carbon monoxide			
Sulfuric acid			
Water			
Glucose			
Sodium chloride			

Discussion

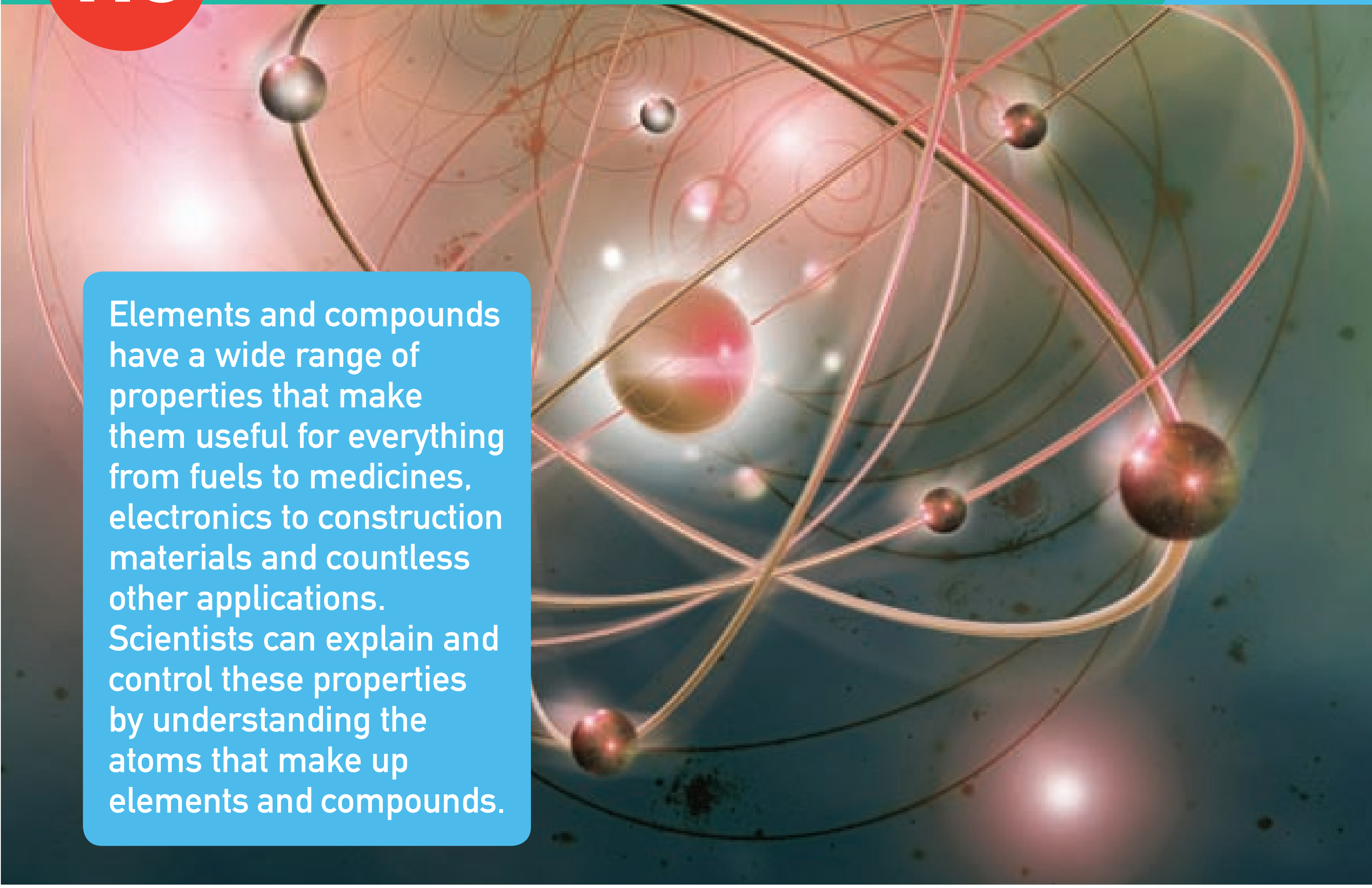
1 **Explain** why you cannot give a number of atoms per molecule for sodium chloride.

2 **Describe** what the chemical formula for a lattice compound tells you about the number and type of atoms in the compound.

3 **Explain** what a molecular formula tells you about the atoms in the molecules of a compound.

4 **Explain** how chemical formulas help scientists to communicate scientifically.

7.3 A closer look at atoms



Elements and compounds have a wide range of properties that make them useful for everything from fuels to medicines, electronics to construction materials and countless other applications. Scientists can explain and control these properties by understanding the atoms that make up elements and compounds.

