

7 Elements, compounds and mixtures

There are millions of different substances in the world. Some, like water, occur naturally. Others, like paper and plastic, are made in factories. Some substances, like sugar and blood, are made by living things. All substances have one important thing in common: they are all made of the tiny building blocks of matter that we call atoms.

Think about substances

- How did plumbers get their name?
- Which metal can drive you crazy?
- Can water be split?
- Can you breathe nitrogen gas?
- What is most of an atom made up of?
- Just what is 'plastic' made from?
- Which precious gem is made from the same substance as charcoal and soot?

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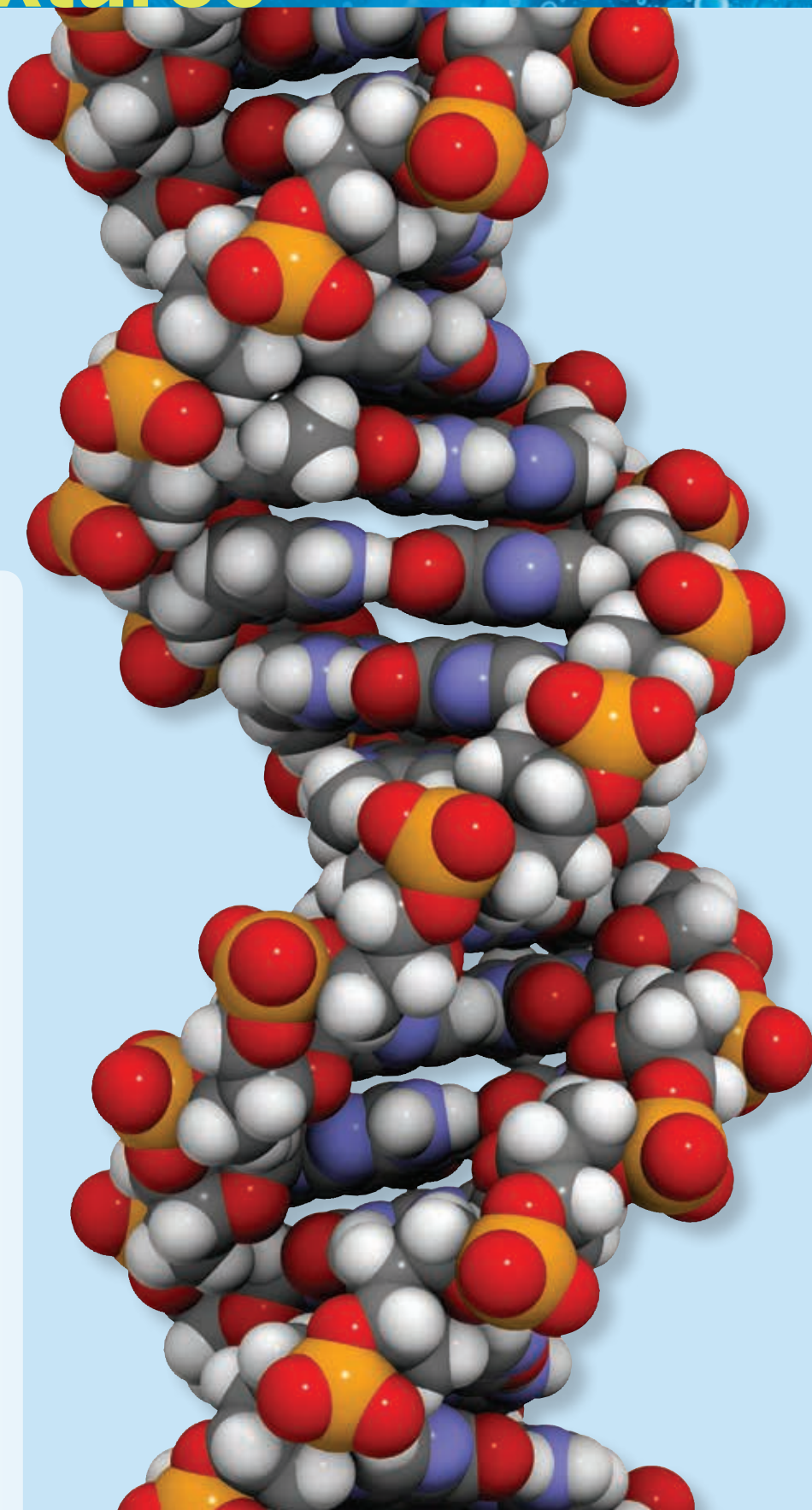
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YOUR QUEST

How small are the bits that matter?

INVESTIGATION 7.1

AIM To investigate division of matter

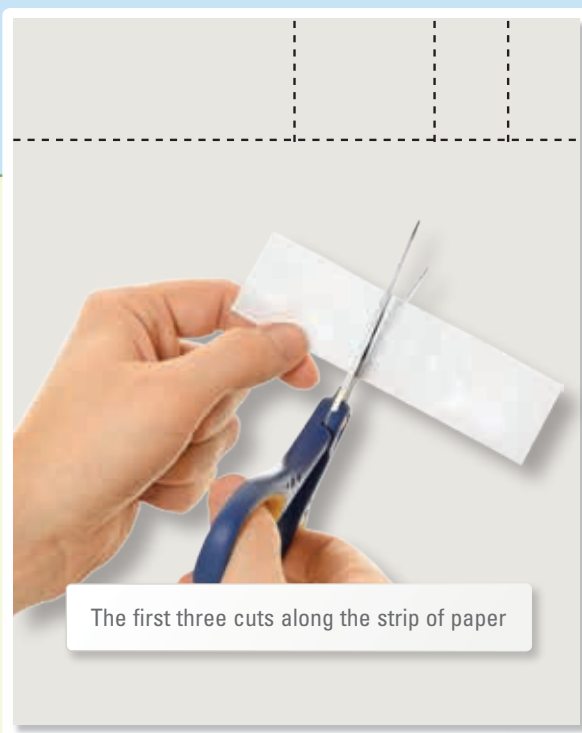
Materials:
 a strip of paper cut from A4 paper (about 30 cm long)
 pair of scissors
 ruler

METHOD

- ▶ Construct a table like the one on the right and record the length of the strip of paper.
- ▶ Cut the strip of paper in half. Put one half aside. Measure the length of the other half.
- ▶ Cut the measured half in half again. Again, put one half aside, and measure and record the length of the other half.
- ▶ Before you go any further, predict how many times you will be able to cut the strip in half.

How small are the bits?

Number of cuts	Length of strip (approximate)
0	30 cm
1	15 cm
2	7.5 cm (easy?)
3	
4	
5	
6	
7	
8	1 mm (you're doing well to get this far!)
9	
10	
12	
14	
18	1 micron (1 millionth of a metre, one thousandth of a millimetre)
22	
26	
31	The size of a single atom



- ▶ Continue this process until you can no longer cut the strip in half.

DISCUSS AND EXPLAIN

- 1 How many cuts were you able to make? Was it more or less than your prediction?
- 2 Estimate the number of cuts you would need to make before the strip would be too small to see.



What's inside?

How do you know what's inside a substance when you can't actually see inside it and it is so small that you can't see it even with the most powerful microscope? It seems impossible — but it can be done!

INVESTIGATION 7.2

AIM To experience the difficulties of describing an object that cannot be seen

Materials:
 sealed box 1, containing a mystery object
 sealed box 2, which is empty

METHOD AND RESULTS

- ▶ Together with a partner, and without opening the boxes, work out what is inside box 1.

- ▶ Ask your teacher for any equipment that you think might be helpful. But remember that you are not allowed to open the boxes!

- 1 Write down any information you can find out about the object.

DISCUSS AND EXPLAIN

- 2 What do you think is in box 1?
- 3 What are the reasons for your decision about what is in the box?
- 4 What was the reason for having box 2 in this activity?

It's elementary

About 1000 years ago, when kings and queens lived in castles and were defended by knights in shining armour, there lived the **alchemists**.

They chanted secret spells while they mixed magic potions in their flasks and melted metals in their furnaces. They tried to change ordinary metals into gold. They also tried to find a potion that would make humans live forever. They studied the movements of the stars and claimed to be able to see into the future. Kings and queens took the advice of the alchemists very seriously.

The alchemists never found the secrets they were looking for, but they did discover many things about substances around us. During the same period people who worked with materials also helped us to understand many everyday substances. Blacksmiths worked with metals to make stronger and lighter swords and armour, fabric dyers learned how to colour cloth, and potters decorated their work with glazes from the Earth. Without the



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Lavoisier and hydrogen

Watch a video from *The story of science* about the discovery of the elements.

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knowledge passed down by these people, the world as we know it would be very different!

Twelve important substances were discovered during these ancient times: gold, iron, silver, sulfur, carbon, lead, mercury, tin, arsenic, bismuth, antimony and copper. Alchemists discovered five of these.

Real science

In about the seventeenth century, people stopped thinking about magic and instead carried out **investigations** based on careful **observations**.

