Chapter 2

Elements

CONTEXT AREA

- Chemicals are all around us. We use them, eat them and breathe them every day. Our bodies, clothes and houses are made of them.
- What are chemicals made of? What are chemicals like inside? Can we draw diagrams or maps of them? How are they classified, and why?
- The best way to learn about chemicals is to do experiments with them. Reacting, separating, observing and reasoning are all important if we are to understand what chemicals are like inside and how and why they change.

PRESCRIBED FOCUS AREAS

4.1 identifies historical examples of how scientific knowledge has changed people's understanding of the world

4.2 uses examples to illustrate how models, theories and laws contribute to an understanding of phenomena

4.3 identifies areas of everyday life that have been affected by scientific developments

DOMAINS

KNOWLEDGE AND UNDERSTANDING

4.7.4 elements

a classify elements as metals or non-metals according to their common characteristics

b identify internationally recognised symbols for common elements

4.7.6 compounds and reactions

a distinguish between elements and compounds

b identify when a chemical reaction is taking place by observing changes in temperature, the appearance of a new substance or the disappearance of an original substance

c distinguish between compounds and mixtures

SKILLS

4.13 clarifies the purpose of an investigation and, with guidance, produces a plan to investigate a problem

4.17 evaluates the relevance of data and information

4.19 draws conclusions based on information available

4.20 uses an identified strategy to solve problems

4.22 undertakes a variety of individual and team tasks with guidance

VALUES AND ATTITUDES

4.23 demonstrates confidence and a willingness to make decisions and to take responsible actions

4.24 respects different viewpoints and is honest, fair and ethical

4.25 recognises the relevance and importance of lifelong learning and acknowledges the continued impact of science in many aspects of everyday life

CONCEPTS

Physical and chemical changes	Explanation and examples
	Experiments
Pure but not pure	Concept of compounds
	Breaking compounds into lighter substances
Elements and compounds	Elements and compounds
	Drawing elements and compounds as circles
	Symbols of the elements
Elements	Identifying common elements
	Tests on some elements
Classifying elements	Reasons for classification
	Metals and non-metals
Metals and non-metals	Examples and uses
Making compounds from elements	Reacting elements
	Comparing properties of elements and compounds
Some important compounds	Examples and uses

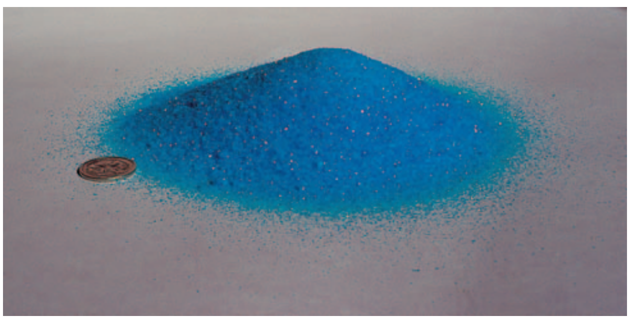
2.1 Physical and chemical changes

When you heat some substances, or mix them together, they will change. Does this change make a new substance? Or is the old substance still there, only it looks different?

The answers depend on which substances you mix and what happens when you supply heat energy. There are two types of changes in chemicals, one is a physical change and the other is a chemical change.

Physical change is a change in the appearance of a substance. The chemical is still the same, it just looks different. Some examples are: melting wax, crushing salt, and dissolving copper sulfate.

Physical changes are often reversible. This means that they can be undone. Wax melts easily. Molten wax can be cooled and turned back into a solid. The wax may have a different shape but it is still wax. Crystals of copper sulfate can be dissolved to make a solution. When the water evaporates crystals form. The crystals may be a different size, but they are still crystals of copper sulfate.



Crystals of copper sulfate (250 g shown beside a 5 cent coin)

Chemical change is a change that makes a new chemical. The substance looks different, smells different, and has different properties—because it *is* different. Some examples are: putting magnesium into acid, burning paper, and making sedimentary rocks.

Chemical changes are usually not reversible (able to go backwards). You cannot 'unburn' paper, or get magnesium back after it has reacted with acid.

How do you know when a chemical change has happened? Some clues to look for are:

- a change in colour
- bubbles, or fizzing, which means a gas is being made
- a change in temperature: the reaction becomes hotter or colder
- a change in solubility: substances may dissolve or become insoluble

When sodium reacts with chlorine, a chemical change happens

When a chemical change has occurred we say a chemical reaction has taken place. A chemical reaction produces new chemicals. Some reactions, like rusting, are slow and some are explosively fast. Reactions can be started with heat energy, or sometimes start by themselves.

The study of chemicals and how to change them is the work of chemists. They study the properties of chemicals and how to make new chemicals. The study of chemicals is called chemistry.

Studying chemicals is exciting. There are many experiments that you can do. There are also many dangers. You must always follow your teacher's instructions. Do not do your own experiments. Do not mix chemicals from different experiments.

Personal protective equipment, called PPE, is equipment that helps protect you from accidents in the laboratory. Wear eye protection, such as safety glasses, while you perform experiments. Wear proper shoes, with leather uppers. Thongs, sandals and nylon footwear are not allowed in any laboratory. And if you are not sure of what to do, stop and ask your teacher.

Chlorine gas

Laboratory Safety

QUESTIONS

1 What treatment is suitable if you burnt yourself by picking up a very hot Bunsen burner?

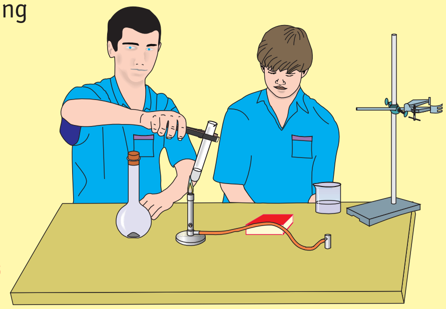
2 Why should students tie back long hair when using a Bunsen burner?

3 What should you do if you cut yourself on broken glass in the laboratory?

4 Why is it strongly advisable to wear safety glasses when doing experiments with chemicals or with Bunsen burners?

5 School uniforms have tight fitting sleeves. Why is this?

6 The drawing below shows two students performing an experiment. Make a list of the things the students are doing incorrectly.



What are these students doing incorrectly?

7 **a** What is the meaning of the term HAZCHEM? Explain why knowing about these types of substances is important.
b The sign below is often placed on the side of chemical jars, as well as other places. How would you explain the significance of the sign to:
i a young child
ii a student beginning to study science in a laboratory.

8 The chemicals that you use at school (and in homes and factories) have safety warning signs on their jars and bottles. Use your knowledge of the following chemicals to match them with the correct warning sign below.

a chlorine gas
b hydrochloric acid
c magnesium
d copper sulfate
e candle wax
f carbon monoxide

CHECKPOINT:

COPY AND COMPLETE

Physical change is a change in the __________ of a substance. The chemical is still the ____, it just looks _________. Physical changes are often __________.

Chemical change is a change that makes a ___ _________. The substance _____ different, ______ different, and has different __________ — because it is _________. Chemical changes are usually not __________.
When a chemical change has ________ we say a ________ ________ has taken place.

