4

ELEMENTS, COMPOUNDS AND MIXTURES

We use materials every single day – our cotton sheets, the springs that make up our bed, the cars we drive and the roads we drive on are all made of materials. Every material we use has been selected for that particular job because of the properties it has, such as being weatherproof, soft or flame-resistant. Developments in technology and increased scientific knowledge have changed how we use certain materials.

ELEMENTS 4.1

All substances are made up of particles. The way the particles interact and the nature of the particles themselves determine the properties of substances.

Students:

- describe the properties and uses of some metal and non-metal elements
- identify that our understanding of the structure and properties of elements has changed due to technological advances
- explain why element symbols are used in science

COMPOUNDS AND MIXTURES 4.2

Elements are the basic components of chemistry. All substances are made of elements. There are 92 naturally occurring elements, but the number of different materials we have access to is much larger. How do we have so many different types of substances?

Students:

- describe the differences between elements, compounds and mixtures in terms of type and arrangement of particles
- identify some common compounds

THE IMPACT OF ELEMENTS AND COMPOUNDS ON SOCIETY 4.3

Physical and chemical properties of materials are very important since they determine what the material can be used for. You would not want to wear clothes made up of iron, and you certainly would not want buildings made from cotton! Human culture and society has evolved and developed because of our understanding of elements and compounds.

Students:

- investigate how people in different cultures in the past have used certain substances to their advantage
- investigate how the chemical properties of a substance help determine its use (additional content)

4.1 ELEMENTS

All matter is made up of particles in the form of atoms or molecules. An element is a pure substance – it is made up of only one type of particle. Different elements have different properties due to the specific particles that make them up and the interactions between those particles. These different properties help determine the uses of each element.

PARTICLE AND KINETIC THEORIES OF MATTER

In year 7 you examined the particle model of matter. This section is a quick revision of this concept, as it is very important for our understanding of how elements and compounds behave.

The particle model of matter

For all substances, we can visualise the **particles** they are made of as being tiny balls. By imagining what these tiny balls would do, we are building a model that helps explain why substances behave as they do. These tiny balls are called atoms, and the model we use to visualise them is called the particle model of matter. The key concepts of the particle model are:

- All matter consists of tiny particles called atoms that are too small to be seen, but have mass.
- Atoms cannot be created or destroyed, and atoms are indivisible.
- Particles are always moving. When it is hotter, particles move faster; when it is cooler, particles move slower.
- All atoms of the same **element** are identical, but are different from atoms of other elements.
- Particles can join to make larger particles. When they combine, their masses add together.
- When atoms combine to form **compounds**, each atom keeps its identity.
- Forces hold particles together to stop them from separating.
- Atoms follow these rules in all substances.

The kinetic theory of matter

The particle model of matter is always true. Every observation and every chemistry experiment can be explained with this model. Because it is always true and has huge amounts of scientific evidence to support it, the model is now called a theory. Its full name is the kinetic molecular theory of matter, but it is also known simply as the **kinetic theory** of matter.

In the particle model of matter, the particles are always moving. The word 'kinetic' refers to anything that is moving. 'Molecular' refers to molecules, which are particles made of atoms. You will learn more about molecules later in this chapter (see page XX).

QUESTIONS 4.1.1: PARTICLE AND KINETIC THEORIES OF MATTER

Remember

1 Define the term 'atom'.

2 Explain the main concepts behind the particle model of matter.

3 Explain what the term 'kinetic' refers to in the kinetic theory of matter.

4 Identify the differences between the particle model of matter and the kinetic theory of matter.

Apply

5 The images in Figure 4.1 are models of some aspects of the particle and kinetic theory of matter. Explain what each model is demonstrating.