These new seekers of knowledge were called **scientists**. They discovered that the 12 substances could not be broken down into other substances. Scientists investigated many common everyday substances as well, including salt, air, rocks, water and even urine! They discovered that nearly

HOW ABOUT THAT!

In days gone by, substances containing the element mercury were used to make hats. In those days it was not known that mercury is a very poisonous element. Poisoning by mercury can affect your nervous system and your mind. This sometimes happened to hat makers who were exposed to mercury for a long time; hence the expression 'mad as a hatter'!

Lewis Carroll's Mad Hatter character in *Alice's Adventures in Wonderland* was mad because mercury was used in the making of hats.



everything around us could be broken down into other substances. They gave the name 'element' to the substances that could not be broken down into other substances. Between 1557 and 1925, another 76 **elements** were discovered. We now know that 92 elements exist naturally. In recent years scientists working in laboratories have been able to make at least another 24 artificial elements.

Warning! Danger!

Many elements are safe to handle. However, there are also many that are not. For example, the elements

sodium, potassium and mercury need special care and handling. Sodium and potassium are soft metals that can be cut with a knife. They both get very hot if they come into contact with water. They are stored under oil so that water in the atmosphere cannot reach them.

Elements are rare

Most of the substances around you are made up of two or more elements. You will not be able to find many of the 92 naturally occurring elements in their pure form. It is possible, however, to examine many of the elements in the school laboratory.

INVESTIGATION 7.3

Checking out appearances

AIM To examine and describe the properties of a selection of elements

Materials:

*samples of chemical elements
(e.g. carbon, sulfur, copper, iron,
aluminium, silicon)*

METHOD AND RESULTS

- 1 Copy the table below into your workbook or obtain a copy from your teacher.
 - ▶ Carefully examine each of the elements in the set (look for colour, appearance, hardness).
- 2 Complete the table by filling in the description and discussing with other students the substances that might include the element. One example is completed for you.

Elements	State	Description	In which substances might the element be present?
Hydrogen	Gas	Clear, colourless, explosive	Acids, water

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 What problems were the alchemists of medieval times trying to solve?
- 2 What is an element?
- 3 Which types of substances did blacksmiths help us to understand?
- 4 How did the scientists differ from the alchemists?
- 5 Why do sodium and potassium need to be stored under oil?
- 6 State one harmful effect of mercury on humans.

THINK

- 7 Is water an element? Give a reason for your answer.
- 8 Give one reason for displaying chemical safety symbols at the entrances of many buildings.

INVESTIGATE

- 9 Many years ago, balloons were filled with hydrogen so that they could float high in the sky. However, hydrogen is no longer used in balloons because it explodes too easily. At fairs, carnivals and in florists' shops, you can often buy colourful gas-filled balloons that fly high into the sky if you let them go. These balloons are filled with an element called helium. Find out who discovered helium, where it was discovered and when.
- 10 The element mercury was known to ancient people and was very important to the alchemists. Find out all you can about this liquid metal. What does its name mean? Where is it found? What has it been used for in the past? What is it used for now? What is the safety procedure if mercury is spilt?

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7.1 How big is an atom?

Elements: The inside story

About 2500 years ago a teacher named Democritus lived in ancient Greece. He walked around the gardens with his students, talking about all sorts of ideas.



Democritus suggested that everything in the world was made up of tiny particles so small that they couldn't be seen. He called these particles *atomos*, which means 'unable to be divided'. Other thinkers at the time disagreed with Democritus. It took about 2400 years for evidence of the existence of these **atoms** (as we now call them) to be found.

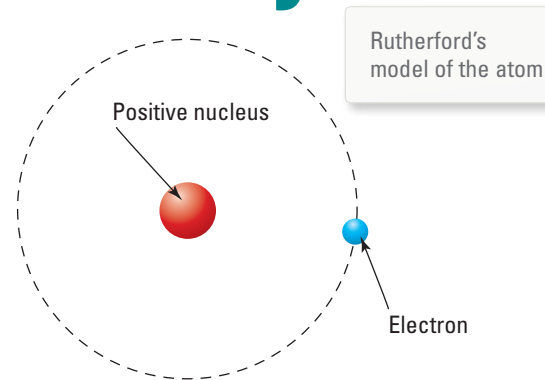
Atoms and elements

We now know that each element is made of its own particular kind of atom. Gold contains only gold atoms, oxygen contains only oxygen atoms, carbon contains only carbon atoms and so on. But what is it that makes atoms different from one another? To answer this question we need to know a little bit more about the atom.

For scientists, the atom was like the mystery box on page 227. Even though the atom couldn't be seen, scientists did experiments over many years and they thought carefully about the information they gathered.

Finding evidence for the existence of atoms was not possible until Galileo wrote about the need for controlled experiments and the importance of accurate observations and mathematical analysis in the 16th century. Galileo's 'scientific method', along with the development of more accurate weighing machines, was used by John Dalton in 1803 to show that matter was made up of atoms. He proposed that atoms could not be divided into smaller particles and that atoms of different elements had different masses.

For the next 100 years, scientists thought the atom was a solid sphere, but discoveries including radioactivity and electric current, and new technology such as the vacuum tube and Geiger counters, allowed scientists to 'peek' inside.

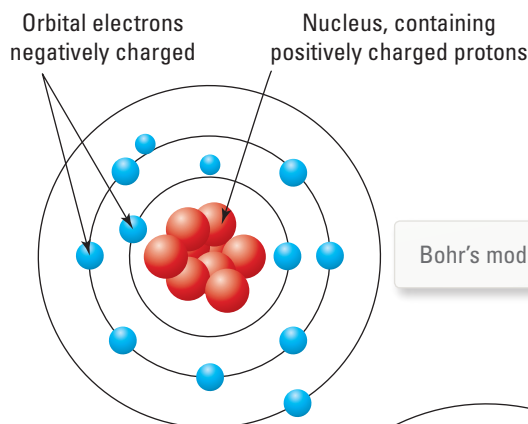


Rutherford's model of the atom

In 1911, New Zealander Sir Ernest Rutherford used some of the new discoveries and inventions to prove that atoms were not solid particles.

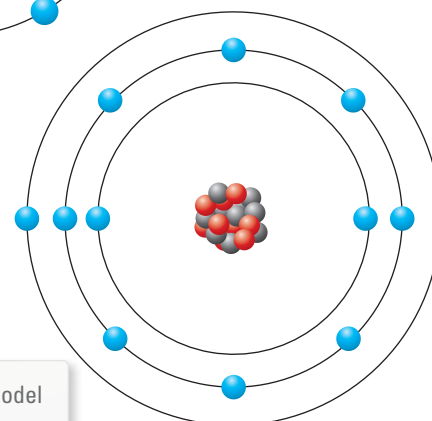
He fired extremely tiny particles at a very thin sheet of gold. Most of the particles went straight through. Only sometimes did they bounce off as if they had hit something solid. He concluded that the tiny particles could be getting through only if most of each atom consisted of empty space.

Niels Bohr proposed the next model of the atom. He suggested that the electrons changed their orbits around the positively charged nucleus and formed electron 'clouds'.



Bohr's model of the atom

In 1932 James Chadwick found another type of particle in the nucleus of the atom — the neutron.



The Chadwick-Bohr model

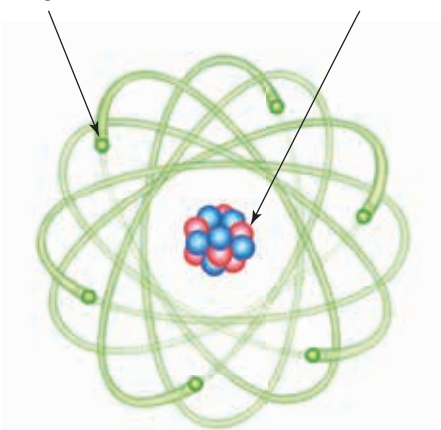
Inside the atom

It is now understood that all atoms are made up of small particles.

The amount of negative charge carried by each electron is the same as the amount of positive charge carried by each proton. In an atom, the number of protons is equal to the number of electrons, so there is no overall electric charge.

Moving very rapidly around the nucleus are **electrons**. Electrons are much smaller in size and weight than both protons and neutrons. Each electron carries a negative electric charge.

The particles in the centre of an atom are called **protons** and **neutrons**. Together they form the **nucleus**. Each proton carries a positive electric charge. Neutrons have no electric charge.



Helium atoms are lighter than all others except hydrogen atoms. This blimp is filled with helium.

Atomic numbers

The number of protons in an atom is called its **atomic number**. Each element has a different atomic number. The blimp above is filled with helium, which has an atomic number of 2. Helium atoms are lighter than all others except hydrogen atoms. All carbon atoms have six protons inside the nucleus, so the atomic number of carbon is 6. For each proton in the carbon atom it also has one electron, meaning a carbon atom has six electrons. Carbon atoms can have 6, 7 or 8 neutrons in their nuclei. The lightest element is hydrogen, which has one proton in each atom and an atomic number of 1. The heaviest natural element is uranium with 92 protons in each atom.