QUESTIONS

1 Which of the following changes are physical and which are chemical?
a burning toast
b melting ice
c cutting paper
d mixing tar and stones to place on roadway
e filtering water from sand
f sand being buried and slowly making sandstone
g acid dissolving a nail
h burning a candle
i clouds condensing from water vapour
j freezing molten wax
k lighting a Bunsen burner
l wetting folded filter paper
m chromatography of pen ink
n mud and silt forming shale

2 What is meant by a physical change and a chemical change?

3 What clues should you look for in chemical changes?

4 What is a chemical reaction? List three chemical reactions.

5 Write six safety rules for working with chemicals in a laboratory.

6 People who work in laboratories wear white or green laboratory coats that are made of non-flammable cotton. Suggest two reasons why people wear these coats.

DEMONSTRATION

AIM: To observe some physical and chemical changes

Your teacher will show you some physical and chemical changes. Look for the clues which tell you whether each one is a chemical or physical change.

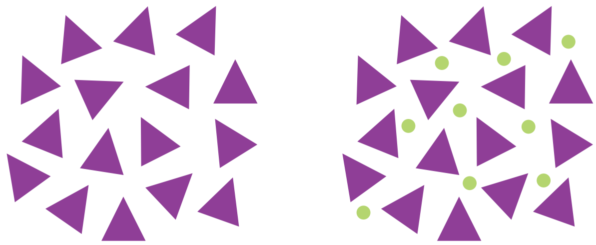
1 Adding magnesium to dilute acid.
2 Filtering chalk dust from water.
3 Drying wet chalk with the Bunsen burner.
4 Watching marble fizz when acid is put on it.
5 Burning magnesium.
6 Melting wax.
7 Burning a wax candle.
8 Heating bread with the Bunsen burner.
9 Adding detergent to water and shaking the mixture.

Your teacher will remind you of the safety precautions needed when you burn chemicals and use acid. Your teacher will do this as they demonstrate the changes.

Drawing particles

We can study physical and chemical changes by thinking about the smallest parts of substances. The smallest parts are called particles. In earlier activities we drew shapes representing the particles in a substance. Different shapes and different colours represented different particles in substances.

In a physical change, only the appearance changes. The chemical substance stays the same. The particles do not change.



pure substance

impure substance (mixture)

EXPERIMENT

AIM: To perform experiments that show physical and chemical changes

Your teacher will make available some of the following chemicals. Follow the instructions written below and given by your teacher as you do some of these experiments. Copy and complete the table of results for each section that you do.

Remember:
Do not use the same spatula for different chemicals. The dirty spatula might put impurities into the jars of pure substances. Clean your bench and dispose of wastes as your teacher says. Record the observations and results of each experiment before beginning the next part.
Personal protective equipment, especially for your eyes, hands and feet, is needed for this experiment. Do not commence work until your teacher has approved your protective equipment.

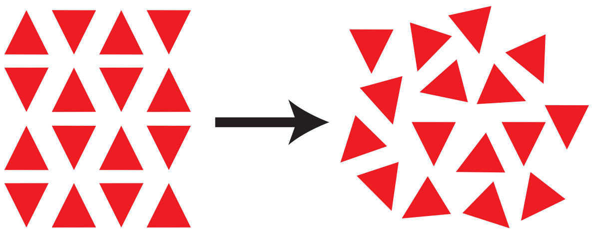
1 Mix a level teaspoon of copper sulfate with 100 mL of water in a 250 mL beaker. Warm the solution to 60°C. Stop heating. Put a small amount of iron wool into the beaker. (Iron wool is often called steel wool.) Record your results. Is this a physical or chemical change?
2 Put five small marble chips into 1 cm depth of dilute acid in a test-tube. Observe and record. Is this a physical or chemical change?
3 Dissolve a level teaspoon of bicarbonate of soda (sodium bicarbonate) in 50 mL of water.
4 Tip the bicarbonate of soda solution made in Part 3 into 50 mL of white vinegar.
5 Grind some blackboard chalk in a mortar and pestle. Remember that the chalk is mixed in the mortar by pushing the pestle around, not hammering it.
6 Add half of this chalk to 50 mL of water and stir.
7 Add the other half of the crushed chalk to dilute acid.
8 Heat ten grains of sugar in a dry test-tube.
9 Mix salt crystals and vinegar in a test-tube and warm them.
10 Add vinegar to warm milk and gently stir.

Write your results in a table similar to this.

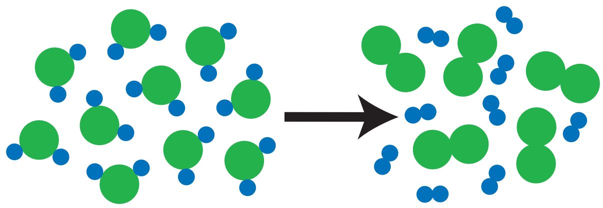
Experiment number	Brief description of what you did	Physical or chemical change	Observations and reasons

In a chemical change a new chemical is made. This means that new and different chemicals are made. This is because each chemical substance is made of its own type of particles. New particles show that a chemical change has occurred. In some chemical changes, particles can be separated to make new chemicals. Sometimes particles join together to make larger particles.

We can use this idea to show physical and chemical changes. Using drawings to show particles is an example of a scientific model. We can use this idea to show physical and chemical changes.



In a physical change, only the appearance changes, because the particles have been rearranged



In a chemical change, a new chemical is made. New chemicals are made of new particles

CHECKPOINT:

COPY AND COMPLETE

We can study physical and chemical changes by thinking about the smallest _____ of __________. The smallest parts are called _________.

In a physical change, only the __________ changes. The particles do not ______.
In a chemical change a new ________ is made. ___ particles show a ________ change has occurred.

QUESTIONS

1 Look back at the previous page and list three physical and three chemical changes.

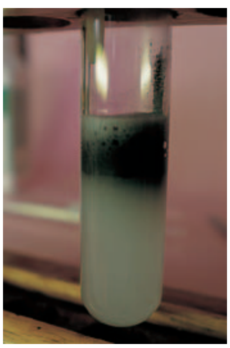
2 Which of the examples to the right (a–e) show physical changes and which show chemical changes? Give a reason for each.

3 What if you read each question backwards? Does this change any answer? Explain.

4 Draw the particles in the following mixtures:
  a salt dissolved in water
  b lumps of chalk in water
  c chalk in filter paper
  d dust floating in air.

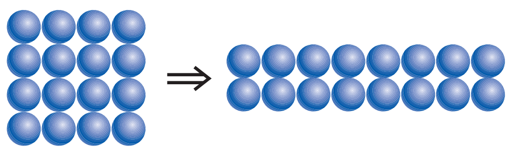
5 What evidence is there that a chemical reaction is taking place in this test-tube?

6 Why is it important to use a clean spatula in each chemical jar?



A chemical reaction

a



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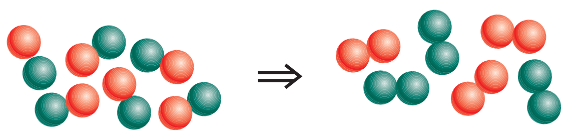

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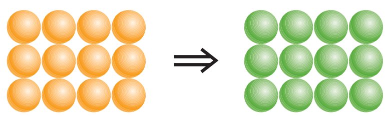

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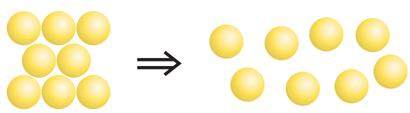
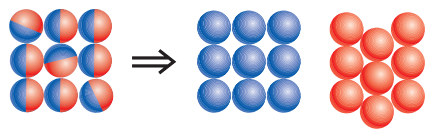


e



2.2 Pure but not pure

If you had a mixture of iron filings, sawdust, sand and copper sulfate, how would you separate them? You would first consider their properties and then decide on the best order for separating them. The properties could be set out in a table such as the one below.

