Matter

Periodic table *and* Elements

Ideas you have met before

Materials

Different substances are made of different materials. Materials have different properties; some are harder than others, some are shinier and some are heavier.

Glass, for example, is a very different material from plastic or metal.

Give reasons, based on evidence from comparative and fair tests, for the use of everyday materials.

In this chapter you will find out

The periodic table

- The chemist's dictionary is called the periodic table.
- The ingredients of the entire Universe are listed in one place.

Elements and compounds

- Atoms of elements combine to form compounds. These compounds have different properties to the elements they contain.
- Compounds are named using chemical formulae. Chemical formulae show us which elements a compound contains and their relative proportions.

Using simple models

- Chemists can represent the building blocks of all materials using simple models and symbols.
- Chemical models and symbols help us understand how elements join and react together to make new materials.

Special materials

- Ceramics, polymers and composite materials have been in use for many thousands of years. Today, many new types of materials are being made, based on the chemistry of these earlier materials. These have exciting applications – such as in racing cars, rockets and modern buildings.

Looking at the periodic table of elements

We are learning how to:

- Navigate the periodic table and identify some elements.
- Identify features of the periodic table and describe how it is organised.
- Explain why the periodic table is useful.

The periodic table lists all the known chemical elements in the Universe. The patterns and trends in the arrangement help chemists explain and predict the behaviour, properties and reactions of all the elements.

Periods and groups

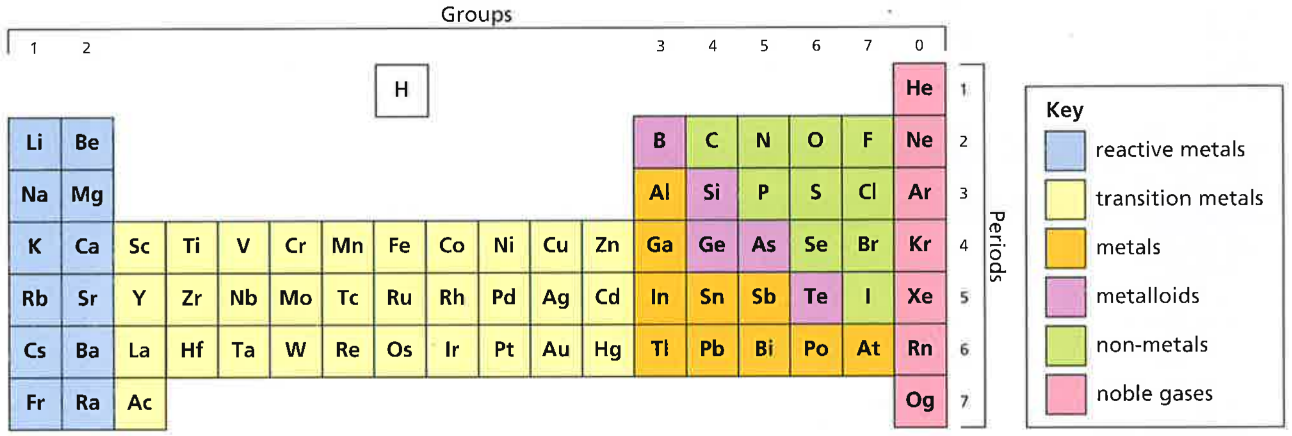

FIGURE 2.5.1a: The periodic table of elements.

The **periodic table** is arranged in rows called **periods** and columns called **groups**. Groups are families of elements with similar properties. Group 1 contains the alkali metals, which all react quickly with water. The halogens are in Group 7; they are good at killing bacteria. The noble gases in Group 0 are all unreactive gases. These characteristics are called chemical trends and patterns.

Another pattern to recognise is that metals are on the left and non-metals, except hydrogen, are on the right. In between are metalloids, which have some of the properties of metals but not all. In the centre of the table are the transition metals. Note, the transition metals are not labelled as separate groups. These contain some of our most used metals such as iron, copper and gold.

1. How many groups make up the periodic table?
2. Name three families of elements.

Did you know...?

The final element for the seventh row in the periodic table was discovered by a Russian-American team of scientists in January 2016. Its suggested name was oganesson (symbol Og) after a Russian scientist.

Atomic number

Each element has a unique number, called its **atomic number**. This number increases from left to right across each period. For example, hydrogen (H) is number 1, helium (He) is number 2, lithium (Li) is number 3 and boron (B) is number 4. This increasing atomic number is an important pattern in the periodic table.

3. Describe how the elements are arranged in the periodic table.
4. Use the periodic table to answer these questions:
   a) In which group would you find carbon (C)?
   b) In which period would you find magnesium (Mg)?

Building the periodic table

Reihen	Gruppo I. — R^2O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

FIGURE 2.5.1b: An early periodic table showing gaps w identified.

John Dalton first defined elements in terms of their different atoms in 1807. Dmitri Mendeleev was the first to publish a periodic table of elements, in 1869, basing it on the properties of the elements. His table contained 64 elements with gaps for new elements that had not yet been discovered. All these gaps have now been filled and new elements have only been produced by smashing lighter atoms into each other. These man-made elements contain very heavy, unstable atoms that often exist for less than a second before breaking down.

5. How do you know that there are no more naturally occurring elements to be discovered?
6. Why might some people say that artificial elements are not true elements?