INVESTIGATION 7.4

Modelling an atom

AIM To model an atom and observe what makes up most of an atom

Materials:

1 hula hoop

rice grains

table-tennis ball

broom and dustpan

1 straw

cotton thread

sticky tape

METHOD AND RESULTS

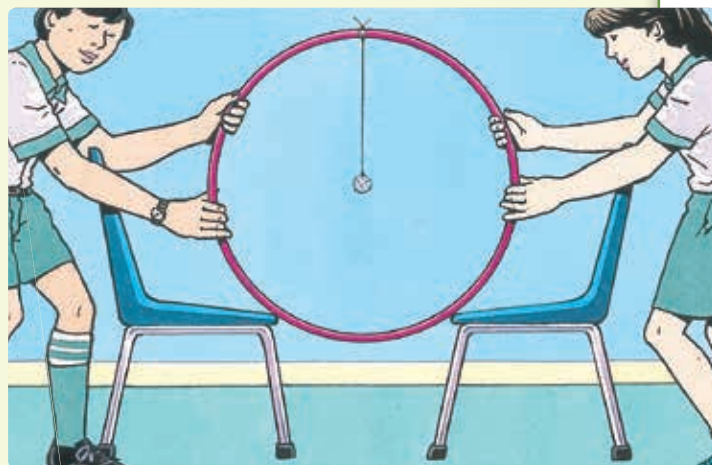
- ▶ Set up the equipment as shown in the diagram.
- ▶ From across the room, but within target distance, use the straw as a peashooter to fire rice grains at the table-tennis ball.
- ▶ Count how many grains go right through and how many hit the table-tennis ball. (*Note: Hits to the cotton thread do not count!*)
- ▶ Use the broom and dustpan to clean up the mess you've left on the floor.

CAUTION Ensure that the rice grains are not fired towards any person.

- 1 Construct a bar graph to display your results.
- 2 Construct a bar graph to show the class results.

DISCUSS AND EXPLAIN

- 3 Which part of the atom does the table-tennis ball represent in this model?
- 4 What does the hula hoop represent?



What's in a name?

As the early scientists discovered more and more elements, it became more important that they all agreed on what to call them. Each element was given a name and a **chemical symbol**.

The chemical symbols of most elements are very easy to understand. The symbol sometimes starts with the capital letter that is the first letter of the element's name. For some elements that is the complete symbol. For example:

O = oxygen, C = carbon,
N = nitrogen, H = hydrogen.

When there is more than one element starting with the same capital letter, a small letter is also used. For example:

Cl = chlorine, Ca = calcium,
Cr = chromium, Cu = copper.

If an element has a symbol that doesn't match its modern name, that's because the symbol is taken from the original Greek or Latin name.

For example:

Na = sodium (*natrium*)
Pb = lead (*plumbum*)
Hg = mercury (*hydro argyros*)
Ag = silver (*argentum*)
K = potassium (*kalium*)
Fe = iron (*ferrum*).

The names and symbols of some of the elements have some interesting origins.

- Einsteinium (Es) is named after the famous scientist Albert Einstein.
- Polonium (Po) was discovered by another famous scientist, Marie Curie. She named polonium after Poland, the country of her birth.
- Helium (He) was first discovered in the sun. It is named after Helios, the Greek god of the sun.
- Sodium (Na) was first called by the Latin name *natrium*.
- Lead (Pb) also used to have a Latin name, *plumbum*. That's where the word 'plumber' comes from. The ancient Romans, who spoke Latin, used lead metal to make their water pipes.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 What idea did Democritus have around 2500 years ago about what substances were made up of?
- 2 How many types of natural atoms are there?
- 3 Name the three parts of an atom and state the location of each part.
- 4 What does the atomic number of an element tell you?
- 5 Explain why electrons don't fly off their atoms.
- 6 In what way is an atom of carbon different from an atom of uranium?
- 7 What makes up most of every atom?
- 8 List the symbols of each of the following elements: hydrogen, carbon, oxygen, nitrogen, iron, calcium, copper, lead, mercury.

THINK

- 9 List some of the discoveries and inventions that scientists have used to learn more about the atom since the time of Democritus.
- 10 What type of electric charge does the nucleus of every atom have?
- 11 What is the atomic number of uranium?
- 12 To which element does the atom illustrated on page xxx belong?

- 13 Why do carbon atoms have six electrons?
- 14 Draw a diagram of an atom that has three protons and one neutron in its nucleus. How many electrons will it have?
- 15 Why is it important for scientists around the world to agree on the names and chemical symbols of the elements?

CREATE

- 16 Construct a model of an atom with three protons, three neutrons and three electrons. Use any appropriate materials. For example, you could use plastic balls, papier-mâché and wire, or perhaps a bowl of jelly with lollies in it.

INVESTIGATE

- 17 Find out the names, atomic numbers and uses of the elements with the following symbols. Construct a table in which to display your findings.
Sn Au Cu N Ne Sr Ca
- 18 Research and report on what nanotechnology is and what connection it has with atoms.

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- 19 Play the **It's elementary! revelation game** in your eBookPLUS and test your ability to identify the symbols of common elements. **int-0229**

Compounding the situation

There are millions and millions of different substances in the world. They include the paper of this book, the ink in the print, the air in the room, the glass in the windows, the wool of your jumper, the cotton and polyester in your shirt or dress, the wood of your desk, the paint on the walls, the plastic of your pen, the hair on your head, the water in the taps and the metal of the chair legs. The list could go on and on.

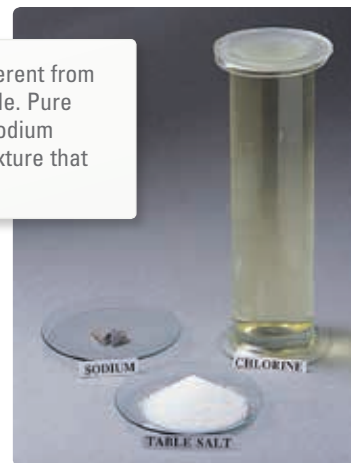
All substances can be placed into one of three groups: elements, compounds or mixtures.

- **Elements** are substances that contain only one type of atom. Very few substances exist as elements. Most substances around us are either compounds or mixtures.
- **Compounds** are usually very different from the elements of which they are made. In compounds, the atoms of one element are **bonded** very tightly to the atoms of another element or elements. The elements that make up a compound are completely different substances from the compound. For example, pure salt (sodium chloride) is a compound made up of the elements sodium (a silvery metal) and chlorine (a green, poisonous gas).
- **Mixtures** can be made up of two or more elements, two or more compounds or a combination of elements and compounds. The substances that make up mixtures can usually be easily separated from each other. When the parts of a mixture are separated, no new substances are formed. Fizzy soft drink is a good example of a mixture. It contains water, gas, sugar and flavours. If you shake the soft drink, the gas bubbles separate from the water and go into the air. You still have the water in the bottle and the gas in the air; they are just not mixed together any more. The parts of the mixture can be separated quite easily. The gas escapes when the lid of the container is opened, and the water can be separated by evaporation, leaving behind sugar and some other substances.

Some common substances

Substance	Type	Composed of:	Scientific name
Gold	Element	Gold	Gold
Diamond	Element	Carbon	Carbon
Water	Compound	Hydrogen and oxygen	Dihydrogen oxide
Pure salt	Compound	Sodium and chlorine	Sodium chloride
Brass	Mixture	Copper and zinc	Brass
Soft drink	Mixture	Water, sugar, carbon dioxide and other compounds	
Sea water	Mixture	Water, sodium chloride and other compounds	

A compound is completely different from the elements of which it is made. Pure salt consists of the elements sodium and chlorine. Table salt is a mixture that consists mainly of pure salt.



When the atoms of different elements bond together, a compound is formed. When heated together, the elements iron and sulfur form a new compound called iron sulfide. Iron sulfide has the formula FeS. Every compound has a formula comprising the symbols of the elements that make it up. Unlike mixtures, the elements within a compound cannot easily be separated from each other.

Elements can be separated from compounds in several ways. These include:

- passing electricity through a compound
- burning the compound
- mixing the compound with other chemicals.

Each of these methods involves a chemical reaction in which completely different substances are formed.

WHAT DOES IT MEAN?

The word *compound* comes from the Latin word *componere*, meaning 'to put together'.