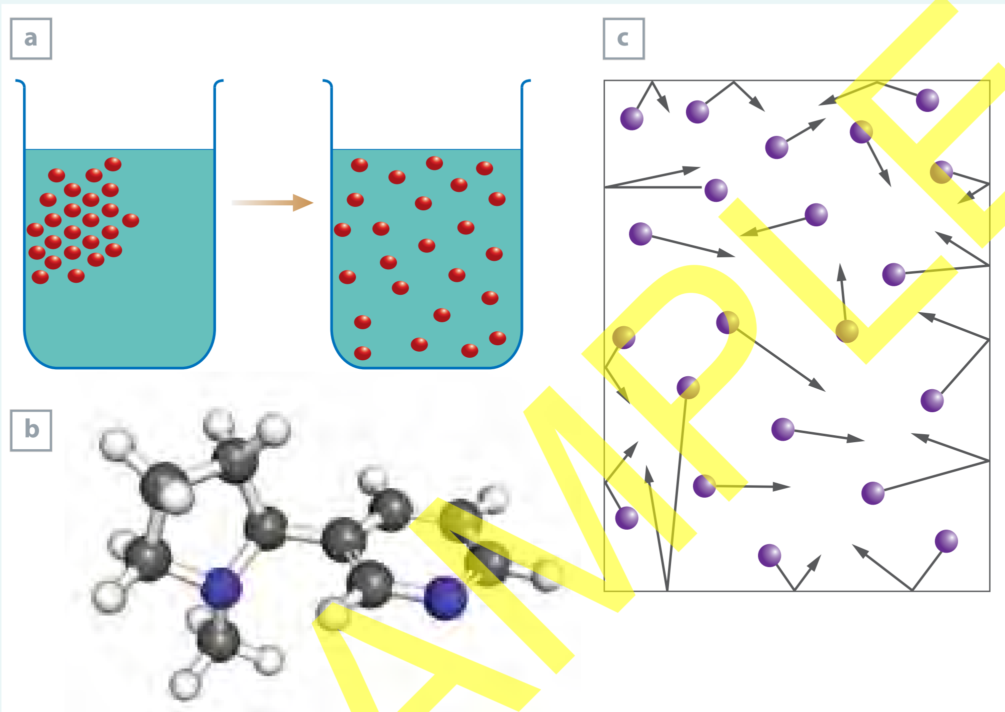

Figure 4.1

ELEMENTS

Elements are substances made up of only one type of atom, and are often referred to as pure substances. If we were to examine every single particle within an element, we would find that each one has the same structure. There are 90 different elements found naturally on the Earth. The smallest atom in terms of mass is the hydrogen atom. The next smallest is helium. Some of the heaviest atoms include those of lead and uranium. Another 20 or so atoms have been made artificially, but these are highly radioactive and are too large to be stable, and therefore they decay (break apart) almost as soon as they are made.

Elements cannot be broken down into other substances because they are already the simplest substances. Elements can be thought of as being 'elementary', which is the origin of the name element. If it was possible to break a lump of gold down to individual atoms, each atom would still be gold.

The differences in the atoms of the different elements explain why different elements have different properties.

Organising elements

The periodic table arranges all the elements in order of the size of their atoms. It also groups together elements with similar properties. Horizontal rows in the table are called **periods**, and vertical columns are called **groups**. Elements in a group often have similar properties, such as the way they look or how they behave.

The main types of elements are **metals**, **metalloids** and **non-metals**. Metals are found on the right-hand side of the periodic table, non-metals are on the left and a thin band of metalloids are between the two. Metalloids are a small set of elements that show properties of both metals and non-metals.

Elements are also classified on the basis of their chemical properties. These include how they react with other substances, such as acids and the oxygen in the air. You will learn more about the chemical reactions of elements in chapter 5.

On the periodic table, elements are represented by their symbols. These symbols consist of one or two letters, often the first one or two letters of the element name. Hydrogen has the symbol H and helium has the symbol He. Other symbols include oxygen (O), carbon (C), nitrogen (N), sulfur (S), gold (Au) and silver (Ag).

DEEPER UNDERSTANDING

The periodic table is an internationally recognisable figure. Scientists worldwide all use the same chemical formula for certain things, even though they may know the elements by a different name. Table 4.1 shows the different names used for the element helium in several different countries.

Imagine the difficulties scientists would have if they were talking about the same element but using their own language. With a common set of symbols, scientists are able to research and discover new information about a substance without repeating each other's research. Collaboration across the scientific community is also easier with a common set of symbols.

Table 4.1 The name for helium in different languages.

Language	Name
English	Helium
Chinese	氦
Spanish	Helio
Arabic	الهليوم
Korean	헬륨
Japanese	ヘリウム
Italian	Elio
Polish	Hel

please note Japanese and Korean use the same font, please check if this is correct