Know this vocabulary

periodic table
period
group
atomic number

Exploring metals in the periodic table

We are learning how to:

- Describe the physical properties of Group 1 metals.
- Describe the pattern in reactions of Group 1 metals.
- Use data to predict the reactivity and position of metals within the periodic table.

Almost 75% of elements are metals. Of the many metals, only a small fraction have properties that make them useful to our everyday lives. The periodic table can help us to see patterns in the properties of the many metals.

FIGURE 2.5.2a: What physical properties make these metals useful?

Metals within the periodic table

Metals are found on the left-hand side and centre of the periodic table. Even within the bigger group of metals, there are sub-groups of metals. Look again at Figure 2.5.1a. Going across the periodic table, from left to right, we can see a pattern from reactive metals, transition metals, metals and metalloids before we reach the non-metals. These sub-groups are based on the physical and chemical properties of the elements.

The metals most likely to be familiar to us are the transition metals. Due to the **physical properties** of some of the transition metals, such as being hard, shiny, malleable, ductile and conducting electricity, they are used in everyday life.

The way that elements react with other elements describes their **chemical properties**. Precious metals such as gold, silver and platinum are extremely unreactive, and this chemical property makes them useful as jewellery.

Did you know...?

Mercury is sometimes called quicksilver and is the only metal that is liquid at room temperature. It was named after the Roman messenger of the gods. Its symbol Hg is derived from the Greek word hydrargyros, which means silver water.

1. List the sub-groups of metals within the periodic table.
2. Suggest why we use transition metals more often than we would use other groups of metals, such as reactive metals.

Properties of Group 1 metals

Group 1 metals, such as lithium, sodium and potassium, are very soft metals and they can be cut with a knife. They have very low melting points and boiling points compared with most other metals. They also have low densities and some of them will float on water.

The Group 1 metals are extremely reactive compared with other metals. They will react with the air and the shiny silver colour becomes tarnished quickly after cutting. They react with water and are also known as the **alkali metals** because they react with water to form an alkaline solution.

FIGURE 2.5.2b: Sodium is a soft reactive metal.

3. Make a table to show the chemical and physical properties of the Group 1 metals.
4. Group 1 metals are stored under oil and must not be handled without gloves; suggest why.
5. Suggest why Group 1 metals are not used to make jewellery or in buildings.

FIGURE 2.5.2c: Potassium is a very reactive metal.

Group 1 patterns

Within Group 1, there are patterns in the physical and chemical properties of the metals. Figure 2.5.2d shows the melting points and boiling points of the Group 1 metals going down the group.

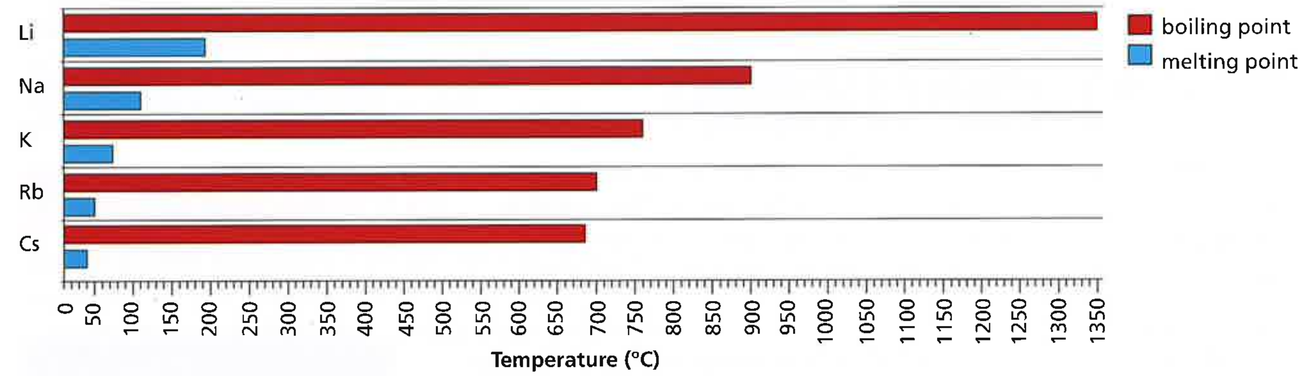

FIGURE 2.5.2d: What is the pattern of melting point and boiling point down Group 1?

Reactivity of the metals increases down Group 1. The reaction of lithium, sodium and potassium with water may be demonstrated in a school laboratory, but the reactions of caesium and francium are too explosive to be safe.

6. Francium comes below caesium, at the bottom of Group 1. Suggest how its melting point and boiling point compare to the other Group 1 metals.
7. Summarise the patterns in some chemical and physical properties of the Group 1 metals.
8. Which of the Group 1 metals would tarnish most quickly when cut? Explain your answer.
9. The table below shows observations of reacting some Group 1 metals with water. Complete the table by predicting how sodium may react.

TABLE 2.5.2

Group 1 metal	Reaction with cold wate
lithium	Metal floated, fizzed steadily until it disappeared.
potassium	Metals floats. Moved around rapidly and set on fire, small explosion at end.

Know this vocabulary

physical properties
chemical properties
alkali metals

Exploring non-metals in the periodic table

We are learning how to:

- Describe the physical properties of the halogens.
- Describe the pattern in reactions of the halogens.
- Use data to predict the reactivity and position of non-metals within the periodic table.

The properties of non-metals are very different to those of metals and so non-metals have very different uses. Understanding the properties of non-metals, such as chlorine and bromine, helps us to understand why certain elements are grouped within the periodic table.