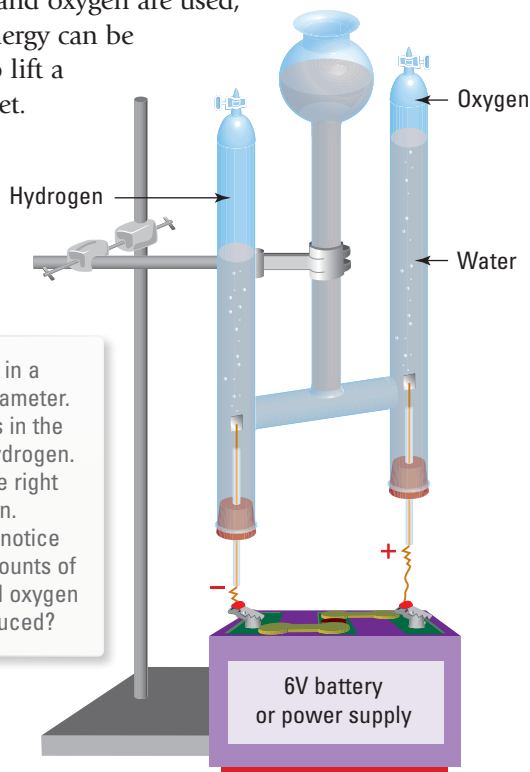
Splitting water

We are surrounded by water. It is in our taps, in our bodies, in the rivers, in the sea, in the air and it comes down as rain. We wash in it, cook with it and drink it. We cannot live without water. Water is not an element — it can be broken down into simpler substances. The illustration below shows an apparatus called a Hofmann voltameter. Water is placed in the voltameter, which is connected to a battery. The electricity splits the water into the elements of which it is made: **hydrogen** and **oxygen**.

Hydrogen and oxygen are both elements. They are both gases, and they look the same; they have no colour and no smell. Oxygen is necessary for substances to burn — even hydrogen does not burn without it. Hydrogen is a much less dense gas than oxygen. This means that a balloon filled with hydrogen will float up very high, but one filled with oxygen will not.

The element hydrogen is present in almost all acids. By placing a piece of metal in an acid, the hydrogen is forced out. The hydrogen can be collected and tested with a flame.

The element oxygen is present in water, air, rocks and even hair bleach. Oxygen is the gas that all living things need to stay alive. It is also necessary for all substances to burn. When hydrogen gas is burned, it combines with oxygen in the air to form water. This releases a lot of energy. If large amounts of hydrogen and oxygen are used, enough energy can be released to lift a space rocket.



Water is split in a Hofmann voltameter. The clear gas in the left tube is hydrogen. The gas in the right tube is oxygen. What do you notice about the amounts of hydrogen and oxygen that are produced?

INVESTIGATION 7.6

Making a compound from its elements

AIM To use a chemical reaction to make a compound from its elements

Materials:

4–5 cm strip of clean, shiny magnesium ribbon. It can be coiled to fit in the crucible.
crucible with lid
pipeclay triangle, tongs and safety glasses
Bunsen burner, heatproof mat and matches

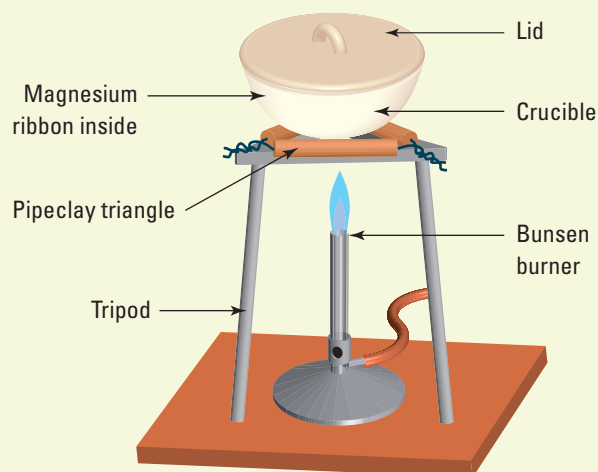
METHOD AND RESULTS

- ▶ Examine the piece of magnesium and note its appearance before placing it in the crucible and covering it with the lid.
- ▶ Put the crucible on the pipeclay triangle as shown in the diagram below.
- ▶ Heat the crucible with a strong blue flame, monitoring the reaction by occasionally lifting the lid a little with tongs.
- ▶ When all the magnesium ribbon has been changed, turn off the flame and leave the crucible on the tripod to cool.

- 1 Describe the substance in the crucible.

DISCUSS AND EXPLAIN

- 2 Is magnesium an element or a compound? Give a reason for your decision.
- 3 Magnesium is one of the reactants in this experiment. What is the other reactant?
- 4 Is the substance remaining in the crucible an element or a compound? What is its name?
- 5 What is the evidence that a new substance has been made?
- 6 Apart from observing whether the reaction is complete, give another reason for lifting the lid of the crucible a little with tongs during the burning.



INVESTIGATION 7.7

Let's collect an element

AIM To observe a chemical reaction between a metal and an acid

Materials:

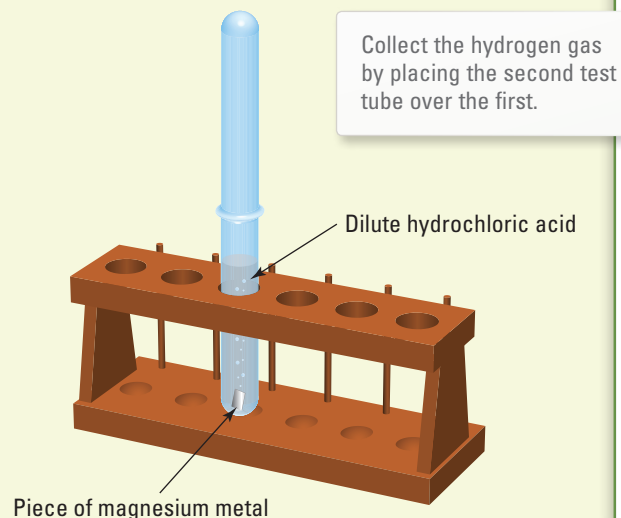
safety glasses	2 test tubes and test-tube rack
matches	dilute hydrochloric acid
measuring cylinder	magnesium metal

METHOD AND RESULTS

- ▶ Measure 10 mL of hydrochloric acid and pour it into the test tube.
- ▶ Add a piece of magnesium and place the second test tube on top of the first as shown in the diagram. Carefully observe what happens.
- ▶ After one minute, take the second test tube off the first. While it is still inverted, immediately light the gas in the second test tube with a match.

- 1 Describe what happened in the test tube containing the metal and the acid.

- 2 What does hydrogen gas look like?
- 3 What happened when you lit the gas?
- 4 Look closely at the second test tube. Describe what you see inside it.



UNDERSTANDING AND INQUIRING

REMEMBER

- 1 How do compounds differ from elements?
- 2 What are the important differences between a mixture and a compound?
- 3 Fizzy soft drink is a mixture of several compounds. List three of the compounds and suggest how each of them could be separated from the mixture.
- 4 What happens when atoms are bonded together?
- 5 Which elements are bonded together to form table salt?
- 6 List three ways in which elements can be separated from their compounds.

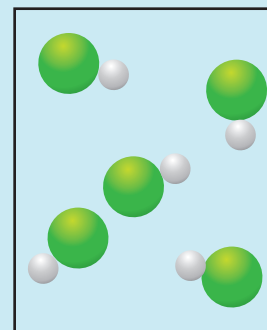
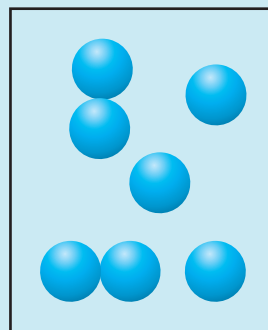
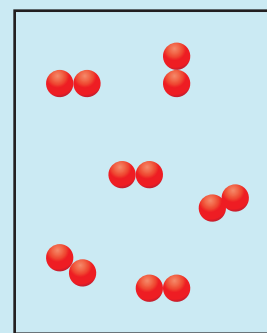
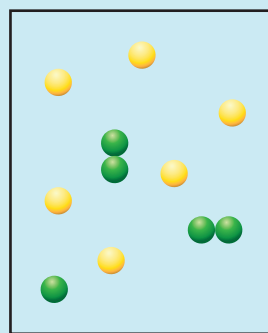
THINK

- 7 How do you know that water is not simply a mixture of hydrogen and oxygen?
- 8 Magnesium oxide is a compound of magnesium and oxygen. How do you know that it is a completely different substance from each of the two elements it is made up of?

INVESTIGATE

- 9 Joseph Priestley was one of the first scientists to discover the element oxygen. He also discovered many compounds that are gases. Research and report on the life of Joseph Priestley.

- 10 Which of the diagrams below represent:
 - (a) elements
 - (b) compounds
 - (c) mixtures?



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work sheet

7.3 Pure substances and mixtures

Grouping elements

It is often convenient to group objects that have features in common.

Shops provide a good example of this. In a department store, the goods are grouped so that you know where to buy them. You go to the clothing section for a new pair of jeans, to the jewellery section for a new watch and to the food section for a packet of potato chips.

Scientists also organise objects into groups. Biologists organise living things into groups. Animals with backbones are divided into mammals, birds, reptiles, amphibians and fish. Geologists organise rocks into groups. The elements that make up all substances can also be organised into groups.

Metals and non-metals

Scientists have divided the elements into two main groups: the **metals** and the **non-metals**.

Metals

The metals have several features in common:

- They are solid at room temperature, except for mercury, which is a liquid.
- They can be polished to produce a high shine or lustre.
- They are good conductors of electricity and heat.
- They can all be beaten or bent into a variety of shapes. We say they are malleable.
- They can be made into a wire. We say they are ductile.
- They usually melt at high temperatures. Mercury, which melts at -40°C , is one exception.