Substance	Soluble in water?	Floats on water?	Magnetic?
Iron filings	✘	✘	✔
Sawdust	✘	✔	✘
Sand	✘	✘	✘
Copper sulfate	✔	✘	✘

What is the best order of separation? Explain your reasons.

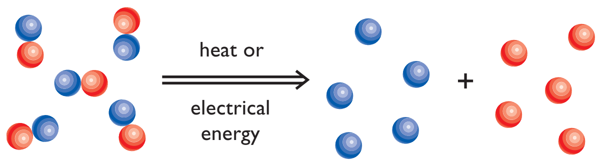
After you have dissolved, filtered and crystallised, you will have separated blue crystals of copper sulfate. Is copper sulfate pure? Yes it is.

But there is a catch. When you heat copper sulfate to high temperatures it will break apart and form new substances. So copper sulfate is pure and it is made of other substances. Confused?

Copper sulfate and Condy's crystals are pure substances, but they are both made of several other substances. Strong heating causes these substances to break apart.

There are many pure substances which are made of two or more substances joined together. Some can be separated using heat. Others need more energy to separate them. Electrical energy can sometimes separate chemicals when heat energy cannot. The use of electrical energy to change a chemical is called electrolysis.

The change can be shown in a particle diagram. Energy is used to pull the particles away from each other to form two new substances.



A particle diagram shows energy changes

EXPERIMENT

AIM: To heat copper carbonate

Your teacher will give you a heaped teaspoon of solid copper carbonate. Weigh the test-tube and its contents. Wear safety glasses as you gently heat it. Note any changes in your note book. When it has cooled, weigh it again. Is copper carbonate made of other substances? Is the change a physical or a chemical change? What are your reasons?

DEMONSTRATION

AIM: To heat compounds

Note: Personal protective equipment is important in these demonstrations.

Your teacher will demonstrate these reactions to you. This is because the temperature needed is high and the gas can be dangerous.

1 Place one teaspoon of copper sulfate in a test-tube and heat gently with a Bunsen burner until the powder is white and condensation is visible at the top of the test-tube. White copper sulfate is the substance used to test for water. Weigh the test-tube again.

2 Condy's crystals, (potassium permanganate, $KMnO_4$), will decompose when heated gently. The test-tube must be clean and dry. Record the weight of the test-tube before and after heating. The purple crystals break apart, releasing oxygen, and form a black powder. The powder can be dissolved in water when it has cooled.

3 White crystalline lead nitrate, $Pb(NO_3)_2$, will decompose when heated with a Bunsen burner in a dry test-tube. Yellow lead oxide and brown fumes of nitrogen dioxide (NO_2) gas are formed. Both substances are poisonous. Heat quarter of a teaspoon of lead nitrate solid, in the fume cupboard, and observe all safety precautions. Save lead compounds for hazardous chemical collection.

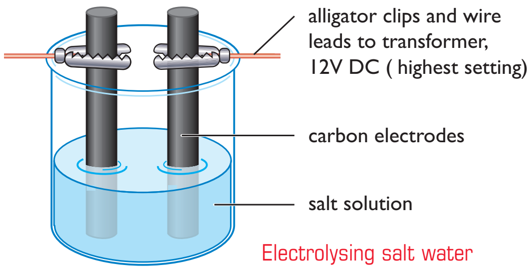
Copper sulfate, Condy's crystals and lead nitrate are pure substances. They are made of other substances as well. Heating causes these substances to break apart.

EXPERIMENT

AIM: To perform electrolysis of salt water

Salt has the chemical name sodium chloride. It is a pure substance made of sodium and chlorine. Strong heating melts salt but does not separate the sodium from the chlorine. Electrical energy can make this happen.

Set up the experiment drawn below. Dissolve a level teaspoon of salt in 100 mL of water in a small beaker.



Electrolysing salt water

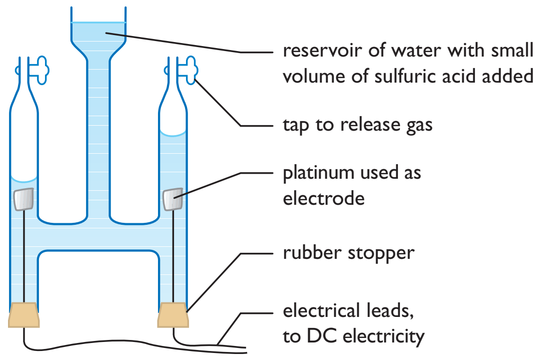
Turn on the electricity for 30 seconds. Carefully smell the chlorine by wafting the fumes towards your nose. To clean up, rinse the beaker thoroughly.

Do you believe that electrical energy pulled the salt particles apart? Where else could the chlorine have come from?

DEMONSTRATION

AIM: To observe Hofmann's voltameter

Water seems pure, and it is. Electrical energy can separate water into the substances which make it up—hydrogen and oxygen. The special apparatus that was designed for this is called Hofmann's voltameter.



Hofmann's voltameter

Your teacher will set up a Hofmann's voltameter and show you the hydrogen and oxygen gas produced, and how to test for these gases.

CHECKPOINT:

COPY AND COMPLETE

There are many pure __________ which are made of ___ or ____ substances ______ together. Some can be _________ using ____. Electrical ______ can sometimes separate _________ when ____ ______ cannot. The use of __________ energy to ______ a chemical is called ____________.

Electrical energy can separate _____ into the substances which make it up—________ and ______ . The special _________ that was ________ for this is called _______’_ ___________.

QUESTIONS

1 Why is protective eye wear important in chemical experiments?

2 When copper sulfate is heated it turns white and condensation (water droplets) is seen at the top of the test-tube. How does this indicate that copper sulfate is made of more than one type of particle?

3 When Condy’s crystals are heated, the sample gets lighter. Where did the rest of the substance go to? How is this evidence that Condy’s crystals are made of more than one type of substance?

4 Lead nitrate crystals are transparent, but when heated a brown gas is released, and a yellow solid remains. Why is this evidence that this substance is a compound?

5 What is electrolysis? Give examples of two substances that can be electrolysed.

6 Why should you waft fumes towards your nose instead of taking a deep breath?

7 In the electrolysis of salt water experiment, you only had the electricity turned on for 30 seconds. What was the reason for this?

8 What is Hofmann’s voltameter? What does it do and show?

9 In the electrolysis of water, energy is used to make hydrogen and oxygen gases. What would happen if these gases reacted together?

10 Name six different compounds discussed (and used in the experiments) in this activity. From your knowledge of them, write your own definition for a chemical compound.

2.3 Elements and compounds

Chemists in the 1800s were learning about chemicals, just as we are doing right now. By doing lots of experiments they found that there were two types of pure substances.

One type is made of two or more pure substances joined together. Examples are copper sulfate, salt and water. These substances are called compounds.

The other type is made of only one substance and was thought of as being simple or elementary. These substances are called elements.

The only way of finding out whether a pure substance was an element or compound was to test it. Chemists tested to see if the substance could be separated by heat energy or electrical energy. They then made lists of elements and compounds, and published them in books and journals. They described how to make newly discovered compounds. They shared this information with everyone.

Some elements have been known for thousands of years. This is because they are easy to separate from compounds occurring in the Earth. Examples are copper and silver. Some substances were not separated until the 1800s. This is because they were so difficult to separate from compounds. Examples are calcium and aluminium.