Atoms in matter

Atoms make up everything around you but are so small that they cannot be seen with even the most powerful optical microscope. Instead, scientists 'see' atoms using a scanning tunnelling microscope or STM. An STM scans a very sharp tip across the surface of crystals. This is similar to the way that a visually impaired person scans their finger across the bumps in a page to read Braille, as shown in Figure 7.3.1. The STM tip senses the atoms as bumps on the surface line by line. It then constructs an image of the atoms like the one shown in Figure 7.3.2.

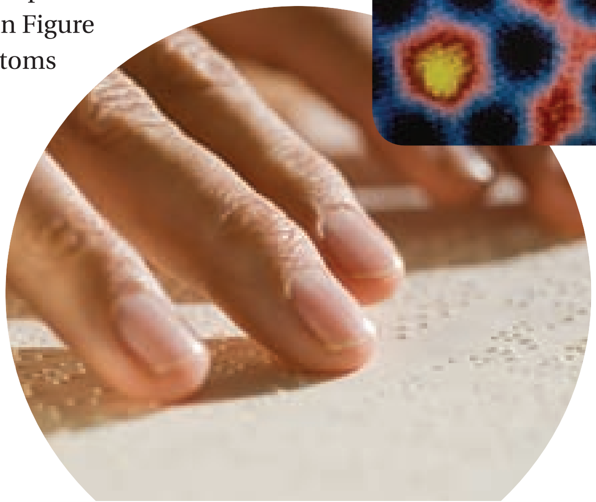


Figure 7.3.1 An STM 'reads' the surface of a crystal like fingers 'read' Braille.

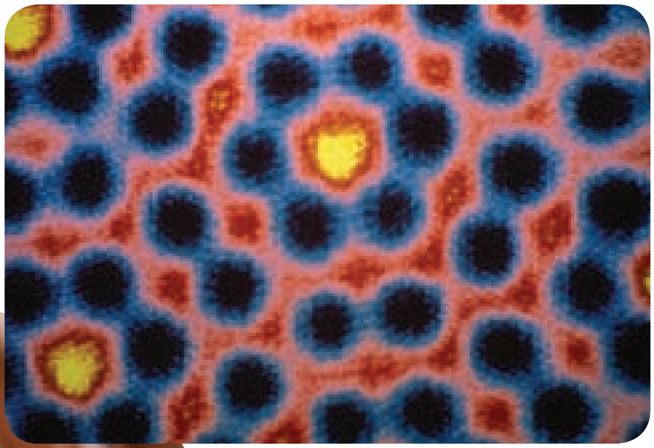


Figure 7.3.2 STM image of a silicon surface made up of silicon atoms arranged in a crystal lattice.

Computer models are used to predict the weather.

Scale models can be used to study how the shape of a plane affects how it will move through air.

Detailed plans are used to understand how a house will look before it is built.

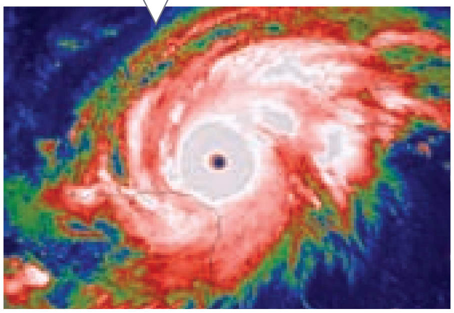


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Figure 7.3.3 Models are used in all areas of everyday life.

The atomic theory of matter

Scientists proposed that matter was composed of atoms long before STMs were invented. The word *atom* comes from *atomos*, a word used by the ancient Greek philosopher Democritus to describe the smallest particles of matter that could not be divided. Since then, scientists have developed a full understanding of atoms through indirect experimental evidence rather than direct observation. From this evidence, they have constructed a scientific **model** that explains what is in an atom and what its structure looks like. This understanding is known as the atomic theory of matter.

A scientific model is a simplified idea that can be used to help make predictions or test assumptions. Some are shown in Figure 7.3.3. For example, a model aeroplane does not have all the complicated moving parts of a real plane but could be used to predict how well the plane will move through the air or explain how a plane flies.

In 1803, British scientist John Dalton (his portrait is shown in Figure 7.3.4) developed a model of matter that used atoms as its building blocks. His model forms the basis of the modern atomic theory of matter. Dalton predicted that:

- all matter is composed of indivisible particles called atoms
- some forms of matter, known as elements, are made up of only one type of atom
- some forms of matter, known as compounds, are made up of more than one type of atom
- atoms cannot be created or destroyed but can be rearranged to form different substances.

Since Dalton developed his atomic theory of matter, there have been many experiments that have confirmed his predictions and provided much more information about the different types of atoms.