Non-metals

Only 22 of the elements are non-metals. At room temperature, 11 of them are gases, 10 are solid and 1 is liquid. The solid non-metals have most of the following features in common:

- They cannot be polished to give a shine like metals; they are usually dull or glassy.
- They are brittle, which means they shatter when they are hit.
- They cannot be bent into shape.
- They are usually poor conductors of electricity and heat.
- They usually melt at low temperatures.

Metalloids

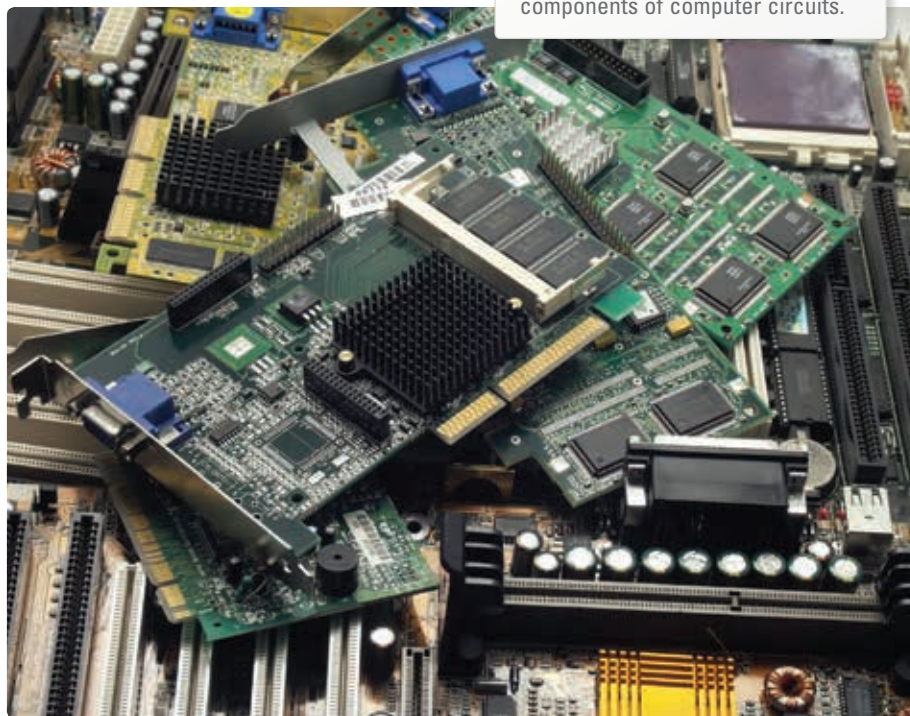
Some of the elements in the non-metal group look like metals. One example is silicon. While it can be polished like a metal, silicon is a poor conductor of heat and electricity, and cannot be bent or made into wire. Those



Common examples of non-metals are sulfur, carbon and oxygen.

elements that have features of both metals and non-metals are called **metalloids**. There are eight metalloids altogether: boron, silicon, arsenic, germanium, antimony, polonium, astatine and tellurium.

Metalloids are important materials often used in electronic components of computer circuits.



INVESTIGATION 7.5

Looking for similarities

AIM To describe the characteristics of a variety of elements

Materials:

- safety glasses
- samples of sulfur, zinc, tin, carbon, silicon, copper
- steel wool or very fine sandpaper
- battery or power pack
- wires with alligator clips
- light globe

METHOD AND RESULTS

- 1 Make a copy of the table on the right and use it to record your observations.
 - Rub each of the elements with the fine sandpaper and observe whether they are shiny or dull.
 - Try to bend the element.
 - Connect the circuit as shown in the diagram to determine whether electricity passes through each of the elements.
- 2 Which of the six elements have a shiny surface when polished?
- 3 Which of the six elements do not have a shiny surface when polished?
- 4 Which of the six elements can be bent?
- 5 Which of the six elements cannot be bent?
- 6 Which of the six elements allow electricity to pass through?
- 7 Which of the six elements do not conduct electricity?

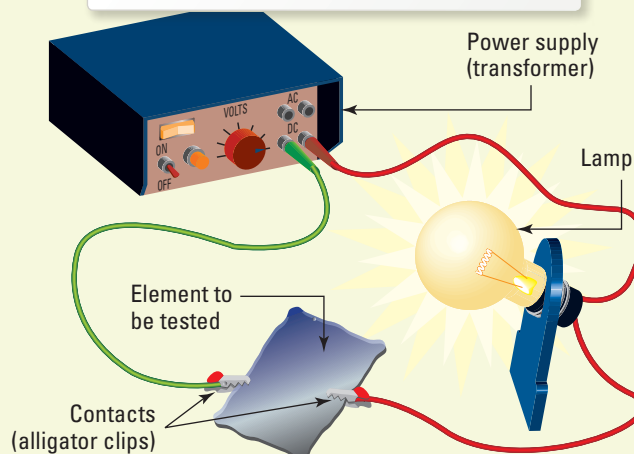
DISCUSS AND EXPLAIN

- 8 Attempt to divide the elements into two groups based on your observations. Suggest names for these groups.
- 9 Which of the six elements tested does not seem to fit into either of these two groups?

Characteristics of some elements

Element	Shiny or dull?	Does it bend?	Does it conduct electricity?
Sulfur			
Zinc			
Tin			
Carbon			
Silicon			
Copper			

Connect your element sample into this circuit.



UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Outline four features that metals have in common.
- 2 Outline four features that non-metals have in common.
- 3 What is a metalloid? List some examples.
- 4 Which metal is liquid at room temperature?
- 5 What does 'metallic lustre' mean?

THINK

- 6 While all metals have similar characteristics, there are also differences between them. List three ways in which metals can differ from each other.
- 7 Silicon is used in the 'chips' of computer circuits, but it is never used in the connecting wires of electric circuits. Why not?

IMAGINE

- 8 Imagine that you are a scientist who has discovered what appears to be a new element. It is golden in colour and very shiny. What experiments would you do to test if it was a metal or non-metal? What results would you expect to get if it was a metal?

INVESTIGATE

- 9 Polonium is a metal discovered by Marie Curie. She also discovered another metal. Find out its name and the important role it played in medicine.

eBook plus

work sheet

7.2 Metals and non-metals

Patterns, order and organisation: Chemical name tags

As more and more elements were being discovered, the early scientists began to find that some of them had things in common.

Because some elements had things in common, scientists decided to organise them into groups. It took a long time and a lot of experimenting to work out the groups. A Russian scientist called Dmitri Mendeleev finally worked out a system for grouping the elements. His system is called the **periodic table** and a modern version is used by scientists today.

	Alkali metals ↓ Group 1	Alkaline earth metals ↓ Group 2	Transition metals							
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	
Period 2	3 Lithium Li 6.94	4 Beryllium Be 9.02							Key 1 ← Atomic number Hydrogen H ← Name 1.008 ← Symbol 2 ← Relative atomic mass Helium He 4.003	
Period 3	11 Sodium Na 22.99	12 Magnesium Mg 24.31								
Period 4	19 Potassium K 39.10	20 Calcium Ca 40.08	21 Scandium Sc 44.96	22 Titanium Ti 47.87	23 Vanadium V 50.94	24 Chromium Cr 52.00	25 Manganese Mn 54.94	26 Iron Fe 55.85	27 Cobalt Co 58.93	
Period 5	37 Rubidium Rb 85.47	38 Strontium Sr 87.62	39 Yttrium Y 88.91	40 Zirconium Zr 91.22	41 Niobium Nb 92.91	42 Molybdenum Mo 95.96	43 Technetium Tc 98.91	44 Ruthenium Ru 101.1	45 Rhodium Rh 102.91	
Period 6	55 Caesium Cs 132.9	56 Barium Ba 137.3	57–71 Lanthanides	72 Hafnium Hf 178.5	73 Tantalum Ta 180.9	74 Tungsten W 183.8	75 Rhenium Re 186.2	76 Osmium Os 190.2	77 Iridium Ir 192.22	
Period 7	87 Francium Fr	88 Radium Ra	89–103 Actinides	104 Rutherfordium Rf	105 Dubnium Db	106 Seaborgium Sg	107 Bohrium Bh	108 Hassium Hs	109 Meitnerium Mt	

The periodic table. Elements 1–92 all occur naturally. Those from element 93 onwards have been made in laboratories and are all radioactive. Those from element 112 onwards are not shown in this table.

Lanthanides

57 Lanthanum La 138.91	58 Cerium Ce 140.122	59 Praseodymium Pr 140.91	60 Neodymium Nd 144.24	61 Promethium Pm (145)	62 Samarium Sm 150.4	63 Europium Eu 151.96
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Actinides

89 Actinium Ac (227)	90 Thorium Th 232.04	91 Protactinium Pa 231.04	92 Uranium U 238.03	93 Neptunium Np 237.05	94 Plutonium Pu (244)	95 Americium Am (243)
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Looking for similarities

A vertical column on the periodic table is called a **group**. Elements in the same group on the periodic table always have some features in common. Sometimes these common features are easy to observe, but some of the similarities are not so obvious. For example, neon and argon are gases that do not change when mixed with other elements except under extreme circumstances. They are said to be **inert**. These two gases are found in the last group of the periodic table along with three other inert gases. The group containing the inert gases is called the **noble gas** group.