For a while aluminium was more expensive than gold. This is because aluminium was harder to separate from compounds than gold. At a dinner party hosted by the French Emperor Napoleon, all his dinner guests had knives and forks made of pure gold. Napoleon used a much more valuable metal for his own knives and forks—it was aluminium.

The last group of naturally occurring elements to be discovered were the noble gases. These are uncommon gases found in the atmosphere, and they do not form stable compounds. Since the development of atomic (nuclear) energy in the 1940s, some radioactive elements have been made. The most common of these is americium, which is used in smoke detectors.

Drawing elements and compounds

To help understand the difference between elements and compounds, we can draw them as circles. Each circle represents the smallest part of all substances. The smallest parts are called atoms. Knowing what we know about elements and compounds, we can now say:

- Elements are made of one type of atom only.
- Compounds are made of two or more types of atoms joined together.

This explains why compounds can be broken into simpler and lighter chemicals. The different types of atoms can be separated from each other.

We will draw each type of atom in a different colour or a geometric pattern.

EXPERIMENT

AIM: To determine if substances are elements or compounds

Heat the following substances in a test-tube over the Bunsen burner. Remember to wear eye protection and have suitable shoes. Write a report of your experiment in your note book. Copy and fill in the table below. Remember that a substance is a compound if it breaks up into other substances. A substance is probably an element if it does not change.

Substance	Appearance before heating	Appearance while hot	Appearance when cooled	Change in weight	Element or compound?
Copper carbonate					
Copper wire					
Copper oxide					

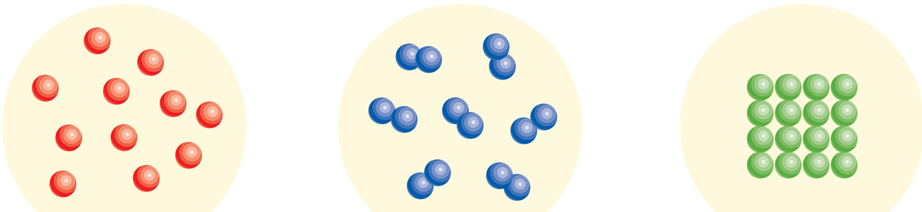
Discuss your results with your class and teacher. Which are elements and which are compounds? Give a reason. Which are you undecided on? Recall the demonstration in activity 2.2 on page 34, when copper sulfate crystals were heated. Were the crystals an element or a compound?

In elements all the atoms are the same. In compounds there are two or more different types of atoms joined together into small groups or into one big group.

Instead of drawing circles as symbols, people now use letters. The letters are an abbreviation of the element's name. The first letter is always a capital letter, and the second letter (if there is one) is lower case.

A Swedish chemist named Jöns Jakob Berzelius thought up the chemical symbols we use today. He used an abbreviation of the element's name as its symbol. Berzelius used the Latin name for some elements. Ten elements have symbols that are based on Latin, instead of their modern names. They are: sodium (Na), potassium (K), iron (Fe), gold (Au), silver (Ag), mercury (Hg), copper (Cu), tin (Sn), lead (Pb), antimony (Sb). One element, tungsten, has the symbol W which was devised from its German name, Wolfram.

Atoms in elements

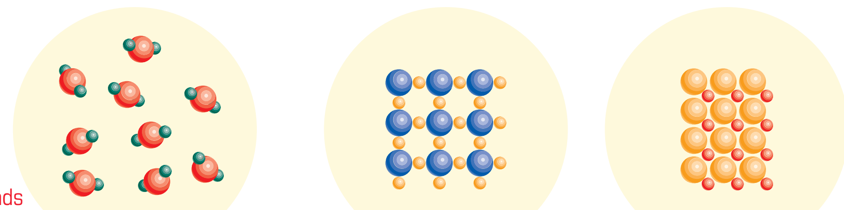


single atoms
e.g. noble gases

pairs of atoms
e.g. hydrogen (H)

large groups of atoms
e.g. iron (Fe)

Atoms in compounds



identical groups of atoms; each group is called a molecule
e.g. water (H_2O)

atoms in regular repeating patterns, called a lattice
e.g. sodium chloride (NaCl)

CHECKPOINT...

COPY AND COMPLETE

The only way of finding out whether a pure substance was an _______ or ________ was to ____ it. Chemists tested to see if the _________ could be _________ by ____ energy or __________ energy.

In elements all the _____ are the ____. In compounds there are ___ or ____ different _____ of _____ joined together into _____ groups or into ___ ___ group.

QUESTIONS

1 What is the difference between an element and a compound?

2 How are elements and compounds similar to each other?

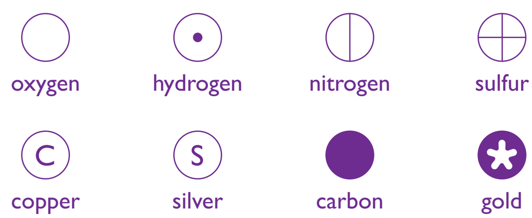
3 How can you tell the difference between an element or compound by doing an experiment?

4 What is the shorthand way of writing the name of an element called?

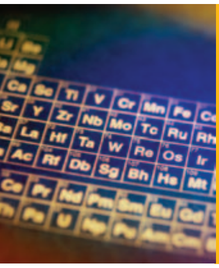
5 Why was aluminium more expensive than gold at one time in the past?

6 Why do some elements have unusual symbols?

7 In 1810 an English chemist, John Dalton, used a system of symbols to represent different elements. Some of them are shown below. Suggest why Dalton's symbols are not used today.



8 Elements such as copper have been used for thousands of years, yet aluminium was only discovered in the 1800s. Suggest a reason for this.



2.4 Elements

Elements are chemical substances which cannot be purified or separated. They are elementary substances. They are made of just one type of atom.

Chemists know of over one hundred different types of atoms. This means that there are over one hundred different elements. Not all of these elements are safe or easy to obtain. Some elements like gold and platinum are rare and valuable. Some elements such as arsenic are poisonous. Some elements like copper, iron, oxygen and chlorine you have seen in experiments. The names of some other elements are probably well known to you, such as lead, calcium and tin.

You should be able to recognise some common elements, and confirm what they are by doing simple chemical tests on them.

DEMONSTRATION

AIM: To experiment with elements

Your teacher will show you some of the elements, and demonstrate some of their reactions. This is because the reactions can be dangerous or produce toxic gases.

After each demonstration, record in your note book the details of the changes and properties of the elements. Watch and explain these reactions.

1 Hydrogen gas is made by reacting magnesium with an acid. The hydrogen gas was part of the compound hydrochloric acid. Hydrogen is a colourless and odourless gas and appears as bubbles.

2 Hydrogen gas is explosive, and is tested with the 'pop' test. Never face open test-tubes at people during the pop test.

3 Oxygen gas is made using black manganese dioxide powder and hydrogen peroxide solution. Both of these compounds are rich in oxygen. The oxygen is a colourless and odourless gas and appears as tiny bubbles.

4 Oxygen is needed for substances to burn. Oxygen is tested with a glowing or smouldering splint or stick. When it is put into a test-tube containing oxygen it ignites and starts to burn brightly.

5 Chlorine is a poisonous gas. It is the smell given off by swimming pool chlorine and bleach. Chlorine is a yellow green colour. Chlorine is tested using the 'bleach' test. Chlorine will bleach colours, such as in litmus paper.

6 Phosphorus is a red powder, and it is kept away from air. It burns with a yellow flame and makes a lot of smoke. A fume cupboard is needed for this demonstration.