Figure 7.3.4 John Dalton is considered to be the first person to propose the fundamental ideas behind the modern atomic theory of matter.

INQUIRY science 4 fun

Magic finger

Yes

Can you observe detergent molecules by indirect observation?

Collect this …

- dinner plate
- washing detergent
- ground pepper
- water

Do this …

1. Fill the dinner plate with water.
2. Cover the surface of the water evenly with ground pepper.
3. Place a small amount of detergent on the end of your finger and dip your finger in the plate of water.

Record this …

Describe what happened to the pepper.

Explain what you think is happening to the detergent particles on your finger.

Types of atoms

Although there are countless types of matter, there are only 117 known types of atoms. Each atom has a unique set of characteristics that scientists know as its properties. These properties can be:

- physical properties such as its size and mass
- chemical properties, which determine how the atom interacts with other atoms.

Inside atoms

All atoms are different. When you put many gold atoms together, you get a nugget of gold that is heavy, metallic and solid. However, if you put many oxygen atoms together, you get oxygen—a light and invisible non-metallic gas. To understand why, you need to look inside the atoms.

Atoms are not simply solid balls but have a very complicated internal structure. It is this internal structure that gives each element its properties.

Atoms are made up of even smaller particles known as **subatomic particles**. These subatomic particles are called **protons**, **neutrons** and **electrons**. Figure 7.3.6 shows how these particles make up an atom. The protons and neutrons sit at the centre of the atom in a cluster called the **nucleus**. The electrons, which are 1800 times lighter than the protons and neutrons, form a cloud around the nucleus.

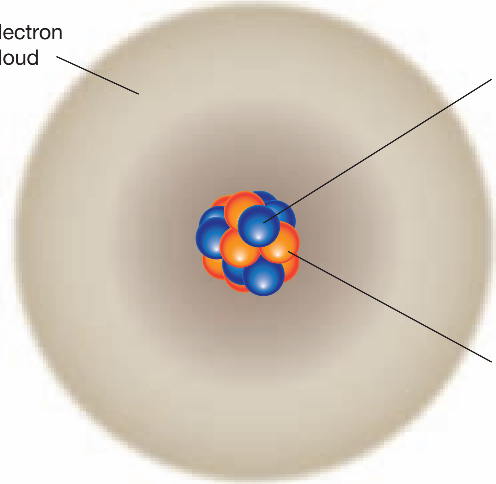


Figure 7.3.6 Atoms are made up of a positive nucleus that contains protons and neutrons. The nucleus is surrounded by a cloud of negatively charged electrons.

SciFile: Now that's strong!

The positive charge on protons means that they would normally repel each other and fly apart. However, protons and neutrons are held together by the strongest force in the Universe, known appropriately as the *strong force*. The strong force is 100 000 000 000 000 000 000 000 000 000 000 000 000 times stronger than gravity. However, the strong force does not reach very far. So the protons or neutrons must be very close before the strong force can stick them together.

SciFile: Atom smashing

Scientists learn about what's inside atoms by literally smashing them together to see what comes out. This requires huge machines called particle colliders that accelerate the atoms to extremely high speeds before smashing them together. The world's largest particle collider is called the Large Hadron Collider (shown in Figure 7.3.5). It consists of a circular tunnel 27 km long passing under the border between Switzerland and France. The particles travel so fast that they go around the tunnel more than 11 000 times per second at speeds close to the speed of light!

Figure 7.3.5 The Large Hadron Collider. The scientist riding a bike alongside it gives an idea of its size.

The electrons are bound tightly to the nucleus because electrons have a negative charge, –1, and protons have a positive charge, +1. These opposite charges attract each other like the opposite poles of a magnet. However, the total charge of an atom is zero because there are equal numbers of electrons and protons. Neutrons are charge neutral, which means they have no charge. These properties are summarised in Table 7.3.1.

Atomic number and mass number

The number of protons in the nucleus determines what type of atom it is and what element it belongs to. For example, all gold atoms contain 79 protons while all oxygen atoms contain eight protons. The number of protons in an atom is called the **atomic number**. In the periodic table, the atoms are ordered by atomic number.

Table 7.3.1 Properties of subatomic particles

Subatomic particle	Location	Mass compared to an electron	Charge
Proton	In the nucleus	×1800	+1
Neutron	In the nucleus	×1800	0
Electron	In the electron cloud surrounding the nucleus	×1	–1

The number of protons and neutrons in an atom is called the **mass number**. These numbers are often written alongside the chemical symbol. For example, an atom of sodium, Na, can be shown as:

Mass number ⟶ 23
Atomic number ⟶ 11 Na

$$^{23}_{11}\text{Na}$$

From this one symbol, you can calculate the number of protons, neutrons and electrons in the sodium atom:

- The number of protons is the atomic number, 11. So there are 11 protons in the nucleus.
- The number of neutrons is the mass number minus the atomic number, 23 – 11 = 12. So there are 12 neutrons in the nucleus.
- The number of electrons is equal to the number of protons so there are 11 electrons spinning in a cloud around the nucleus.