Questions

Choose an element from the periodic table and research:

a what the element is known by in other

overmatter

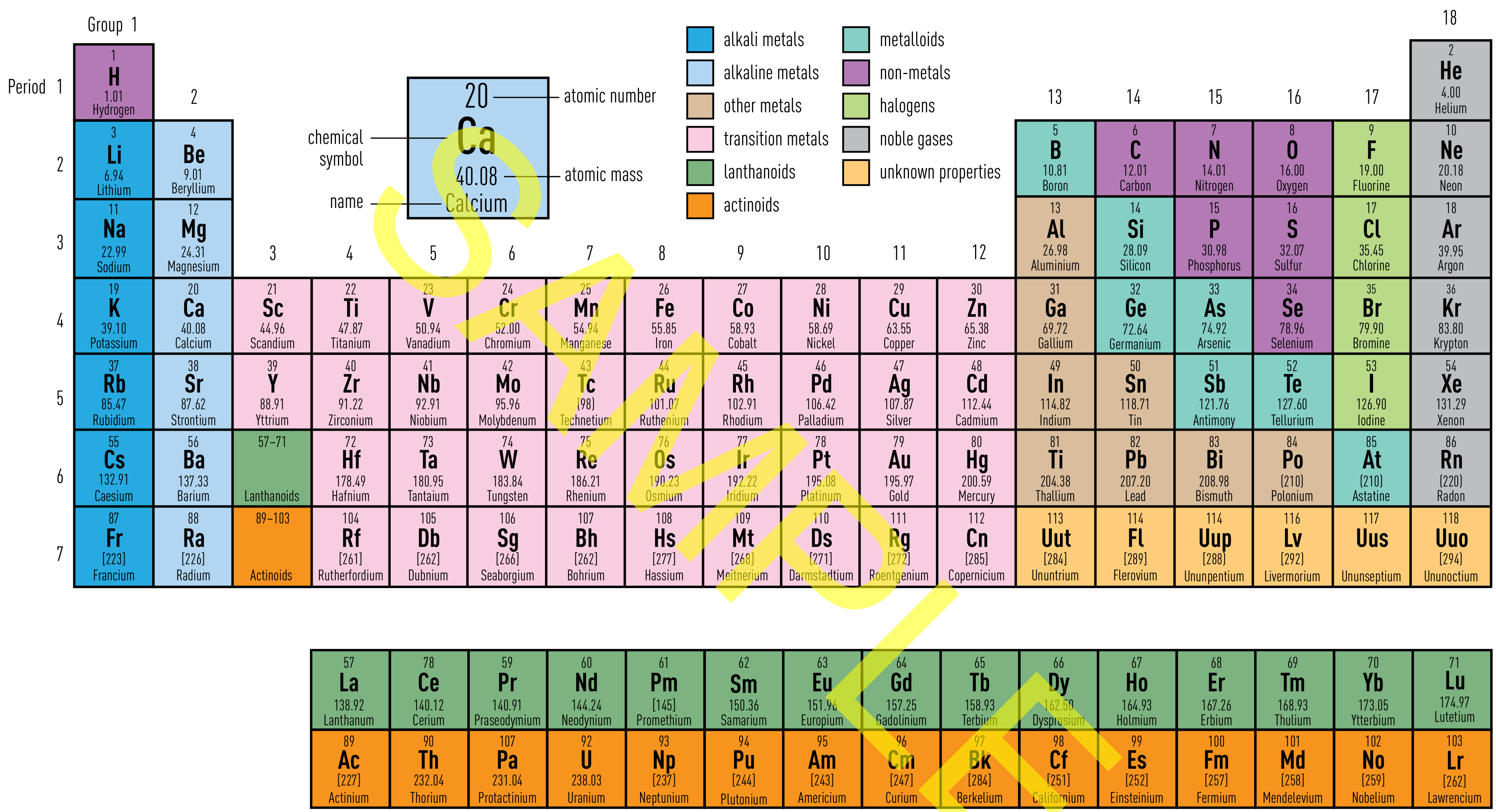

Figure 4.2 The periodic table of elements.

ACTIVITY 4.1.1: CLASSIFYING ELEMENTS

What you need: cardboard, felt-tip pens, scissors

1 Make up some cards like the ones shown in Figure 4.3 to represent the different elements.

2 Sort the cards into those with a one-letter symbol and those with a two-letter symbol.

- How many elements have a one-letter symbol?
- How many have a two-letter symbol?
- Why is classifying elements according to their symbol a bad idea?
- Sort the cards according to the colour of the element.
- How many elements are coloured silver?
- How many elements have another colour?
- Why is classifying elements according to their colour a bad idea?
- Sort the cards according to whether they are solids, liquids or gases.
- How many elements are solids, liquids and gases?
- Why is classifying elements according to their state a bad idea?