7 Sulfur is a yellow powder. It melts into a red thick liquid and then burns with a pale blue flame. The gas produced is sulfur dioxide, which is poisonous. In small concentrations it triggers asthma and wheeziness in many people. A fume cupboard is essential for this demonstration.

Some elements (left to right): calcium, iodine, phosphorus, sulfur

Properties of some common elements

ELEMENT	SYMBOL	STATE	COLOUR	FEATURES AND USES
These elements are safe to look at:				
Aluminium	*Al*	*solid*	*shiny silver*	*used to make foil wrap and silver paper*
Carbon	*C*	*solid*	*black, dull*	*found impure in charcoal and soot*
Magnesium	*Mg*	*solid*	*shiny silver*	*burns with a bright white flame*
Sulfur	*S*	*solid*	*yellow, dull*	*found near volcanoes, part of sulfuric acid*
Iron	*Fe*	*solid*	*silvery grey*	*magnetic, commonly used metal*
Phosphorus	*P*	*solid*	*dark red, dull*	*used on match heads, flammable*
Lead	*Pb*	*solid*	*silvery grey*	*used to make fishing sinkers*
Nickel	*Ni*	*solid*	*shiny silver*	*main metal in 'silver' coins*
Copper	*Cu*	*solid*	*shiny brown*	*used in electrical wires and water pipes*
Gold	*Au*	*solid*	*shiny yellow*	*used in electronics, used as money*
Tin	*Sn*	*solid*	*shiny silver*	*used in tin cans, will not taint food*
Zinc	*Zn*	*solid*	*shiny silver*	*metal used to galvanise iron*
Silver	*Ag*	*solid*	*shiny silver*	*used in jewellery*
These are the elements which your teacher will make. They can be dangerous if not used correctly.				
Oxygen	*O*	*gas*	*colourless*	*needed for breathing, tested with glowing splint*
Hydrogen	*H*	*gas*	*colourless*	*explosive, lighter than air, tested by pop test*
Chlorine	*Cl*	*gas*	*yellow-green*	*poison, used in bleaches and disinfectants*
These are some elements which are hazardous. Most schools do not have these elements.				
Mercury	*Hg*	*liquid*	*shiny silver*	*used in thermometers, some switches*
Calcium	*Ca*	*solid*	*shiny grey*	*reacts quickly with water and air*
Iodine	*I*	*solid*	*shiny crystals*	*stains your fingers brown, sublimes easily*
Sodium	*Na*	*solid*	*shiny, soft*	*very reactive in air and water, burns skin*
Potassium	*K*	*solid*	*shiny, soft*	*similar to sodium*
Bromine	*Br*	*liquid*	*dark red*	*fuming liquid, burns skin very badly*

EXPERIMENT

AIM: To identify elements

Your teacher will have available some elements for you to look at. Some activities that you can do are described below.

1 Burn magnesium. It is supplied as a ribbon, like flattened wire. Don't look directly at the flame which gives off harmful ultraviolet light. You can see how bright it is by the shadows on the wall.

2 Burn steel wool. Wave it around and it burns more strongly.

3 Look at the elements supplied by your teacher. Use the table to identify as many elements as you can.

Optional

1 Copy the table above into your note book.

2 Confirm the test for hydrogen and oxygen by repeating them yourself. Check with your teacher.

CHECKPOINT:

QUESTIONS

1 How would you recognise or test for each element in the list below? Write the details about each element as well as their special test or features.

carbon	sulfur	iron
copper	hydrogen	oxygen
calcium	phosphorus	magnesium
aluminium	lead	zinc
gold	silver	chlorine

2 Give some uses for the elements listed below.

aluminium	carbon
phosphorus	nickel
tin	zinc
chlorine	mercury
iron	

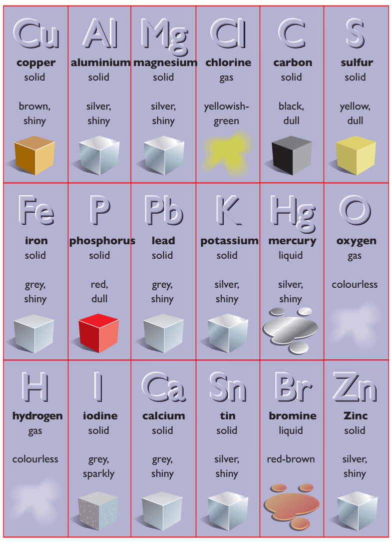
2.5 Classifying elements

How could you classify the elements? Could you sort them into groups? How have chemists sorted them into groups? The best classification of elements is based on their properties. The two big groups of elements are metals and non-metals.

ACTIVITY

AIM: To investigate elements

Cut out the cards of the elements. (These are printed at the back of this book.) The cards have the properties and symbols of the elements written on them.



Some examples of element cards

Move the cards around and sort them according to the instructions below. Answer the questions in your note book as you go. The heading is 'Classifying Elements'.

1 How many elements have a one-letter symbol? How many have a two-letter symbol? Why is classifying elements based on their symbol a bad idea?

2 How many elements are silver-coloured? How many elements have another colour? Why is classifying elements based on their colour a bad idea?

3 How many elements are solids, liquids and gases? Why is classifying elements based on their state a bad idea?

The best classification of elements is based on their chemistry. Their chemistry is how they react, what they do in acids, how they react with oxygen, how they conduct electricity, and so on. For someone who knows the elements, this is the only way to classify them.

The two big groups of elements are metals and non-metals.

4 Rearrange the cards into the groups of metals and non-metals. Look back to the table on the previous page for hints. Glue the cards into your book in the correct group. You should have ten metals and eight non-metals.

EXPERIMENT

AIM: To compare the properties of metals and non-metals

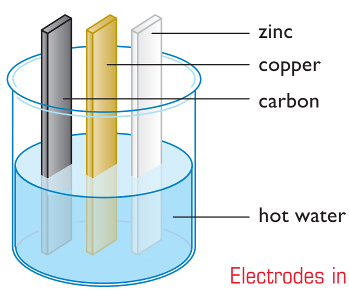
Compare the properties of some metals and some non-metals in a series of experiments. Record the results in a table in your note book.

1 Do metals or non-metals conduct heat better?

Your teacher will give you some electrodes, including carbon and some metals like copper and zinc. Boil a 2 cm depth of water in a beaker, and stand the electrodes in the hot water. Carefully touch each metal. Which elements conduct heat the best? Which elements do not conduct heat?

2 What happens when metals and non-metals are placed in acid? Do they react?

Your teacher will give you samples of magnesium, zinc, carbon and sulfur. Place these into test-tubes of dilute acid. Observe carefully. How could you test the gas given off?



Electrodes in hot water

3 Do metals or non-metals have the shiniest lustre? Use the electrodes from part 1, and scrub them with steel wool. Do metals or non-metals have the shiniest lustre? Don't breathe the dust made when rubbing.

4 Do metals or non-metals conduct electricity? This requires a transformer, a lamp, and three wire leads. Test the electrodes used in part 1, as well as rubber, glass and plastic. These substances (rubber, glass, plastic) are not elements but are made entirely from non-metals. Carbon is an exception in terms of its electrical conductivity.

5 Are metals or non-metals the most brittle? This is best done as a teacher demonstration. Your teacher will hit pieces of carbon electrodes, zinc and tin granules, and lead sinkers with a hammer. Which elements are brittle and smash apart? Which elements can be hammered into a different shape? (Substances which can be hammered into new shapes are said to be malleable.)