7.9

WORKED EXAMPLE

Calculating numbers of subatomic particles

Problem

An iron atom has the atomic symbol $^{56}_{26}\text{Fe}$.

Identify the mass number and atomic number, and then calculate the number of protons, neutrons and electrons.

Solution

Mass number = 56

Atomic number = 26

Number of protons = atomic number = 26

Number of neutrons = mass number – atomic number
= 56 – 26 = 30

Number of electrons = atomic number = 26

Electron shells

Even the electron cloud that surrounds the nucleus has structure. The electron cloud can be broken down into **electron shells** that surround the nucleus like the layers of an onion, as shown in Figure 7.3.7. Each shell can only hold a certain number of electrons. The innermost shell is small and can only hold two electrons, the second shell holds eight electrons, the third shell holds up to 18 electrons while the fourth electron shell can hold a maximum of 32 electrons. The nucleus is tiny in comparison, being around 100 to 1000 times smaller than the electron shells. This means that the electron shells take up most of the space in an atom.

2 p271

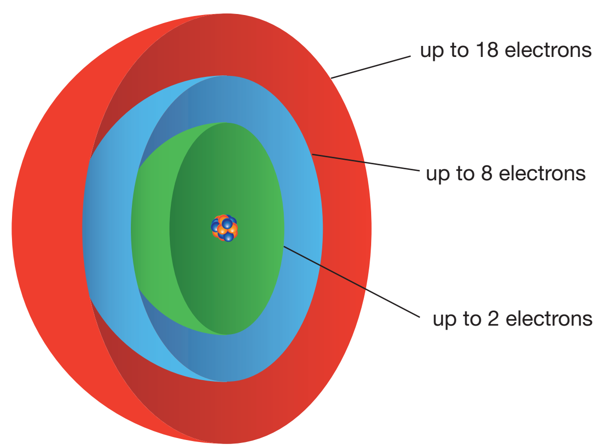


Figure 7.3.7 The electron clouds form shells around the nucleus. The innermost shell is small and can only hold two electrons, the second shell can hold up to eight and the third shell can hold up to 18 electrons.

SciFile

Empty atoms

If the nucleus of an atom was the size of a golf ball, then the electron cloud would be the size of football stadium and the electrons would be the size of a single grain of sand. This means most of an atom is empty space!

7.3 Unit review

Remembering

1 **State** the names and charges of the three subatomic particles in an atom.

2 **List** Dalton's four predictions that make up the basis of the modern atomic theory of matter.

3 **Specify** the feature of an atom that determines which type of atom it is.

4 **Recall** how many electrons can be contained in the first, second and third electron shells.

Understanding

5 **Define** these terms:
- **a** atomic number
- **b** mass number.

6 **Describe** the structure of an atom in terms of protons, neutrons and electrons.

7 **Explain** what a scientific model is and how scientists use them.

8 **Explain** why the electrons in an atom don't fly off.

9 **Outline** how the number of neutrons can be calculated from the atomic and mass numbers.

Applying

10 **i** **State** the name of the following atoms.
ii **Calculate** the number of protons, neutrons and electrons in each.

- **a** $^{4}_{2}He$
- **b** $^{14}_{7}N$
- **c** $^{39}_{19}K$
- **d** $^{63}_{29}Cu$

11 **Determine** the atomic symbol that completely describes the following atoms.
- **a** An oxygen atom with 8 protons, 8 neutrons and 8 electrons
- **b** A calcium atom with 20 protons, 20 neutrons and 20 electrons
- **c** A gold atom with 79 protons, 114 neutrons and 79 electrons
- **d** A uranium atom with 92 protons, 146 neutrons and 92 electrons

Analysing

12 **Compare** the five lightest atoms by copying and completing Table 7.3.2 below.

Evaluating

13 Early alchemists tried to change lead into gold.
- **a** **Assess** what would need to happen to change a lead atom into a gold atom.
- **b** **Propose** why the alchemists weren't successful.

14 **a** **Assess** whether you think it would be easier to remove an electron from the first electron shell or the second electron shell.
b **Justify** your answer.

Creating

15 **Construct** a diagram of the carbon atom $^{12}_{6}C$ showing the correct number of protons and neutrons in the nucleus and the correct number of electrons in each of its shells.

Inquiring

Investigate the life of a scientist who has had an important impact on the development of the atomic model. Outline their life and other scientific achievements. Some names to start with are: Dalton, Bohr, Rutherford, Thomson and Democritus.