Non-metals within the periodic table

Non-metals are found on the right-hand side of the periodic table, except hydrogen, which is positioned in the middle, see Figure 2.5.1a. There are fewer non-metallic elements than metallic elements. Most non-metals are unreactive gases at room temperature.

Nitrogen gas makes up most of our atmosphere and oxygen gas is vital for animals and plants to generate energy through respiration. Sulfur is a solid at room temperature. It is essential that humans take in sulphur through their diet as it is needed to make proteins.

1. What state are most non-metals in at room temperature?
2. Choose three familiar non-metals from the periodic table and describe a use for each.

FIGURE 2.5.3a: Sulfur has many uses including making car tyres and gunpowder.

Properties of the halogens

Group 7 contains fluorine, chlorine, bromine and iodine, which are known as the **halogens**. Table 2.5.3 shows examples of uses of the halogens.

Bromine is unusual because it is a liquid at room temperature. However, it quickly evaporates to a brown/orange gas. Both bromine and chlorine gas are very harmful if breathed in. Iodine is unusual because when it is heated, the solid turns to a (purple) vapour without becoming a liquid.

'Halogen' means 'salt forming' and they have this name because these non-metals react with metals to form salts. For example, fluorine forms fluoride salts and these are used in toothpastes to strengthen teeth.

FIGURE 2.5.3b: Chlorine, bromine and iodine halogens give off colourful vapours.

TABLE 2.5.3

Halogen	Appearance	Use
fluorine	pale yellow, highly flammable gas	in a compound, is used in toothpastes and added to some drinking water
chlorine	green gas	as a disinfectant, for example in bleaches and in swimming pools
bromine	brown/orange liquid	in pesticides and in making plastics or as a disinfectant in pools
iodine	grey solid	as an antiseptic, sometimes cleaning skin prior to an operation

3. Identify the most reactive halogen.
4. Identify a similar property of chlorine, bromine and iodine.
5. Suggest why chlorine and bromine must be kept in a fume cupboard.

Patterns in Group 7

Displacement reactions can be used to demonstrate that the reactivity of the halogens decreases down the group. In fact, fluorine is so reactive that it isn't used in schools.

Figure 2.5.3c shows the melting points and boiling points of the halogens. Both the melting points and boiling points increase as you go down Group 7.

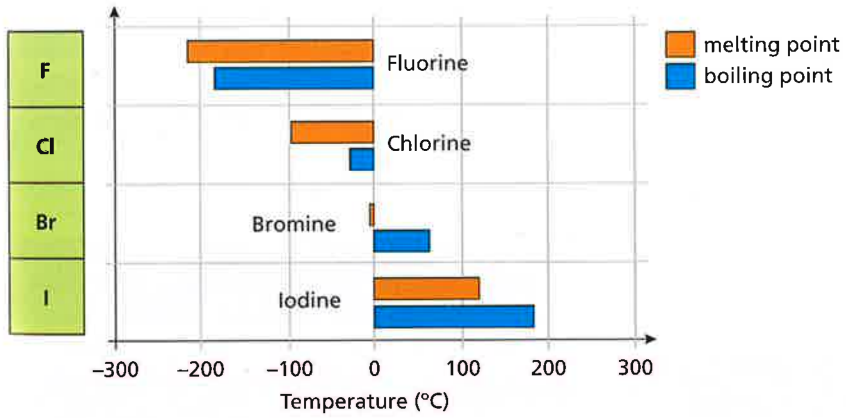

FIGURE 2.5.3c: Is the pattern the same for both melting point and boiling point?

6. Describe the trend in both a physical and a chemical property of the halogens.
7. The element astatine, At, is found underneath iodine in Group 7. Suggest how its:
   a) reactivity and **b)** melting points and boiling points would compare with those of the other halogens.

Did you know...?

Chlorine is named after Greek word for green, 'chloros', because of the colour of the gas. It was used as a weapon in World War 1, poisoning thousands on the battlefield.

Know this vocabulary

halogens

Analysing wider patterns within the periodic table

We are learning how to:

- Sort elements using chemical data and relate this to their position in the periodic table.

It is important that scientists can make good observations and interpret information. They use their knowledge to explain what the patterns in data mean. Understanding patterns within the periodic table can help us to make accurate predictions about elements and their properties.

FIGURE 2.5.4a: Helium balloons float because helium is less dense than air.

Knowing the elements

Understanding the structure within the periodic table can help us to predict the properties of other elements within that group. That can then help us to decide whether an element may be useful for a particular purpose. Group 1 metals are extremely reactive and so we would not consider using them for pipes, jewellery or in construction. Transition metals are often hard and conduct electricity, so we have many uses for them. Group 7 contains the halogens which are coloured elements, some of them commonly used as disinfectants or antiseptics. Group 0 consists of the seven **noble gases**. These are all colourless, odourless, unreactive gases. As they are unreactive, they can be used to stop other elements reacting with each other.

Did you know...?

Gold jewellery and silver coins are 'fake'! Nine carat gold is less than half gold, because pure gold is too soft. 50p coins are 75 per cent copper and 25 per cent nickel, which is cheaper and harder than silver.

1. Describe where on the periodic table you would look to identify:
   a) an unreactive gas
   b) a reactive metal to make jewellery
   c) a coloured gas.

Exploring patterns across the periods

We can use data to compare physical properties across a whole period. Table 2.5.4a shows data linked with the elements in Period 2. This shows that both **melting point** and boiling point increases across the metals and then decreases across the non-metals. As we know that the noble gases are extremely unreactive, we can assume that reactivity decreases moving across periods from Group 7 to Group 1.