Use your knowledge of these experiments, and other demonstrations, to complete the following table.

Feature	Metal	Non-metal
Brittle?		
Malleable		
Lustre		
State		
Conducts heat?		
Conducts electricity?		
Reactions with acid?		

A note of caution

Some elements cannot be classified easily as either metals or non-metals. For example, mercury is a metal that is a liquid at room temperature, and black carbon (graphite) is the only non-metal that conducts electricity.

A few elements are difficult to classify, with seemingly opposing properties. The most important are silicon and germanium. They are called metalloids or semi-metals. Semi means half. Their special properties mean that silicon and germanium have special uses in electronics.

Silicon

CHECKPOINT:

COPY AND COMPLETE

The best ______________ of elements is based on their _________. The two big groups of elements are ______ and ___-______.

A few elements are difficult to ________, with seemingly opposing __________. The most important are _______ and _________. They are called __________ or semi-metals.

QUESTIONS

1. What are the two big groups of elements?
2. What is meant by malleable, brittle, state, conductor of heat, and lustre?
3. What is meant when you describe a 'substance's chemistry'?
4. List the main differences between metals and non-metals.
5. Name one metal and one non-metal which do not have all the properties of metals and non-metals.
6. Uranium is a metal. Using your knowledge of metals predict the lustre, state, and conductivity of electricity, of uranium.
7. Selenium is a non-metal. Using your knowledge of non-metals predict its lustre, conductivity of electricity, and reaction with acid.
8. If you were a space explorer and you went to a different planet or solar system, would you expect to find the same elements?
9. There are only two elements that are liquids at room temperature. Look back at the table on page 39 and find their names.
10. There are two elements which have properties that place them between metals and non-metals. What are they, and what are their uses?

2.6 Metals and non-metals

If you had gone to school four thousand years ago you would have learnt that there were four elements—earth, air, fire and water. Everything in the world was a mixture of these elements. They are not like modern elements.

In Europe from the 1500s on, people began studying chemistry and doing experiments. Their goal was to convert cheap common metals such as lead into a valuable metal like gold. They thought that they might be able to make gold if they mixed lead with something yellow like urine or sulfur or yellow flowers. Other people looked for a magic drink that would make you live forever.

These ancient chemists who used magic in their experiments were called alchemists. They invented most of the equipment you use in your classroom, such as condensers and flasks. Some elements were discovered by alchemists, for instance, phosphorus. It was part of the residue left after boiling off the water from forty large buckets of horse urine. Phosphorus was named because it glowed in the dark.

Each modern element is made of a different type of atom. There are 109 different types of atoms, so there are 109 different elements. The element gold is made of millions of gold atoms. Carbon is made of millions of carbon atoms.

The discovery of phosphorus

Most atoms occur naturally. You can find them on the Earth. There are 89 naturally occurring elements. The other elements are artificial. They have been made in nuclear reactors or accelerators. Some of these atoms last for only one-thousandth of a second before they break apart. Atoms which break apart are said to be radioactive. The energy and particles they release are called radiation.

Radioactivity can be good and bad. Radioactivity from nuclear reactors and radio-active atoms can kill people. Even small doses of the radiation from radioactive atoms can cause cancer. Radiation can be used to kill cancer cells and in making scans of lungs, brains and other organs. Radioactivity is used to date old objects. Carbon dating is used to date (= find the age of) objects which have carbon atoms in them. It is used for objects less than 20 000 years old.

Carbon-dated bodies: mummified skins of the 'Weerdinge Couple'

Atoms in people

Our bodies are made of many complex substances which allow us to grow and move and think. All of these substances are made of just 16 different elements.

In activity 2.3 we saw that calcium is a metal which reacts with water and makes hydrogen gas. But calcium is also present in compounds. The calcium in our bodies is in compounds in our teeth and bones. When we drink milk our bodies remove the calcium from the compounds in the milk and put the calcium into compounds in our teeth and bones. At no stage is there calcium metal floating around inside us.

Some other important elements are:

Iron is the most commonly used metal. It is cheap, strong and easy to separate from iron ore. Iron is converted to steel by adding small amounts of carbon and some metals. Adding different metals gives the steel different properties.

Copper does not corrode easily and conducts electricity very well. It is used in electrical wiring including the thin wires in electric motors.

Aluminium is the most common metal in the rocks on the Earth, but the most difficult to extract. It is strong, light and does not corrode.

Pouring molten metal

Chlorine is made by the electrolysis of salt water. Salt water contains sodium chloride. Chlorine is used to kill bacteria in our drinking water, to disinfect pools and as a bleach.

Sulfur is mined underground as pure sulfur. Most of it is used to make sulfuric acid, although some sulfur is added to rubber to make it tough.

Oxygen is obtained from the air. Most living things need this gas to stay alive. It is used in hospitals to treat very sick people and premature babies. It is also used in some factories.

Carbon is found in the Earth in different forms. The most common form of carbon is graphite, which is the black carbon left after fires and the black in lead pencils. The valuable form of carbon is diamond.

A galvanised iron downpipe

CHECKPOINT:

QUESTIONS

1 What is radioactivity? Give one benefit and one disadvantage of radioactivity.

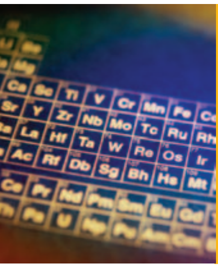
2 For the elements mentioned in the text, draw up a table using the following headings. You may use elements mentioned in earlier activities too.

Element *Metal or non-metal?* *Uses*

3 When people say that milk contains calcium which is good for our teeth and bones, they don't mean pure calcium. What do they mean?

4 Iron is an element. What about steel? Is it an element, a compound or a mixture? Why?

5 Four thousand years ago people thought that there were four elements: earth, air, fire and water. What is something they didn't know about that is the same in each element?



2.7 Making compounds from elements

We can separate compounds into the substances that they are made from. (We did this in Activity 2.2). We can also join elements together to make compounds. Are compounds like the elements that they are made from? Or do they have different properties?

A compound is a pure substance that is made from other substances. Activities 2.2 and 2.3 were about breaking compounds into other simpler substances. Some of these were elements. This activity is about joining elements together to make new compounds. We will also look at their properties to see how different, if at all, compounds are from the elements from which they are made.

The properties of compounds can be different from the properties of the elements from which they are made. There are many examples—in fact, every compound is an example. Water is made of hydrogen and oxygen, both of which are gases. Salt is made of sodium and chlorine, both of which are harmful as elements.

We can show the formation of compounds from elements using particle diagrams. Compounds are made of different particles joined together.

DEMONSTRATION

AIM: To make a compound of iron and sulfur

Your teacher will demonstrate these reactions for you. They are violent chemical reactions. Your teacher will wear safety glasses and do these reactions in a fume cupboard. Don't sit too close!

1 Mix one level teaspoon of iron powder with one heaped teaspoon of sulfur powder together in a test-tube. Hold the test-tube with a solid pair of tongs or a test-tube holder. Heat the mixture gently at first and then strongly until a reaction starts. The test-tube glows red hot inside. Leave the test-tube to cool. The new compound you have just made is iron sulfide.

The reaction of iron with sulfur

2 Test the properties of iron and sulfur while the compound iron sulfide is cooling. Fill in the following table.

Property	Iron	Sulfur	Mixture of iron and sulfur	Compound of iron and sulfur
Element or compound				
State				
Colour				
Magnetism				
Effect of acid				

Your teacher will only add a few drops of acid to the iron sulfide. Smell it carefully. Remember to waft the fumes toward your nose.