Table 7.3.2

Atom	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons	Atomic symbol
Hydrogen	1			0	1	$^{1}_{1}H$
Helium		4		2		
Lithium	3			4		
Beryllium	4	9				
Boron						$^{11}_{5}B$

7.3 Practical activities

1 Indirect observation

Purpose
To determine the nature of objects through indirect observation.

Materials
- objects of various shapes and sizes such as ball bearings, pebbles, paperclips, erasers etc.
- opaque drawstring bag or similar

Procedure
1. Work in pairs. One person should fill the drawstring bag with 1–5 objects and give it to their partner.
2. The second person should use indirect observation to write down as much detail as possible about the marbles in the bag.
3. Open the bag to see how accurate the description was and what could not be observed.
4. Once this is complete, reverse roles and repeat.
5. Record your observations in the table like the one in the Results section.

Results
Copy and complete the following table.

Trial number	Properties observed by indirect observations	Properties observed by direct observation
1		
2		
3		

Discussion
1. **List** the properties of the objects that could be determined by indirect observation.
2. **List** the properties of the objects that could not be determined by indirect observation.
3. **Explain** how this problem is similar to when scientists try to determine the structure of an atom.

2 Coloured flames

Purpose
To observe the coloured light produced when electrons hop between shells.

SAFETY
Wooden icy-pole sticks should be dried, not burnt, in the flame. Remove the icy-pole stick from the flame at the first signs of charring.

Materials
- wooden icy-pole sticks soaked in distilled water and solutions of barium chloride, copper chloride, potassium chloride, sodium chloride and strontium chloride
- Bunsen burner, bench mat and matches
- tongs

Procedure
1. Use the tongs to hold each soaked icy-pole stick in a blue Bunsen burner flame as shown in Figure 7.3.8.
2. Record your observations in the table like the one in the Results section.

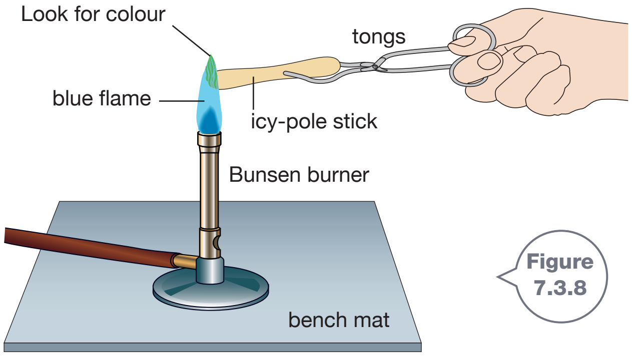


Figure 7.3.8

Coloured flames continued on next page

Coloured flames continued

Results

Copy and complete the following table.

Solution	Chemical formula	Elements present	Ratio	Observations
Distilled water	H_2O			
Barium chloride	$BaCl_2$			
Copper chloride	$CuCl_2$			
Potassium chloride	KCl			
Sodium chloride	$NaCl$			
Strontium chloride	$SrCl_2$			

Discussion

1 a **Identify** what elements are present in each compound and add them to your table.
  b **Identify** if the ratio of the elements in each compound is 1:1 or 1:2. Add your answer to the table.

2 Coloured light is produced whenever electrons hop between electron shells.
  a **State** whether you think the structure of the electron shells is the same or different for each element.
  b **Justify** your answer.