Element	Symbol	Melting point	Boiling point
lithium	Li	180 °C	1347 °C
beryllium	Be	1278 °C	2970 °C
boron	B	2300 °C	2550 °C
carbon	C	3500 °C	4827 °C
nitrogen	N	−210 °C	−196 °C
oxygen	O	−219 °C	−183 °C
fluorine	Fl	−220 °C	−188 °C
neon	Ne	−249 °C	−246 °C

TABLE 2.5.4a: Melting points and boiling points of the elements in Period 2.

2. Plot a graph of melting point and boiling point of elements in Period 2 (Table 2.5.4a). Can you identify any elements that do not fit the trend?
3. The Group 1 metals are extremely reactive. Fluorine in Group 7 is very reactive and the other halogens are reactive, too. Use this information to suggest the pattern in reactivity across the periods.

FIGURE 2.5.4b: Gallium is a metal that melts in your hand.

Predicting properties and positions

We can use data to predict which group an element belongs to by comparing data from other known elements. For example, if we have an unidentified coloured gas, we may begin by investigating whether it sits within Group 7 as it has a similar appearance to the halogens. Further tests could then be carried out to determine other properties, such as those listed in Table 2.5.4b.

Element	Group/ position	Conducts heat	Conducts electricity	Melting point (°C)	Density (g/cm³)	Other properties
graphite	Group 4	not well	yes	3730	2.25	brittle
X		no	no	−270	0.15	inert
lead	Group 4	yes	yes	327	11.30	poisonous
aluminium	Group 3	yes	yes	660	2.70	protective layer
hydrogen	above period 1	no	no	−259	0.07	flammable
Y		yes	very well	961	10.50	shiny
gallium	Group 3	yes	yes	30	5.91	poisonous
Z		yes	yes	98	0.97	very reactive
iron	transition metal	yes	yes	1535	7.86	rusts
copper	transition metal	yes	very well	1083	8.92	non-**toxic**

TABLE 2.5.4b: Properties of some common elements.

4. Use information in Table 2.5.4b to predict which region or area of the periodic table each of the elements X, Y, Z are likely to be found in. Explain your reasoning.
5. Use the information here and the periodic table in Figure 2.5.1a to compare:
   a) helium and chlorine
   b) iodine and chlorine
   c) bromine and argon
   d) metals and non-metals.

Know this vocabulary

noble gas
melting point
density
toxic

Combining elements

We are learning how to:

- Explain what is meant by a compound.
- Recognise how compounds are formed and named.
- Interpret the ratio of atoms and formula of compounds.

Elements can combine together to form new compounds with different properties from the original elements. This is why there is such a variety of substances made from only 92 naturally occurring elements.

FIGURE 2.5.5a: Bricks can be combined to build a house just as elements combine to form compounds.

Using models

The building bricks in Figure 2.5.5a can be joined together to create many different structures. Each structure has a different number or type of bricks joined in a particular way. There are only certain ways in which the bricks can join. This is a good model to explain how **atoms** of an **element** join to create different **compounds**.

1. How does the house model help explain why there are many different materials but relatively few elements?

TABLE 2.5.5a

Name of element	Symbol
hydrogen	H
oxygen	O
nitrogen	N
carbon	C
iron	Fe
zinc	Zn
copper	Cu
sulphur	S
aluminium	Al
iodine	I
bromine	Br
chlorine	Cl
sodium	Na
potassium	K
magnesium	Mg

Elements, molecules and compounds

In Topic 5.1 we saw how the periodic table lists all of the elements. Elements are the chemical building blocks of materials. Each element is made up of only one type of atom. Sometimes atoms of the same element combine to form a molecule.

Molecules of an element may contain two to thousands of the same type of atom joined together. Examples are hydrogen and oxygen. Both hydrogen and oxygen molecules contain two atoms (Figure 2.5.5b). They have the formulae H_2 and O_2.

When atoms of different elements combine they form a compound. A compound is a pure substance made up of two or more elements strongly joined together.

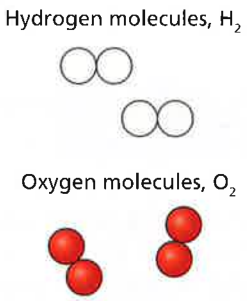

FIGURE 2.5.5b: Atoms of hydrogen and oxygen combine to form molecules.

2. What is the difference between elements and compounds?

3. Which elements make up the sugar glucose ($C_6H_{12}O_6$)?

Chemical formulae

The **chemical formula** of the compound represents which elements are present in the compound as well as the **ratio** of atoms in each unit of the compound.

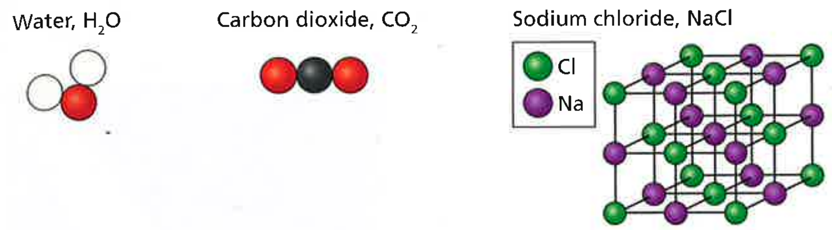

FIGURE 2.5.5c: Chemical formulae of compounds shown using circle pictures.