The group number corresponds to the number of electrons in the outer shell.

The period number refers to the number of the outermost shell containing electrons.

New radioactive elements are still being produced — the most recent one at the time of publication was element 118.

Group 10	Group 11	Group 12
28 Nickel Ni 58.69	29 Copper Cu 63.55	30 Zinc Zn 65.38
46 Palladium Pd 106.4	47 Silver Ag 107.9	48 Cadmium Cd 112.4
78 Platinum Pt 195.1	79 Gold Au 197.0	80 Mercury Hg 200.6
110 Darmstadtium Ds	111 Roentgenium Rg	112 Copernicium Cn

Group 13	Group 14	Group 15	Group 16	Group 17 ↓ Halogens	Group 18 ↓ Noble gases
5 Boron B 10.81	6 Carbon C 12.01	7 Nitrogen N 14.01	8 Oxygen O 16.00	9 Fluorine F 19.00	10 Neon Ne 20.18
13 Aluminium Al 26.98	14 Silicon Si 28.09	15 Phosphorus P 30.97	16 Sulfur S 32.06	17 Chlorine Cl 35.45	18 Argon Ar 39.95
31 Gallium Ga 69.72	32 Germanium Ge 72.63	33 Arsenic As 74.92	34 Selenium Se 78.96	35 Bromine Br 79.90	36 Krypton Kr 83.80
49 Indium In 114.8	50 Tin Sn 118.7	51 Antimony Sb 121.8	52 Tellurium Te 127.8	53 Iodine I 126.9	54 Xenon Xe 131.3
81 Thallium Tl 204.4	82 Lead Pb 207.2	83 Bismuth Bi 209.0	84 Polonium Po (209)	85 Astatine At (210)	86 Radon Rn (222)

Metals ← → Non-metals

64 Gadolinium Gd 157.25	65 Terbium Tb 158.93	66 Dysprosium Dy 162.50	67 Holmium Ho 164.93	68 Erbium Er 167.26	69 Thulium Tm 168.93	70 Ytterbium Yb 173.04	71 Lutetium Lu 174.97
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96 Curium Cm (247)	97 Berkelium Bk (247)	98 Californium Cf (251)	99 Einsteinium Es (254)	100 Fermium Fm (257)	101 Mendelevium Md (258)	102 Nobelium No (255)	103 Lawrencium Lr (256)
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UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Obtain a copy of the periodic table from your teacher. Colour in the elements that you have already seen in the laboratory.
- 2 Write down the symbols for the following elements: hydrogen, carbon, oxygen, nitrogen, iron, tin, calcium, sulfur, copper and krypton.
- 3 What is similar about all of the gases in the noble gas group of the periodic table?

CREATE

- 4 Make up a 'Guess the element' card game, finding out and using information about at least twenty of the elements.

Making molecules

The naturally occurring elements are the building blocks of everything in our world. The atoms of various elements can be joined in a wide variety of ways to produce many compounds. Elements and compounds can be combined in many ways to make countless mixtures.

Atoms can join, or bond, in many different ways. In some substances, atoms are joined in groups called **molecules**. For example, in oxygen gas, oxygen atoms are joined in groups of two. In the

compound carbon dioxide, one carbon and two oxygen atoms are joined in every molecule. Atoms can join to form small or large molecules of many different shapes.

Some compounds are not made up of molecules. Instead the atoms bond by lining up one after the other. Sodium bonds to chlorine, which bonds to sodium and so on. Common table salt is an example of a substance that is bonded in this way.

INVESTIGATION 7.8

Mix 'n' match

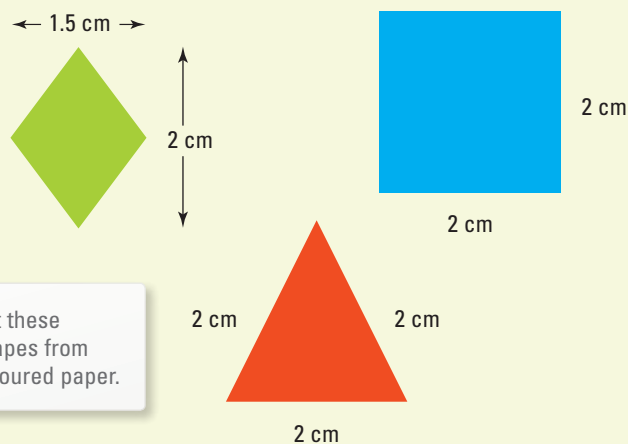
AIM To model the molecules of a variety of compounds

Materials:

green, red and blue sheets of paper
scissors pencil ruler
1 large sheet of cartridge paper

METHOD AND RESULTS

- ▶ Cut out 15 diamonds, each 2 cm long and 1.5 cm wide, from the green sheet of paper.
- ▶ Cut out 30 equilateral triangles, with each side 2 cm, from the red sheet of paper.
- ▶ Cut out 15 squares, with each side 2 cm, from the blue sheet of paper.



Cut these shapes from coloured paper.

- ▶ Imagine that different types of atoms are represented by particular shapes:
 - a blue square = carbon
 - a green diamond = oxygen
 - a red triangle = hydrogen
 and that, by placing them side by side on the sheet of paper, you are joining them.

- ▶ Place two green diamonds next to each other on the sheet. This represents the oxygen molecule, as shown in the diagram below.



A green diamond represents an atom of oxygen. Together, two diamonds represent a molecule of oxygen.

- ▶ Place one blue square on the sheet between two green diamonds. This represents the compound carbon dioxide. Label it with its name and symbol.
- ▶ Represent and label the following substances:
 - water, which contains 1 oxygen and 2 hydrogen atoms
 - methane (natural gas), which contains 1 carbon and 4 hydrogen atoms
 - benzene (in petrol), which contains 6 carbon and 6 hydrogen atoms
 - glucose (sugar), which contains 6 carbon, 12 hydrogen and 6 oxygen atoms
 - hydrogen peroxide (found in hair bleach), which contains 2 oxygen atoms and 2 hydrogen atoms.

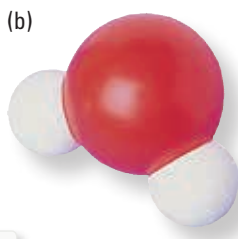
DISCUSS AND EXPLAIN

- 1 Which of these compounds contain only hydrogen and carbon atoms?
- 2 In what ways are these two substances different from each other?
- 3 Which of the compounds contain only oxygen and hydrogen? Do these compounds have the same characteristics?
- 4 Think about the appearance of the compound sugar. How does it differ in appearance from the elements from which it is made?

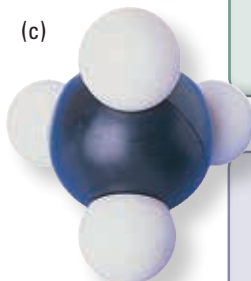


(a)

Models representing the molecules of the compounds (a) carbon dioxide, (b) water and (c) methane. The black balls represent carbon; the red, oxygen; and the white, hydrogen.



(b)



(c)

plastic 'glass', polystyrene foam for packaging and cups, note money, cases for electronic appliances such as computers and televisions, clothing, glues, shopping bags, sports equipment and even tea bags!

WHAT DOES IT MEAN?

The word *polymer* comes from the Greek word *polymers*, meaning 'of many ports'.

Compounds of today and tomorrow

Polymer is the name given to a compound made of molecules that are long chains of atoms. Most polymers are made up of chains containing carbon atoms. **Plastics** are synthetic polymers, while cotton and rubber are examples of natural polymers. Although scientists first developed polymers in laboratories in the 1800s, it was not until after World War II that most modern polymers were invented. Modern polymers are used in food wrapping, paint,

HOW ABOUT THAT!

- Nitrogen is an element. It is a clear, colourless gas made up of molecules. Each molecule is made up of a pair of atoms. Nitrogen makes up 80 per cent of the atmosphere, which means that four-fifths of each breath you take is nitrogen. Our bodies cannot use this nitrogen so we breathe it straight out again! The gases oxygen, hydrogen and chlorine also exist as molecules made up of pairs of atoms.
- Gold is the only metal element found in large amounts in its pure form, rather than bonded in compounds with other elements.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 What is a molecule? Name two compounds that are made up of molecules.
- 2 Are all compounds made up of molecules? Explain.
- 3 Name four elements that are made up of molecules.
- 4 What are polymers?

THINK

- 5 What is the difference between an atom and a molecule?
- 6 Copy and complete the table below. Use the formula of each compound to work out how many elements are present and which ones they are. (The formula of a

compound not only tells you which elements are present, but also indicates the ratio of atoms of the different elements. For example, in the compound NH_3 there are three hydrogen atoms for each nitrogen atom.)