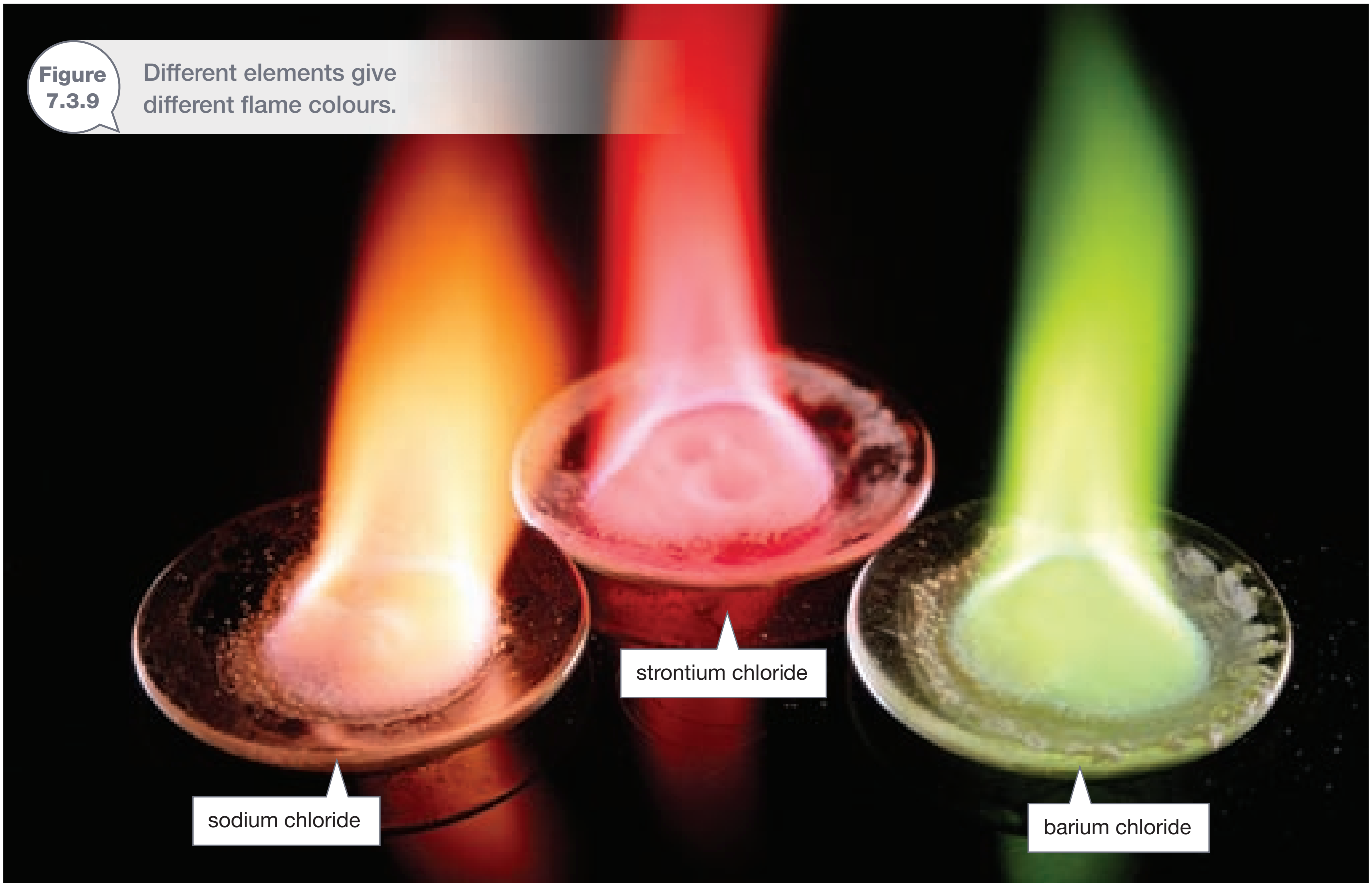


Figure 7.3.9 Different elements give different flame colours.

7 Chapter review

Remembering

1 **Name** the tiny particles that make up all matter.

2 **State** the two broad categories that elements can be divided into.

3 **List** the names of two elements and three compounds found in air.

4 **List** the names of the three subatomic particles that make up atoms.

5 **State** the number of electrons that can be held in the first, second, and third electron shells of an atom.

Understanding

6 **Explain** why it is impossible to have a monatomic compound.

7 **Describe** the structure of an atom in terms of the three subatomic particles.

8 **Explain** what an alloy is and why they are useful.

9 **Explain** why electrons stay around the nucleus of an atom.

Applying

10 **Identify** the name and number of each type of atom in the following molecules.

- a Ozone, O_3
- b Hydrofluoric acid, HF
- c Water, H_2O
- d Natural gas, CH_4
- e Petrol, C_8H_{18}
- f Deadly nightshade poison, $C_{45}H_{73}NO_{15}$

11 **Identify** the name of each of the following atoms and calculate the number of protons, neutrons and electrons each.

- a $^{12}_{6}C$
- b $^{16}_{8}O$
- c $^{35}_{17}Cl$
- d $^{65}_{30}Zn$

Analysing

12 **Compare** elements, compounds and mixtures by listing their similarities and differences.

13 **Classify** the following as elements, compounds or mixtures: lemonade, carbon (C), zinc (Zn), bronze, air, tap water, pure water (H_2O), carbon dioxide (CO_2), chlorine gas (Cl_2), sodium chloride (NaCl), shampoo, iron (Fe).

14 **Classify** the following as monatomic, molecular or crystal lattice: gold, helium, pure water, sodium chloride, carbon dioxide, copper, neon, nitrogen.

Evaluating

15 **Propose** a reason why neutrons might be needed to stabilise the protons in the nucleus.

Creating

16 **Construct** a three-part diagram showing how:

- two hydrogen atoms and one oxygen atom form a molecule of water
- molecules of water form a glass of water.