Some things to think about

1 Think about how you could separate a mixture of iron and sulfur. (There are two ways.) Can you separate the compound iron sulfide in the same way? Is there anything similar between the mixture of iron and sulfur and the compound of iron and sulfur?

2 If this experiment was done using an iron nail instead of iron powder, you would not have noticed the reaction. Why is the reaction insignificant when a nail is used?

3 How would this reaction change if your teacher had used a less active metal (such as copper) or a more active metal (such as zinc)?

DEMONSTRATION

AIM: To compare the properties of elements and compounds

Your teacher will demonstrate this for you. It uses chlorine gas which is poisonous. A fume cupboard is essential. Your teacher will need to wear safety glasses.

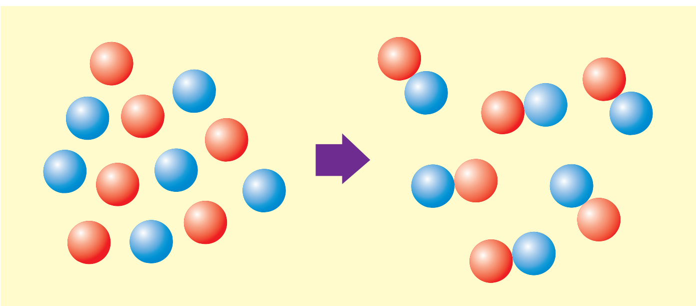
1 Make some chlorine gas in a gas-jar. Adding hydrochloric acid to swimming pool chlorine powder does this well. There are chlorine atoms in both compounds. Put the lid on the gas-jar.

2 Hold some iron wool in some crucible tongs, and warm it gently. Some of the ends may smoulder pale red as they burn slowly.

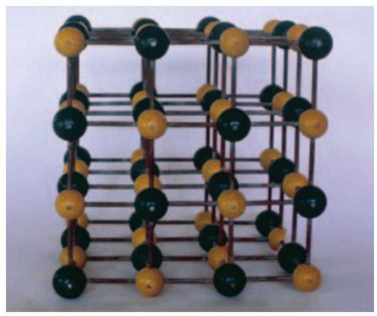
3 Take the lid off the gas-jar, and hold the warm iron wool inside the top of the gas-jar. A large amount of orange smoke is made. It is a new compound called iron chloride.

How different is the orange compound iron chloride from the elements iron and chlorine? Write this heading into your note book, and copy and complete the following table. You will have to guess some of the information based on your previous knowledge of elements.

Property	Iron	Chlorine	Iron chloride
Element or compound?			
State			
Colour			
Action with acid			



The formation of compounds from elements



The structure of sodium chloride (salt)

CHECKPOINT:

COPY AND COMPLETE

We can separate _________ into the __________ that they are made from. We can also join ________ together to make _________.

The __________ of compounds are totally different from the __________ of the ________ from which they are made. There are many examples—in fact, every ________ is an _______. Salt is made of ______ and ________, both of which are _______ as ________.

QUESTIONS

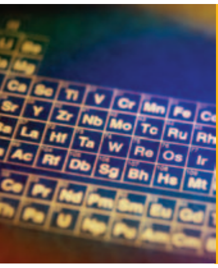
1 What is the difference, in terms of atoms, between elements and compounds?

2 When two elements make a compound, is it a physical or chemical change? Explain.

3 Water is made from atoms of hydrogen and oxygen. Draw a table contrasting the differences in properties between hydrogen, oxygen and water. Use the details given in previous activities.

4 Table salt is made of atoms of sodium and chlorine. Draw a table contrasting the differences in properties between sodium, chlorine and salt. Use the details of sodium and chlorine given in the previous activities.

5 Sugar is made from atoms of carbon, hydrogen and oxygen. Draw a table contrasting the differences in properties between these elements and the compound sugar.



2.8 Some important compounds

When atoms join to make compounds they form a new substance with entirely new properties. No two compounds have the same properties. Some compounds have properties which make them useful to our society. Some of these compounds, and their uses, are described here.

One of the most useful compounds, and the easiest to obtain, is salt. Its chemical name is sodium chloride. It is obtained in Australia by the evaporation of seawater. Salt is purified by crystallisation. The main use of salt is in making other substances. Only a small amount of it is used in cooking and preparing food.

Sodium hydroxide is made by the electrolysis of seawater. Chlorine is made at the same time. Sodium hydroxide is used in making other chemicals such as soap, paper, bleaches, dyes and is used in processing food, metals and rubber. Sodium hydroxide has the common name of caustic soda. In the home it is used as an oven cleaner and to dissolve blockages in kitchen pipes. Sodium hydroxide is very corrosive.

Hydrogen chloride is a corrosive gas which is made from salt and acid. It is dissolved in water to make hydrochloric acid. Hydrochloric acid has many uses, one being to clean the scale and rust off metals before they are painted. It is also used to clean cement off bricks.

Sulfuric acid is a colourless oily liquid. It is a powerful dehydrating chemical, which means that it removes water from other substances. Sulfuric acid is used to make fertilisers, paints, detergents, soaps, dyes and plastics. It is the acid in car batteries.

Ammonia is a smelly gas made from nitrogen and hydrogen. Almost all the ammonia made is converted into fertilisers such as nitram. Ammonia was once widely used in refrigeration equipment.

Soap is a compound made from the reaction of sodium hydroxide with fats or oils. Soap is soluble in both grease and water. Soap works because it dissolves oil and grease, and then dissolves in the washing water. The soap that you buy has perfumes and colouring substances added.

Many compounds are derived from crude oil. This is a mixture which is separated by fractional distillation. Propane gas, used as a fuel for some (LPG) Bunsen burners and barbecues, is separated from crude oil.

Some of the products from the fractional distillation of crude oil are not valuable. In the process called cracking, more valuable compounds are made. The most important of these is ethene. It is used to make polyethene, or polythene, plastics. Most plastic goods including clingwrap are polythene. Ethene also makes solvents, additives to make petrol burn better in engines, and other plastics such as polystyrene and PVC.

Sand is easy to obtain although it has to be washed before it can be used. It is used in the construction of buildings. It goes into making mortar and concrete. Sand grains are very hard and sand is used as an abrasive (= rubs away other substances), such as on sandpaper and sand blasting.

Carbon dioxide is a gas in the air. Breathed-out air contains carbon dioxide which is also made by burning fossil fuels. Pure carbon dioxide has many uses. It can be solidified to make dry ice. Dry ice is used to keep food cold and also makes the mist effect on the stage in plays and concerts. Carbon dioxide is also packed into some fire extinguishers.

Dry ice (solid carbon dioxide) is used to make mist for stage performances

Aspirin and soap are two important compounds

Water is an abundant and important compound. Water on the Earth is rarely found pure because it is a good solvent. Solutions in which water is the solvent are said to be aqueous. The biggest aqueous solution is the oceans which are rich in salt. Two-thirds of the weight of a person is water. Water moves around the environment through the water cycle.

The sugar on the table at home has the chemical name of sucrose. It is extracted from sugar cane or sugar beet. It is used as a sweetener. There is a lot of sugar in some foods, such as soft drinks. White sugar is extremely pure, while raw sugar has many impurities.

Nylon is an important compound belonging to a group of compounds called polymers. A polymer is made from many small compounds joined end-to-end. All plastics are polymers. Cotton and wool are impure natural polymers. Nylon is made in factories from the chemicals in crude oil.