INVESTIGATE

- 7 Australia has led the way in the production of polymer banknotes. Find out all you can about how these notes are made.
- 8 Complete the **Making molecules** interactivity in your eBookPLUS by creating the correct model of the molecule as each chemical formula appears. **int-0228**

eBookplus



7.4 The periodic table — atomic structure

Compound	Formula	Number of elements	Names of elements
Copper sulfate	CuSO_4	3	Copper, sulfur, oxygen
Zinc sulfide	ZnS		
Ammonia	NH_3		
Sulfuric acid	H_2SO_4		
Hydrochloric acid	HCl		
Table salt	NaCl		

Carbon: It's everywhere

That's carbon?

Carbon is a most amazing element. It is found naturally in three different forms. One form is diamond, another is graphite (the 'lead' in lead pencils), and the third is called amorphous carbon (coal, charcoal and soot).

Diamond is the hardest substance known and is used to make drill tips and cutting tools. The three forms are different from each other because the carbon atoms are joined in different ways.

Carbon is found combined with other elements in a huge range of compounds. No other element forms as many different types of compounds as carbon. Carbon is found in everything from the skin of an elephant to paint on the walls!

The chemistry of life

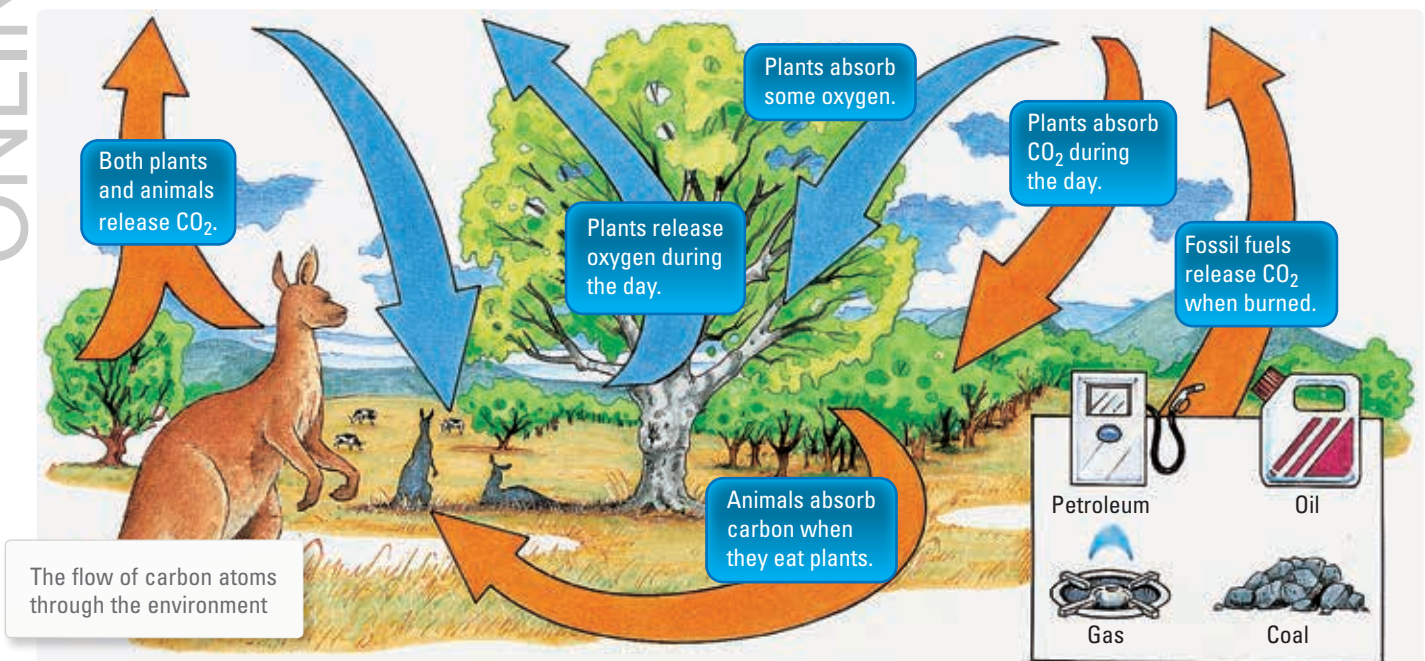
All living things are made up of compounds including proteins, fats and carbohydrates. The main element in these compounds is carbon. Carbon is not found only in living things, but also in the air in carbon dioxide and under the sea in limestone. The carbon atoms in carbon dioxide were once carbon atoms in living things. The carbon atoms in living things will eventually become carbon atoms in the air or carbon atoms in limestone under the sea. The illustration below shows how nature constantly recycles carbon atoms.

Plants take in carbon dioxide through their leaves and, in a process known as **photosynthesis**, use the carbon

dioxide and water to make sugar. Sugar is a compound made up of carbon, hydrogen and oxygen atoms. Plants use the sugar to make other substances and for energy to grow. Animals eat plants or plant-eating animals. The carbon atoms then become part of the animals' bodies.

Carbon atoms in the bodies of living things return to the air in several ways: **respiration**, **decomposition** and **burning**.

- Respiration is a process that occurs in the cells of every living thing, from a microscopic water plant to a humpback whale. Respiration releases energy and produces carbon dioxide. The carbon dioxide released by the cells in your body is taken by your blood to your lungs. The carbon dioxide that you breathe out contains carbon atoms that were once part of your body.
- Decomposition is what happens when plant or animal material breaks down, such as in a compost heap or after something is buried. Microscopic living creatures called decomposers absorb some of the substances in the dead material and release carbon dioxide to the air by respiration.
- When substances containing carbon are burned, carbon dioxide is released. Coal, natural gas and oil are all **fuels** formed from living things, and contain carbon atoms. Fuels are **combustible**; that is, they are easily ignited. When these fuels are burned in homes, cars, factories and power stations, carbon dioxide is released into the air. Bushfires also release carbon dioxide back to the air.



INVESTIGATION 7.9

Looking for carbon

AIM To test for the presence of carbon in a range of substances

Materials:

- safety glasses
- Bunsen burner, heatproof mat and matches
- metal tongs
- small samples of substances to investigate: woollen cloth, cottonwool, sugar cube, wood, bread, peanut, steel wool, glass, paper, aluminium foil

METHOD AND RESULTS

Your task in this investigation is to find out whether the element carbon is present in some common substances. If carbon is in a substance, the substance turns black when it is burnt. Your teacher may allow you to burn some plastics in the fume hood, including artificial fabrics such as nylon and rayon.

CAUTION Burning plastics produce poisonous fumes. A fume cupboard must be used.

- ▶ Hold a small piece of the substance you are going to test in the metal tongs.
- ▶ Put the substance in the blue flame of the Bunsen burner.
- ▶ When the substance catches alight, take it out of the flame and, keeping it above the heatproof mat, allow it to burn slowly. Does it turn black?

- 1 Draw up a table like the one below and record your observations.

DISCUSS AND EXPLAIN

- 1 In which of the substances tested is carbon present?
- 2 Can you be sure that, if the substance went black, carbon was present? Give a reason for your answer.
- 3 Can you be sure, if a substance didn't go black, that it didn't contain carbon? Give a reason for your answer.

Substance	Observations	Is carbon present?
Wood		
Cotton wool		

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 List and describe the three different forms of the element carbon.
- 2 How do plants get the carbon that they need to make sugar?
- 3 Describe three ways in which carbon can return to the atmosphere.
- 4 Where does respiration take place?
- 5 Some fabrics are more combustible than others. What does this mean?

THINK

- 6 How do animals obtain carbon?
- 7 Where does the carbon come from to form limestone at the bottom of the sea?
- 8 The amount of carbon dioxide in the Earth's atmosphere is increasing. Why is this happening?
- 9 Many different materials are used to provide heating. The table above right shows how much carbon is in some of them. The last column indicates how much heat (in MJ) 1 kg of each material typically provides.
 - (a) Draw a bar graph showing the percentage carbon content of each material.
 - (b) Which is the best material for heating?

Material	Carbon content (%)	Heat production (MJ)
Wood	11	17.9
Brown coal	73	29.5
Black coal	80	35.9
Natural graphite	90	39

- (c) Does the table indicate any relationship between the amount of carbon in a material and the amount of heat that it provides? Explain your answer clearly.

INVESTIGATE

- 10 Fuels may be solids, liquids or gases. Search the internet or use a library to find as many examples as possible of solid, liquid and gas fuels, and complete a table like the one below.