17 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

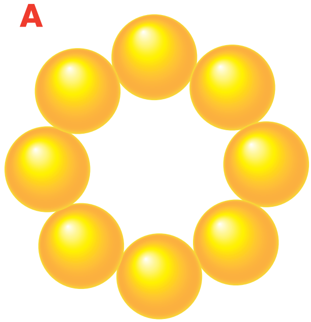
matter
atom
molecule
crystal lattice
element
compound
mixture
electron
proton
neutron

7.10

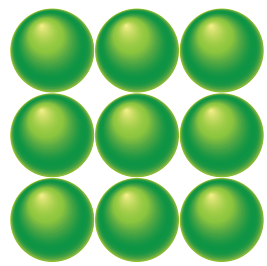
Thinking scientifically

Q1 Elements are substances made up of only one type of atom. Which one of the following does *not* represent an element?

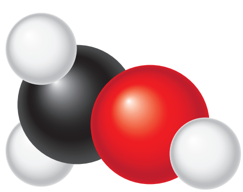
A



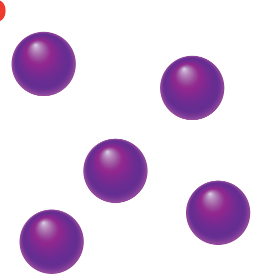
B



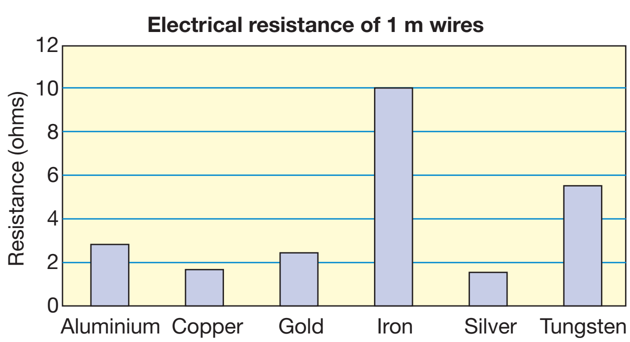
C



D



Q2 Alberto measures the electrical resistance of 1-metre wires made from different metals and plots the resistances in the graph below.

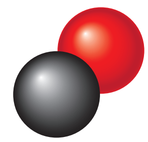


The three wires with the highest resistance in order from highest to lowest resistance are:

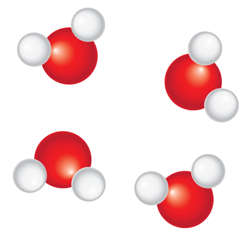
A silver, copper, gold
B iron, tungsten, aluminium
C iron, tungsten, gold
D aluminium, tungsten, iron.

Q3 Compounds are substances that are made up of more than one type of atom. Which one of the following diagrams does *not* represent a compound?

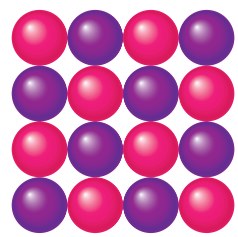
A



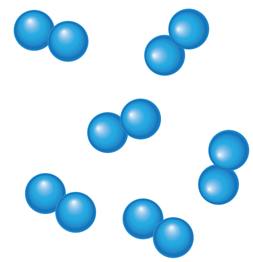
B



C

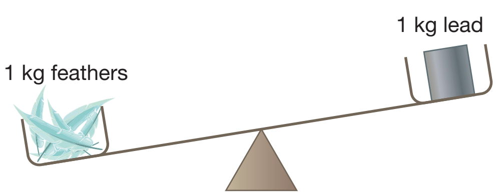


D

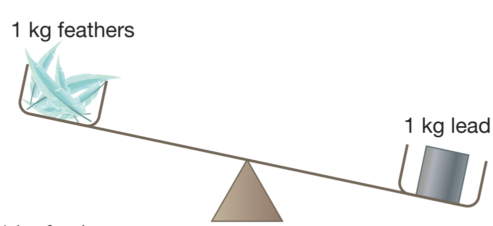


Q4 1 kilogram of feathers and 1 kilogram of lead were placed on a balance. Which of the following diagrams shows what would happen?