Aspirin is a compound which is used as a medicine. When aspirin is taken it is absorbed through our stomach and carried in the blood stream. Aspirin interacts with the compounds in our body which cause swelling and a rise in our body temperature.

Rubber is a compound obtained from the sap of rubber trees. Natural rubber is elastic and soft. The rubber in car tyres has been treated with sulfur to make it hard and durable (long lasting). Rubber can also be made in factories using the chemicals which come from crude oil.

Many chemicals which once could only be obtained naturally can now be made in factories. An example is rubber. Initially all the world's rubber came from rubber trees growing in the topics. During World War Two chemists worked out a way of making synthetic (factory-made) rubber.

By combining elements in different ways chemists have been able to make a large number of compounds. Knowledge of elements and compounds has allowed chemists to make new compounds with the special properties needed by our society.

CHECKPOINT:

COPY AND COMPLETE

When ______ join to make __________ they form a new substance with entirely new __________. No two __________ have the same __________.

By combining __________ in different ways _________ have been able to make a large __________ of compounds. Knowledge of __________ and __________ has allowed chemists to make new compounds with the ________ ________ needed by our _______.

QUESTIONS

1 What is the difference between an element and a compound?

2 What compound is dry ice?

3 What is a polymer? What is the other name for this group?

4 What is the difference between natural and synthetic? Is nylon synthetic? Explain.

5 Why can such a large number of compounds be made from only one hundred elements?

Review and Research

Review questions

1 Are these statements true or false? If false, what is the mistake?

- **a** An element cannot be changed into simpler substances.
- **b** Burning toast is a physical change.
- **c** Soluble substances will not dissolve.
- **d** All metals (except mercury which is a liquid) are malleable.
- **e** Every element is a metal.
- **f** A physical change makes a new substance with new particles in it.
- **g** Every non-metal is a solid.
- **h** Using electrical energy to make a chemical change is called electricity.
- **i** The abbreviation of the name of an element is called its sign.
- **j** There are two big groups of metals, called elements and non-metals.

2 Match each element to the correct statement below. The answers (mixed up) are oxygen, hydrogen, sulfur, phosphorus, carbon, chlorine, iron, and magnesium.

- **a** black solid, also called soot and charcoal
- **b** yellow solid, burns to make poison gas, used to kill pests in gardens
- **c** hard shiny metal, goes rusty in air, makes cars and refrigerators
- **d** colourless gas, lets us breathe and helps things burn
- **e** yellow-green poison gas, kills bacteria in swimming pools
- **f** deep-red solid, burns easily, is the red solid on match heads
- **g** shiny metal, burns with a bright white flame
- **h** colourless gas, explosive, tested with the pop test

3 Which of these are physical changes, and which are chemical changes?

- **a** burning toast
- **b** ice cream melting
- **c** milk going sour
- **d** dynamite exploding
- **e** toaster element getting hot
- **f** gas burning on a stove
- **g** clothes drying on the line
- **h** sugar dissolving in water
- **i** iron rusting
- **j** an apple rotting away

4 Write the meaning of these words or phrases.

- **a** physical change
- **b** element
- **c** symbol of an element
- **d** compound
- **e** brittle
- **f** malleable

5 In an experiment to find out whether some substances were elements or compounds, Simone heated them in a test-tube. Which are elements and which are compounds?

- **a** green powdery solid, bubbled and turned black
- **b** copper wire, melted and formed a blob on the end
- **c** white crystals, turned yellow and made brown smoke

6 Write the name, with correct spelling, for the elements with these symbols.

a C	**b** P	**c** N
d H	**e** O	**f** Cl
g Ca	**h** Al	**i** Mg
j Fe	**k** Na	**l** Cu
m Zn	**n** Pb	**o** S

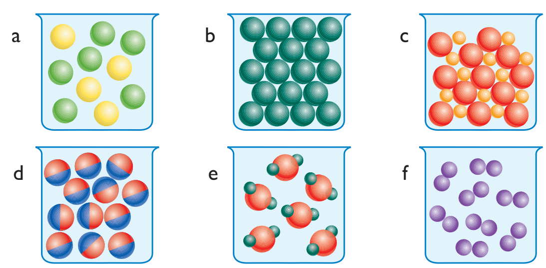
7 Complete the table of comparisons of properties of these elements and the compounds they form.

Property	*Carbon*	*Hydrogen*	*Oxygen*	*Cooking oil*
Symbol or formula				
State				
Colour				
Flammability				
Feel				

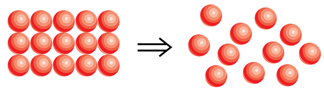
8 Elements have been classified as metals or non-metals. Why was this division selected instead of name, colour or physical state of the elements?

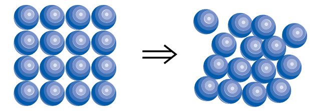
Thinking questions

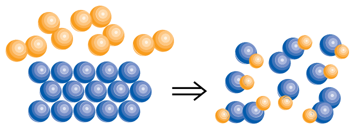
1 State whether each of the drawings drawn below represents an element, a compound or a mixture.

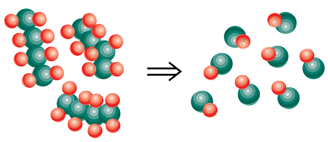


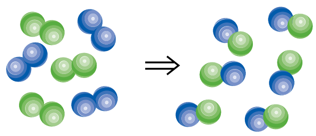
2 The drawings below represent physical changes and chemical changes. Write whether each is a physical or chemical change, giving a reason in each case.

a 

b 

c 

d 

e 

Research questions

1 Find out how to make one of these important chemical substances. Write a one page description and draw a diagram to show the steps in the process. Select from the following substances.

a iron
b chlorine
c sodium hydroxide
d aluminium
e copper
f hydrochloric acid
g sulfuric acid
h ammonia
i ethene
j carbon dioxide
k soap
l another substance that your teacher approves

2 There have been many important chemists whose work has helped us understand elements and compounds. Write a one-page summary of the life and discoveries of one of these famous chemists. Select from Humphry Davy, Hennig Brand, Jöns Jacob Berzelius, Carl Scheele, Joseph Priestley, Michael Faraday.

3 Choose one element and find out how it was discovered. Do not select an element which has been known since ancient times. Check with your teacher before you start.

Extension experiment

AIM: To identify unknown substances

Your teacher will give you four small containers labelled A, B, C and D. In these containers will be four white powders. Use the information in the table at the bottom of the page, and your experimental skill and knowledge, to identify each of the four powders.

Word check

dissolve	physical change	chemical change
reaction	chemistry	protection
element	compound	pure
electrolysis	waft	voltameter
symbol	phosphorus	sulfur
lead	chlorine	brittle
lustre	malleable	alchemist
radioactivity	radiation	acid
aqueous		

Concept map

Draw a concept map of the main ideas in this topic.

Substance	*Chemical name*	*Soluble in water?*	*Result of electrolysis*	*Reaction with acid*
Powdered marble or chalk	*Calcium carbonate*	*No*	*None, does not dissolve*	*Fizzes*
Powdered sugar	*Sucrose*	*Yes*	*No effect*	*No reaction*
Powdered salt	*Sodium chloride*	*Yes*	*Produces chlorine*	*No reaction*
X-ray barium	*Barium sulfate*	*Yes*	*None, does not dissolve*	*None, may dissolve slightly*