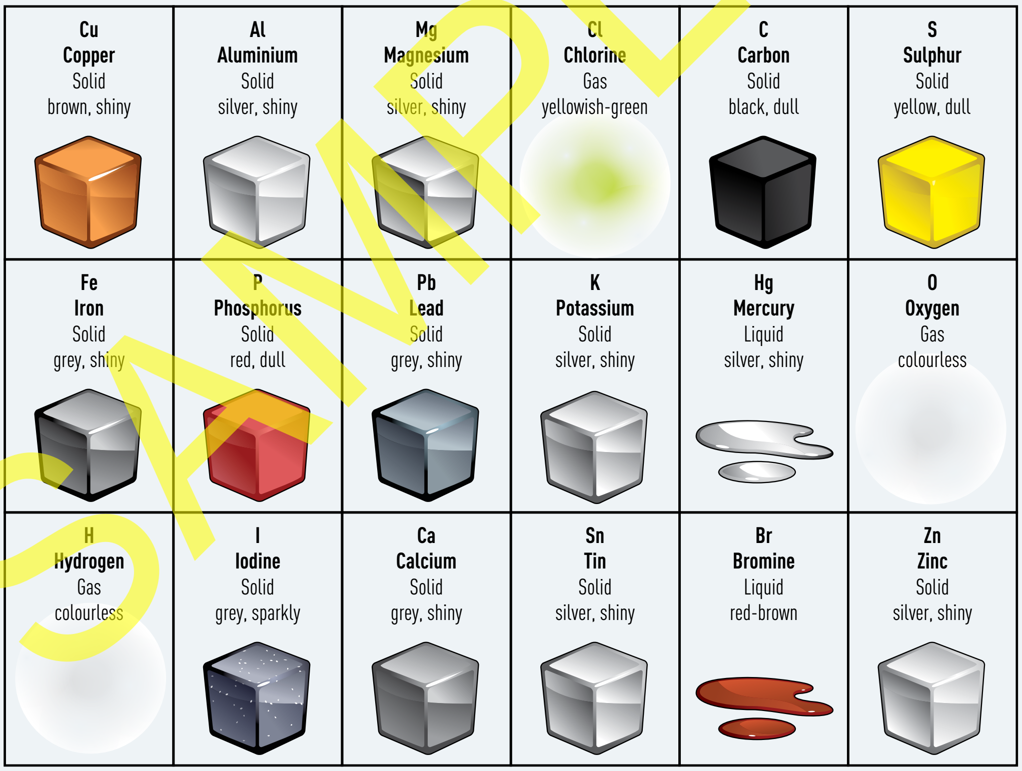

Figure 4.3 Some element information cards.

ACTIVITY 4.1.2: WHAT'S IN A NAME?

Have you heard of Marie Curie, Albert Einstein, Glenn Seaborg and Niels Bohr? These are all scientists who made great discoveries about the structure and behaviour of atoms. But they also have another thing in common: they all have elements named after them.

- Find out the actual names of the elements named after these scientists. Find out about the work of these people. What did they discover? Why has their work been so important?
- Look through some names of other elements. Identify as many elements as you can that have been named after people or places. Make a table listing these elements and the origin of their name.

Figure 4.4 Madame Curie.

QUESTIONS 4.1.2: ELEMENTS

Remember

1 Recall another term used to describe an element.

2 Recall the name given to elements with one atom.

3 Identify an example of a diatomic element.

Apply

4 Suggest a reason why only some of the element symbols come from their Latin names.

5 Some common elements are gold, silver, calcium, sodium, nitrogen and carbon. Locate each of these elements on the periodic table in Figure 4.2 and identify the element symbol for each.

6 Explain why chemical symbols are used rather than the full names of elements.

CHEMICAL AND PHYSICAL PROPERTIES

All the properties of elements, compounds and mixtures can be classified into two different types: chemical properties and physical properties.

Physical properties

Physical properties of matter are properties that can be measured by physical means. You already examined some of these properties when looking at metals and non-metals (see page XX). Physical properties include things like:

- whether something is a solid, liquid or gas at room temperature
- boiling or melting point
- whether it conducts electricity
- density
- strength
- ductility (ability to be stretched into wires)
- malleability (ability to be hammered or bent into shape).

You will already be familiar with the physical properties of compressibility, density, strength and hardness, particle pressure, melting and boiling points, heat conductivity and heat capacity from Year 7. Viscosity and electrical conductivity are two other important physical properties of matter.

Figure 4.5 Engine oils are labelled with viscosities.

Viscosity

Viscosity is the thickness or 'gooiness' of a liquid. It is a measure of how easily a liquid flows or pours. Viscous liquids such as honey are hard to pour. Viscosity is caused by friction between particles in the fluid, which is influenced by the attraction between the particles.

Viscosity of an element or a compound is usually measured at 25°C because viscosity usually decreases when a substance is heated. Usually, all measurements to do with properties of various chemicals and substances are taken at 25°C. This value is considered to be a standard temperature as it is easy to achieve in laboratory conditions.