	State		
	Solid	Liquid	Gas
Examples			
Uses			
Advantages			
Disadvantages			

STUDY CHECKLIST

ELEMENTS AND ATOMS

- describe some common chemical elements
- recall the chemical symbols of some common elements
- identify some of the dangers associated with some chemical elements
- model the structure of the atom and describe the characteristics of the three main particles
- recall that each chemical element is identified with a unique atomic number, which is equal to the number of protons in its nucleus
- distinguish between metals, non-metals and metalloids
- identify similar properties of groups of elements in the periodic table

COMPOUNDS AND MIXTURES

- distinguish between elements, compounds and mixtures
- recall that the atoms in compounds are bonded very tightly together
- recall that elements can be separated from compounds only through a chemical reaction


- recognise that the properties of compounds are different from the elements that make them up
- use the formulas of simple compounds to identify the elements that make them up
- model the arrangement of atoms in the molecules of some compounds
- identify and describe some common compounds and their uses

SCIENCE AS A HUMAN ENDEAVOUR

- describe how the understanding of the particles that make up all matter has changed over time
- explain how the ideas about elements and the atom have changed over time
- describe the contributions of some of the scientists who have added to our knowledge of the atom and the elements
- recognise the impact of new scientific discoveries and technology on our understanding of the atom, elements and compounds

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DIGITAL RESOURCES

 **ANSWERS** for this chapter can be found online in your eBookPLUS.

Online section

This section of the chapter can be found online in your eBookPLUS.

7.8 Thinking tools: Affinity diagrams and cluster maps 

Individual pathways

Activity 7.1
Investigating substances
doc-6069

Activity 7.2
Analysing substances
doc-6070

Activity 7.3
Investigating substances further
doc-6071

FOCUS activity

Access more details about focus activities for this chapter in your eBookPLUS.

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Interactivities

It's elementary! revelation game

In this revelation game, you must identify common elements from their symbols to reveal the full periodic table. You must answer quickly to complete the game in time.

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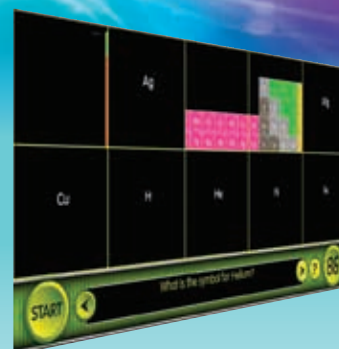
Making molecules

In this interactivity, you will use carbon, chlorine, hydrogen, nitrogen and oxygen atoms to create the correct models of a series of chemical formulae. Instant feedback is provided.

Searchlight ID: int-0228

Add **'Lavoisier and hydrogen'** watch a video from *The story of science* about the discovery of the elements.

Searchlight ID: eles-1722



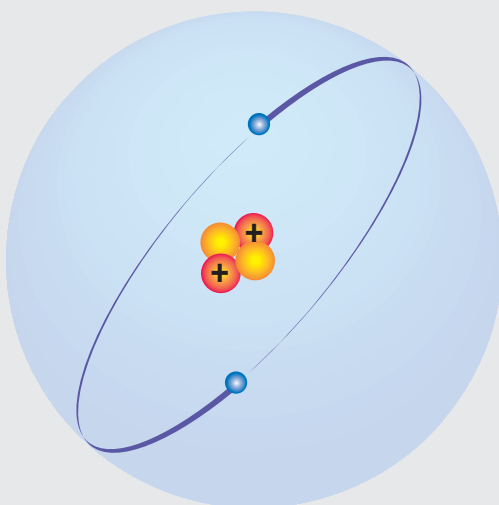
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LOOKING BACK

- About 2500 years ago, Democritus suggested what all substances were made up of.
 - In what way was Democritus' idea about substances the same as the model that scientists currently use to describe substances?
 - Suggest why most thinkers of the time disagreed with Democritus.
- Copy and complete the following table, which describes the structure of atoms.

Part of atom	Location	Size and weight (relative)	Electric charge
		Large	Positive
Neutron			
	Outside the nucleus		

- If a neutral atom has 12 protons, how many electrons does it have?
- What takes up most of the space in an atom?
- Identify the one feature that every single atom of the element sodium has in common.
- What is the atomic number of each of the following elements?
 - Hydrogen
 - Carbon
 - Uranium
- How many protons does each of the elements listed in question 6 have in its nucleus?
- How many electrons does each of the elements listed in question 6 have in its nucleus?
- Make a copy of the diagram of the atom below and label an electron and the nucleus. Answer the following questions.
 - How many protons does this atom have?
 - How many neutrons does this atom have?
 - How many electrons does this atom have?
 - What is the atomic number of this atom?
 - Describe one use of the element that is made up of these atoms.



Link to assessON for questions to test your readiness **FOR** learning, your progress **AS** you learn and your levels **OF** achievement. www.assesson.com.au

- Complete the following table to summarise what you know about metals and non-metals.

	Metals	Non-metals
Conduct electricity well		
Conduct heat well		
Surface features		
State at room temperature		
Malleable		
Ductile		
Brittle		

- Which of the elements iron, lead, hydrogen, oxygen, silicon, uranium and sodium are:
 - metals
 - metalloids
 - non-metals?
- (a) Which element is used inside illuminated signs like the one below?




- To which group in the periodic table does this element belong?
- What event must take place in order to separate a compound into separate elements?
 - How are the molecules in polymers different from the molecules of other compounds?
 - Complete the table on the next page to indicate whether the substances listed are elements, compounds or mixtures. Also indicate why you made that decision.

Substance	Element, compound or mixture	Why do you think so?
Gold		
Diamond		
Carbon dioxide		
Air		
Sea water		
Pure water		
Iron		
Ammonia		
Table salt (NaCl)		


16 Which of 'the bits that matter' is represented by each of the cartoons below?

the smallest particle of any of the elements




A

a particle made up of two or more atoms bonded together




B

a substance made up of atoms of two or more elements bonded together



C

a substance containing only one type of atom



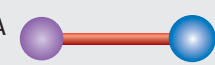
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17 What do diamonds, the 'lead' in pencils and coal have in common?

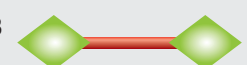


18 Each of the diagrams below represents one of 'the bits that matter' that make up substances.

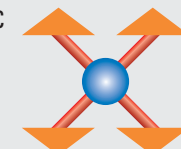
A




B



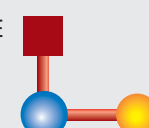
C




D




E



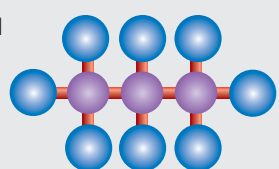
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G



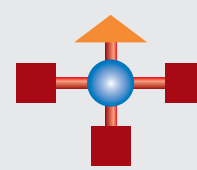
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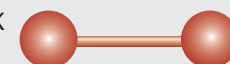
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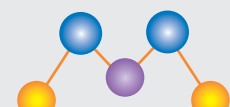
J



K



L



19 Which of the diagrams represents:
 (a) an atom of an element
 (b) a molecule of an element
 (c) a molecule of a compound?

20 Most of the substances around you are compounds and mixtures.
 (a) What differences could be observed between a mixture of hydrogen and oxygen, and a compound of hydrogen and oxygen?
 (b) Explain the difference between a compound and a mixture in your own words.

21 Respiration is a chemical reaction in which carbon dioxide is produced.
 (a) Where in your body does respiration take place?
 (b) What is released during respiration apart from carbon dioxide?
 (c) Suggest how the carbon atoms in carbon dioxide enter your body.

22 Why doesn't water appear in the periodic table?

projectsplus

Science TV

SEARCHLIGHT ID: PRO-0090

Scenario

In the media world, programs that combine entertainment and education are known as 'edutainment'. With the success of edutainment programs such as *Mythbusters* (SBS/7Mate), *Scope* (Network 10) and *The Experimentals* (ABC), it seems that science is attracting a bigger share of the television market than many network executives would have expected. Now, your local TV network — Channel 55 — has decided to jump on the 'science as edutainment' bandwagon and has announced that next year it will develop a program called *Science TV*.

To make *Science TV* more appealing to a younger audience, the developing executives of the program want it to be presented by a team of school students, who will do all of the introductions, explanations and experiments for each of the segments. It is important that the right team of students is found or the program will be canned after only a few episodes, so Channel 55 has announced that it is accepting online audition files from groups of students who think they have what it takes to be the *Science TV* stars.

Your task

Your group is going to put together a video submission that you could send to the Channel 55 developers to showcase how suitable you would be as the stars of *Science TV*.

The guidelines for the video submission from the Channel 55 website are as follows:

- The video must be between four and five minutes in length.
- The target audience of *Science TV* is between 8 and 14 years old.
- At least two people must be shown on camera.
- The video must be in the form of a chemistry segment that explains one of the following:
 - a. What is the difference between a physical change and a chemical change?
 - b. What are elements, compounds and mixtures?
 - c. How would we separate a mixture of iron filings, sand, copper sulfate and chalk dust?
- At least one experiment must be shown being performed in the segment — the experiment must be relevant to the segment and safe to perform (i.e. no explosions and no dangerous fumes produced).

The segment should be engaging and informative. It should have an introduction (either a scenario played out or a discussion between the presenters), an experiment to either test or demonstrate an idea, an explanation of the main concepts involved and a resolution that ties back into the original scenario or discussion. Remember: the main idea is to show that science is FUN!

Process

Open the ProjectsPLUS application for this chapter located in your eBookPLUS. Watch the introductory video lesson and then click the 'Start Project' button to set up your project group. Save your settings and the project will be launched. The rest of the process is outlined online in your ProjectsPLUS application.