A



B



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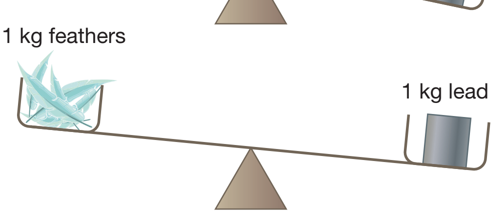
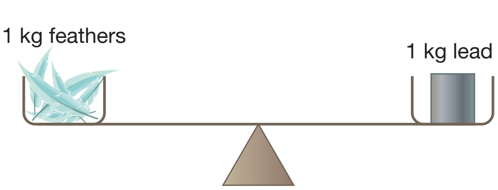


D

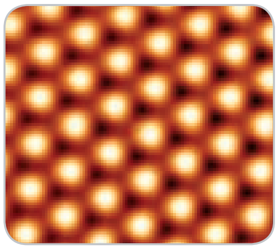


Glossary

Unit 7.1

Allotropes: different forms of the same element

Atoms: the smallest building blocks of matter



Atoms

Brittle: easily crumbled or shattered

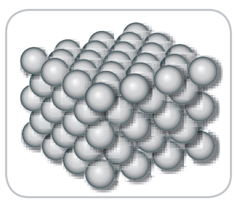
Ductile: able to be stretched to form a wire

Elements: substances made up of only one type of atom

Lattices: grid-like structures of atoms

Malleable: able to be hammered or bent into new shapes

Metals: substances that have a metallic shine, conduct heat and electricity, and can be hammered into sheets and drawn into wires



Metal

Molecules: clusters of atoms

Monatomic: elements that consist of single atoms

Non-metals: substances that are usually dull (not shiny), do not conduct heat and electricity and break or crumble

Non-metal

Periodic table: a table that shows all the known elements

Properties: the characteristics of a substance

Scanning tunnelling microscope (STM): a microscope that can see atoms by scanning a tip across the surface of crystals and sensing the atoms as bumps on the surface

Unit 7.2

Alloys: mixtures of a metal with other metals or non-metals

Alloy

Compounds: substances made of lattices or identical molecules with two or more types of atoms

Immiscible: liquids that do not mix

Miscible: liquids that can be mixed

Mixtures: any combination of two or more elements and compounds

Mixture

Unit 7.3

Atomic number: the number of protons in an atom

Electrons: the negatively charged subatomic particles that form a cloud around the nucleus of an atom

Electron shells: areas around the atom in which electrons spin

Mass number: the number of protons and neutrons in an atom

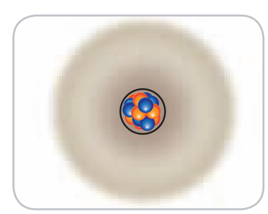
Matter: anything that has mass and takes up space

Model: a simplified representation

Model

Neutrons: the neutral subatomic particles that sit in the nucleus of an atom with the protons

Nucleus: the cluster of protons and neutrons at the centre of an atom



Nucleus

Protons: the positive subatomic particles that sit in the nucleus of an atom with the neutrons

Subatomic particles: the particles that make up atoms—protons, neutrons and electrons

Look who is using science

FOOD TECHNOLOGIST

My name is Robert Reeves. I'm a food technologist and I work in food science. Like many food technologists, I started my career as a chef. I moved into food science when I joined a food manufacturing company.

Food technologists ensure safe and tasty foods are available in supermarkets. Part of my job is product development. Here I combine my skills and tastebuds from my career as a chef with food science to create new foods. Studying food science allows you to understand what happens to foods when you blend them together and cook them in different ways.

Food technologists also look at ways of preserving food using methods such as freezing, canning and drying. I ensure that food is safe to eat not just on the day it is prepared, but for several days, weeks, months or, in the case of some canned food, years.

GEOLOGIST

My name is Courtney Brennan and I am a geologist. Geologists study rocks to understand how they form. I work for an energy company.

A day's work could see me using high-tech software on a computer to imagine what ancient landscapes looked like millions of years ago, or studying rock fragments under a microscope. All this work is used to predict where oil and gas may be found underground. I also plan how to best get these materials out of the ground while taking care of the environment at the same time. It's very exciting and often quite challenging work.

I studied geology and physics at university. So far my job has taken me across Australia and to Asia, Africa and the Americas, giving me a first-hand look at geology in the field. Geology has been really great for me because I learn something new every day and can be creative at the same time. If you like nature and understanding how things work, you might enjoy being a geologist too!

CHEMICAL ENGINEER

My name is Francisco Trujillo and I'm a chemical engineer.

Chemical engineering studies changes at a large (industrial) scale. Chemical engineering combines the sciences of physics, chemistry and biology with mathematics to change raw materials into other useful substances. Most of the objects that you see around you have been produced by chemical engineering processes. For example, paper and cardboard are produced from wood. The gasoline that runs your car is processed and transformed from petroleum.

Chemical engineering also deals with foods that are produced at an industrial scale, such as chocolate bars and potato chips. Chemical engineers are involved in improving the environment by designing processes to purify wastewater and transform waste material into a useful form again. Chemical engineering is a very exciting profession, one where you can apply science and creativity to transform the world around you.