There are rules that help us to understand and write the names of compounds. When non-metals form a compound, their name changes to end in '-ide'.

TABLE 2.5.5b: How many atoms of each element are in a molecule of carbon dioxide?

Element	Compound name	Example	Proportion of atoms
chlorine	chloride	sodium chloride, NaCl	1 sodium: 1 chlorine
oxygen	oxide	carbon dioxide, CO_2	1 carbon: 2 oxygen

The name of the compound sometimes gives a clue to the ratio as well as the elements that make it. When each carbon atom combines with two oxygen atoms, carbon dioxide is formed. 'di' tells us that two oxygen atoms are included. One carbon atom can also combine with one oxygen atom to form carbon monoxide, CO. The prefix 'mono' tells us that one oxygen atom is involved. The prefix 'tri' would suggest three atoms were contained in each molecule of the compound. Table 2.5.5c shows the formula to represent each of sodium hydroxide, sulfate, nitrate and carbonate compounds.

TABLE 2.5.5c: What are the formulae to represent sulfate, nitrate and carbonate?

Compound	Formula	Elements present	Proportion of atoms
sodium hydroxide	NaOH	sodium, oxygen, hydrogen	1:1:1
sodium nitrate	$NaNO_3$	sodium, nitrogen, oxygen	1:1:3
copper sulfate	$CuSO_4$	copper, sulfur, oxygen	1:1:4
copper carbonate	$CuCO_3$	copper, carbon, oxygen	1:1:3

4. How do the names of compounds help us understand what they are made of?

5. What is the difference between oxygen and an oxide?

6. Use chemical formulae and models to explain how carbon monoxide and carbon dioxide are different.

Did you know...?

Many compounds contain the elements carbon, hydrogen and oxygen, CHO. These are known as carbohydrates and are an essential energy source. We can break the name down to work out what it contains: 'carbo', 'hydr' 'ate'. The 'ate' ending tells us that the compound contains oxygen.

Know this vocabulary

atom
element
compound
chemical formula
ratio

Comparing elements and compounds

We are learning how to:

- Describe the properties of elements and the compound that they form.
- Compare the properties of elements with the properties of the compounds that they form.

Iron is a shiny silver metal. When iron combines with oxygen and water from the air, rust is formed; its chemical name is iron oxide. Iron oxide is very different to both iron and oxygen. Are compounds always different to the elements from which they are formed?

FIGURE 2.5.6a: Gold can be melted and solidified many times.

Chemical changes

We heat gold to make it into new shapes. The gold melts but it does not react with any other element. This is a physical change and no new **products** are made.

When elements react to form new compounds, chemical changes take place. The reaction is irreversible. Burning is an example of a chemical change to produce a compound from an element. During burning, elements combine with oxygen to form an oxide.

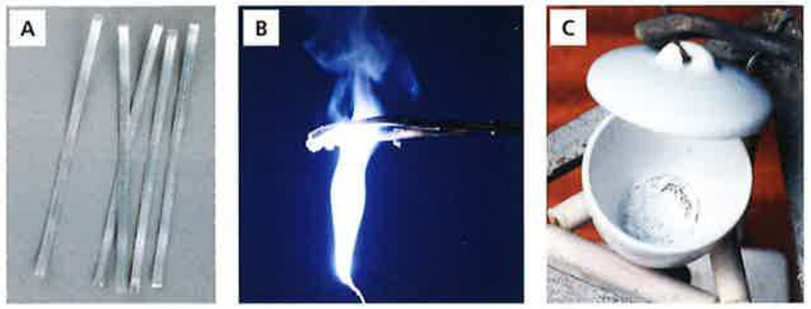

FIGURE 2.5.6b: When a strip of magnesium (A) is heated in air (B) it glows bright white and leaves a white powdery ash (C).

1. What is the difference between a chemical change and a physical change?
2. How do you know that gold does not burn?

Observing elements and compounds

Consider the elements copper metal, magnesium strip and iron powder (iron filings). See Figure 2.5.6c.

We can observe these elements and compare them to the compounds formed by heating. When we make observations, it is good practice to plan the information that will be gathered before making observations. For example, you could prepare a table to record the state, colour, appearance and whether it is magnetic. Table 2.5.6 shows some properties of elements and the compounds that they form when burned in air.

FIGURE 2.5.6c: How would you describe these elements?

TABLE 2.5.6: Observations allow us to compare elements and the compounds that they form.

Element/ compound	Colour	Appearance	Magnetic
copper	red/orange	soft metal	no
copper oxide	black	powder	no
magnesium	silver/ white	soft metal	no
magnesium oxide	white	powder	no
iron	silver grey	large particles	yes
iron oxide	black	powder	no

Health and safety must also be considered when carrying out chemical reactions. Safety notes should be checked and used to make a risk assessment. Once the risks have been considered, a decision should then be made on whether the activity should go ahead and what precautions will be taken.

3. What evidence suggests that a new product is formed when heating iron?
4. Suggest what new product may be formed when potassium is heated in oxygen.
5. Sodium is a highly reactive, soft metal. It combines with chlorine to form sodium chloride. How does sodium chloride differ from sodium?

Explaining observations

When magnesium is heated, the new compound has a different appearance to the original element. We can show the reaction using a word equation:

Magnesium + oxygen → magnesium oxide

REACTANTS PRODUCTS

Two atoms of magnesium react with one molecule of oxygen to produce two units of magnesium oxide. The number of atoms of each element must be the same on both sides of an equation – this is called a balanced equation.

6. Use word equations to explain the reactions between oxygen and:

   a) iron **b)** copper.

7. Write a symbol equation for the reaction between copper and oxygen. Try to balance the equation.

Did you know...?

Cellulose is the most abundant compound made from plants.

Student Safety Sheet

MAGNESIUM

HAZARDOUS

- Highly flammable

Comment

It is moderately difficult to ignite but, once burning, it does so very vigorously and is difficult to extinguish. Ordinary fire-fighting methods are not suitable, but dry sand may be used. The flame is very bright and may damage eye sight.
It reacts readily with acids to produce hydrogen, an extremely flammable gas.

Typical control measures to reduce risk

- Conduct all experiments on a small scale.
- Wear eye protection and avoid looking directly at the flame from burning magnesium.

FIGURE 2.5.6d: Hazard information for magnesium. What safety precautions should be taken when heating magnesium?

$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

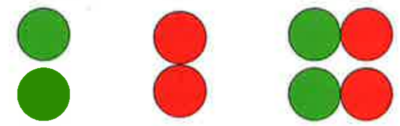

FIGURE 2.5.6e: Magnesium and oxygen react to form magnesium oxide.

Know this vocabulary

product
reactant

Exploring polymers

We are learning how to:

- Describe what a polymer is, using examples.
- Explain how the properties of polymers relate to their function.

Polymers have been around since the start of life. Natural polymers make up the constituents of organisms. The usefulness of polymers in nature has inspired people to imitate their chemistry. What makes polymers so special?

FIGURE 2.5.7a: This beetle has a hard covering of a polymer called chitin.

What is a polymer?

Polymers can be found in nature. They are chemicals made of long chains of repeating chemical units – the repeating molecule is called a **monomer**. One of the most familiar natural polymers is **starch**. Plants store glucose in the form of starch – glucose is its monomer.

Synthetic polymers were only first developed in the 1900s. In the development of synthetic polymers, carefully selected monomers were heated under great pressure. Catalysts were added until, almost by chance, polymers were made. **Polythene** is a synthetic polymer which has many uses. It is a type of plastic.

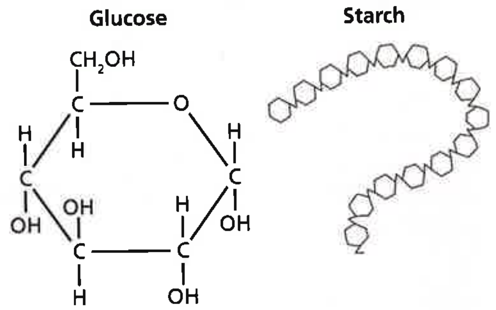

FIGURE 2.5.7b: Starch is made up of many glucose monomers.

1. Polymers can be broken down to the molecules they are made from. Is this a physical or a chemical change?
2. What are the similarities between synthetic polymers and natural polymers?

Uses of polymers

Plants store glucose as starch, which is insoluble in cold water – this means that starch can be stored within plants. Glucose, however, is soluble in cold water. When a plant needs glucose, enzymes break bonds in the starch. This releases glucose molecules for the plant to use. **Cellulose** is another polymer that is also formed from the glucose monomer. Cellulose is found in plant cell walls. Proteins are one of the most important natural polymers. They are made from amino acid monomers.

Most synthetic polymers are derived from monomers that come from crude oil. They are mostly made of carbon and hydrogen.

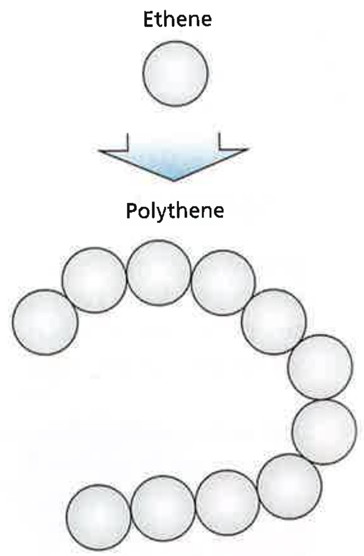

FIGURE 2.5.7c: Polythene can be made from its monomer, ethene.

3. Why is it useful to store small molecules (such as glucose) in the form of polymers (such as starch)?
4. Plants store sugar in the form of starch; animals store it in the form of glycogen. What prediction(s) can you make about glycogen?
5. Describe some examples of uses of synthetic polymers in place of metals.

TABLE 2.5.7: Uses of some polymers.

	Name of polymer	Uses of polymer
Natural polymers	starch	storage of glucose in plants
	cellulose	strengthening of cells wall in plant cells
	protein	many uses, for example, enzymes, muscle fibres, haemoglobin in red blood cells.
Synthetic polymers	polythene	plastic bags, plastic containers, cling film, plastic milk bottles
	polystyrene	packaging, model kits, containers
	acrylics	aircraft canopies, covers for car lights
	nylon	ropes, fabrics, gear wheels
	polypropene	ropes, containers
	polychloroethene	water pipes

Linking structure to function

Polymers have very large molecules. Their structure often has a particular shape that provides them with particular properties. The arrangement of particles within a polymer defines this shape.

Many natural polymers are strong because of the number of chemical bonds within their structure. Some are elastic, like muscle fibre and rubber.

By understanding the chemistry of synthetic polymers, scientists have found ways to improve on their properties. Rubber tyres are an example of a natural product being improved. By adding small amounts of sulfur to natural rubber, the material becomes much stronger than rubber and can be used to make tyres.

6. Do you think that polymers are chemically the same as the monomers that make them? Explain your answer.

Did you know...?

Kevlar is a synthetic polymer used to make bulletproof vests. Its strength comes from many strong intermolecular bonds between the polymer chains.

Know this vocabulary

polymer
monomer
starch
polythene
cellulose

Exploring ceramics and composites

We are learning how to:

- Describe what is meant by ceramic and composite, using examples.
- Explain how the properties of ceramics and composites relate to their function.

Ceramics and composite materials have been in use for centuries, demonstrated in ancient ceramic pots and mud bricks. Both of these materials have been developed hugely over time, providing a wider range of uses. Could ceramics and composite materials one day replace our need for metals?

What are ceramics and composites?

Ceramics are probably the most widespread materials in use today. A ceramic is an inorganic (non carbon-based), non-metallic solid. It is prepared by the action of heat followed by cooling. Ceramics are used for making tiles, glass, bricks, plates, vases and ornamental objects, and also in dentistry.

Composites are formed when two or more materials, often with different properties, are combined. The composite material is usually stronger than, more durable than or has other desirable properties not found in the original materials. The materials involved are often not chemically combined within the composite. Examples of composites are concrete, carbon fibres and bone (a natural composite).

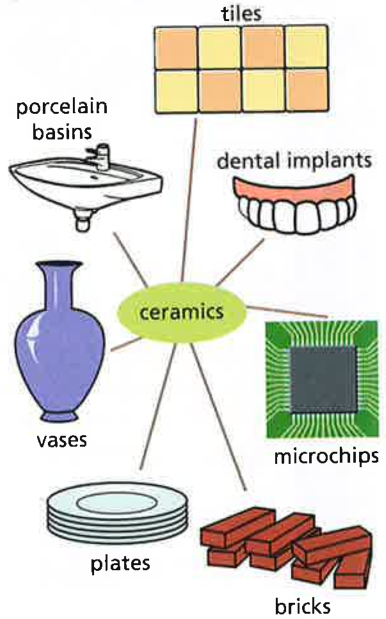

FIGURE 2.5.8a: Some of the uses of ceramics.

1. List three items made from ceramics in your home.
2. Ceramic materials have been uncovered from earliest human history. What does this tell you about the nature of ceramics?

Developments in ceramics and composites

Clay and sand were important in early ceramics. Nowadays, hardly any natural materials are used and advanced ceramics are based on oxides such as aluminium oxides and carbides such as boron carbide. The ingredients can be manipulated to ensure specific properties, but generally ceramics are:

- hard and resistant to wear
- relatively light
- brittle – they can break easily if a force is applied
- thermal insulators – they keep heat in
- electrical insulators – they do not allow electric current to pass through
- non-magnetic
- chemically stable – they do not break down in air
- non-toxic – they can be used for food and drink
- non-ductile – they cannot be drawn out into wire.

Did you know...?

Formula One racing cars are made almost entirely of carbon fibre. Each costs over one million dollars to build.

FIGURE 2.5.8b: A racing car made from carbon fibre.

Human-made composites are relatively new. Many of them are based on combinations of plastic, ceramic and metal materials with different materials added to reinforce (make stronger) the composite, such as glass and carbon fibres.

FIGURE 2.5.8c: Denver International Airport is made from fibreglass.

3. Draw a table to compare the properties of ceramics with metals.
4. Glass and carbon fibres are strong and lightweight. What makes glass and carbon fibres a popular choice as reinforcers?

Linking structure to function

Both ceramics and composites are challenging metals used in some applications. Advanced applications of ceramics include high temperature parts for aeroplane engines, turbo-jet engine blades and missile nose cones.

Composites such as carbon fibre are used in making car, aircraft and spacecraft bodies and in the manufacture of bikes. Table 2.5.8 compares some properties of composites with those of metals.

TABLE 2.5.8

Type of material	Material	Density (g/cm^3)	Strength (MPa)*	Strength/ weight ratio
composite	fibreglass	1.9	3400	1307
composite	carbon fibre	1.6	4300	2457
metal	aluminium	2.8	600	214
metal	stainless steel	7.86	2000	254
composite	concrete	2.3	12	4.35

*The pressure needed to squash the material until it breaks.

5. Suggest why ceramics may be chosen over metals to make turbo-jet engine blades.
6. What conclusions can you draw from the data in Table 2.5.8?

Know this vocabulary

ceramics
composites

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

☐ Give some examples of elements, locate them in the periodic table and use the table to identify metals and non-metals.	☐ Give examples of elements and explain how they are organised in the periodic table.	☐ Define elements, and link the organisation of the periodic table to element features and explain how scientists organised the periodic table.
☐ Recall that Group 1 contains metals with similar chemical and physical properties, the alkali metals. Name some examples of alkali metals.	☐ Describe the properties of the Group 1 metals as soft, reactive metals. Explain how their properties affect their uses. Recall that there are patterns of some properties within Group 1.	☐ Identify patterns in the chemical and physical properties of the Group 1 metals, for example, melting point, boiling point and reactivity. Use data to place an unknown element within Group 1 and make predictions about properties of elements within the group.
☐ Recall that Group 7 contains gases with similar chemical and physical properties, the halogens. Name some examples of halogens.	☐ Describe the properties of the Group 7 halogens as colourful gases that react with other elements to form salts. Describe uses of the halogens. Recall that there are patterns of some properties within Group 7.	☐ Identify patterns in the chemical and physical properties of the Group 7 halogens, for example, melting point, boiling point and reactivity. Use data to place an unknown element within Group 7 and make predictions about properties of elements within the group.

☐ Describe an example of a compound and represent a chemical reaction using a simple model.	☐ Explain how compounds can be formed and explain a chemical reaction using simple models.	☐ Make links between simple models of compounds and chemical symbols.
☐ Define elements, atoms and compounds. Recall that elements combine to form compounds and these compounds have different properties to the elements that they contain.	☐ Use chemical formulae to represent simple compounds and identify elements within compounds from their formulae.	☐ Use formulae to determine proportions of atoms of each element present within a compound and predict the names of unfamiliar compounds using formulae and naming rules.
☐ Describe what is meant by 'polymer', 'ceramic' and 'composite' with examples.	☐ Describe the properties of polymers, ceramics and composites, using examples, and relate these to their uses.	☐ Use models to explain how polymers, ceramics and composites are formed and explain how this affects their properties.

Questions

KNOW. Questions 1–11

See how well you have understood the ideas in this chapter.

1. If you were studying an element and wanted to find others with similar properties, should you look: [1]
a) anywhere in the periodic table? **b)** up and down the groups?
c) across the periods? **d)** somewhere else, because the periodic table won't help?

2. The halogens are found in: [1]
a) Group 1 **b)** Group 2 **c)** Group 7 **d)** Group 0

3. Choose two correct descriptions of the alkali metals: [2]
a) soft **b)** inert **c)** reactive **d)** used in construction.

4. Name the most reactive halogen and describe the pattern in reactivity down Group 7. [2]

5. Describe how the periodic table is organised. Refer to both 'periods' and 'groups'. [2]

6. Which of the following is a natural polymer? [1]
a) cement **b)** protein **c)** plastic **d)** brick.

7. What does the formula of carbon dioxide, CO_2, tell us about each molecule? [1]
a) It has one atom of carbon and one of oxygen.
b) It has two atoms of carbon and one of oxygen.
c) It has one atom of carbon and two of oxygen.
d) It has two atoms of carbon and two of oxygen.

8. Describe the difference between a polymer and a composite. [2]

9. Compounds formed with oxygen, such as iron and oxygen, have the general name: [1]
a) oxide **b)** oxate **c)** oxite **d)** oxalate.

10. The word 'sulfate' is represented by the formula: [1]
a) SO_3 **b)** SO_4 **c)** SOH **d)** SOH_4

11. Explain why ceramics and composites are replacing metals in some uses such as making aircraft parts. [2]

APPLY. Questions 12–16

See how well you can apply the ideas in this chapter to new situations.

12. An unknown element is described in the box.

Which group in the periodic table is the element likely to be found in? Explain your answer. [2]

> Conduct heat – no
> Conduct electricity – no
> State at room temperature – gas
> Reactivity – inert
> Density – low

13. Explain why a regular pattern may not be seen in melting point across Period 4 (from Group 1 to 0). [2]

14. Which of the circle pictures in Figure 2.5.10a represents methane, CH_4? (Carbon is represented by the black circles and hydrogen by the grey.) [1]

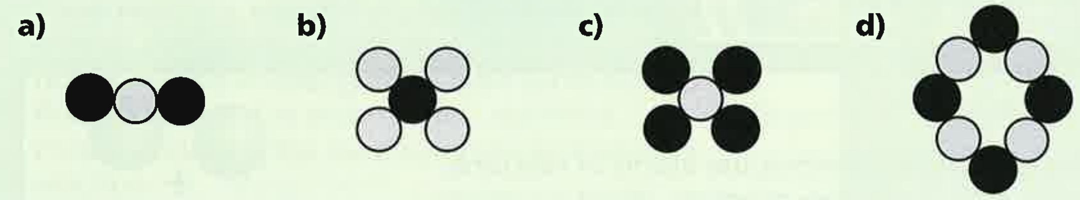

FIGURE 2.5.10a

15. Draw diagrams to show the difference between a molecule of oxygen and a molecule of carbon dioxide. [2]

16. A metal is heated in pure oxygen. State 2 observations that would suggest that a compound has been formed. [2]

EXTEND. Questions 17–18

See how well you can understand and explain new ideas and evidence.

17. A student carried out reactions to work out the order of reactivity of four elements in one group, W, X, Y and Z. He reacted each element with compounds of the other elements. His results are shown below.

	W compound	X compound	Y compound	Z compound
W		No reaction	Reaction	No reaction
X	Reaction		Reaction	Reaction
Y	No reaction	No reaction		No reaction
Z	Reaction	No reaction	Reaction	

TABLE 2.5.10

a) Use these results to place the elements in the group in order of reactivity from most to least reactive. Explain your answer. [2]

b) The student then reacts each of them with water. How could his observations of the reactions with water help him to be sure that these elements are all in the same group? [1]

18. Figure 2.5.10b shows four substances: iron, sulfur, a mixture of iron and sulfur, and iron sulfide. Iron sulfide is formed by a chemical reaction that takes place when sulfur and iron are heated together. Draw and label a circle picture to represent each of the four substances. [2]

FIGURE 2.5.10b: Iron (top left), sulfur (top right), iron and sulfur mix (lower left) and iron sulfide (lower right).