Water has a relatively low viscosity. Cooking oil is more viscous than water, and honey is even more viscous than oil. Engine oils used in different engines have different viscosities depending on their use. Chemically, the viscosity of a liquid is due to the size of particles and the attraction between the particles. Water is made up of very small particles, and even though the particles are very attracted to each other it is quite easy to separate them. Honey is made up of very large particles that are very attracted to each other. Imagine you had very fine magnetic fillings versus large magnets. The fine magnetic fillings would 'flow' more easily.

Although oil and honey are both made up of large particles, the particles of oil are less attracted to each other compared with the particles of honey. Imagine very large magnets and very large ball bearings. The ball bearings would 'flow' more easily even though they are the same size as the magnets.

Electrical conductivity

Conductivity is how easily something moves through a substance. Electrical conductivity refers to how easily an electric current flows through a substance. Metal elements have a high conductivity, which means they conduct electricity readily. This is why substances with high conductivity are commonly called conductors.

Figure 4.6 Electrical cables contain copper wiring with high electrical conductivity, surrounded by layers of insulating plastic with low electrical conductivity.

Materials such as rubber and plastic have a low electrical conductivity and do not conduct electricity. Elements and compounds that do not conduct electricity are called insulators.

Chemical properties

Chemical properties of matter are only obvious when we react the element or compound with another substance. Chemical properties are a measure of **reactivity** of the substance with other substances and include things such as:

- how easily a substance ignites (**flammability**)
- how easily a substance reacts with water (solubility)
- how dangerous it is to organisms **(toxicity)**

Overall, chemical properties relate to how stable or reactive matter is in any given environment. Just looking at a substance or measuring it on its own cannot determine its chemical properties. The substance in question must be combined with different substances and any reactions observed to determine its chemical properties.

Corrosion

You may have heard of iron 'rusting'. Chemically, this means the substance is reacting with both oxygen and water and corroding. Gold is highly resistant to **corrosion**. Some chemicals corrode a lot easier than others. For example, iron corrodes faster than copper. When copper corrodes, it forms a green layer known as a 'patina' rather than rust. Corrosion is a big problem for iron structures, especially ships that are exposed to salt water all the time. Some metals such as gold and platinum do not corrode at all. Other metals such as zinc and magnesium will corrode over much longer periods of time than iron. So why is iron still used? Iron is commonly available and very cheap, which makes it a commercially appealing option.

Most metals tend to form flakes of corrosion, which fall off and expose the metal beneath for further corrosion. However, the corrosion of some other metals forms a hard layer on the surface of the metal. This layer of corrosion, which is called a passive film, bonds tightly to the metal beneath and actually protects the metal from further corrosion. Aluminium, stainless steel, titanium and silicon all form passive films.

Figure 4.7 The iron of this ship has almost complete corroded.

Flammability

Flammability is how easily a substance will burn or catch fire (ignite). Substances that are easy to light have a high flammability. Substances that are hard to light have a low flammability. If a substance cannot burn or catch fire, it is called non-flammable (rather than inflammable). Confusingly, the words 'flammable' and 'inflammable' mean the same thing.

Substances that have a high flammability are often referred to as 'fuels'. These include things such as petrol, ethanol, methanol, paper, wood, phosphorus and acetone. Some chemicals are non-flammable such as water.

The storage of flammable substances is very important. If they are stored incorrectly, they can cause fires or even explosions. Highly flammable solids tend to be stored under oil so they cannot react with the gases found in the air (because most substances require oxygen to burn). Flammable liquids need to be stored in airtight, locked, storage cabinets.

Figure 4.8 Crude oil, a main ingredient in petrol, is highly flammable.

Toxicity

Toxicity measures how much damage a substance can cause to a living organism. Toxicity is highly dependent on the dosage (amount) and organism is exposed to. Even water, the least toxic of all known substances, can become toxic in extremely high doses. In contrast, substances such as snake venom are extremely toxic in very small doses.

The most toxic natural substance is produced by a species of bacteria known as *Clostridium botulinum*. The toxin causes a disease known as botulism, which has symptoms including paralysis of muscles. Death can often occur due to paralysis of the diaphragm – the muscle that controls the action of the lungs.

Other toxic substances include mercury, lead and chlorine. Mercury is a bioaccumulant, which means it cannot be used up by the body or excreted. When an organism absorbs mercury, the mercury remains in that organism until a predator eats it or until it dies. Mercury fumes are particularly dangerous, as you cannot see them under a normal light.

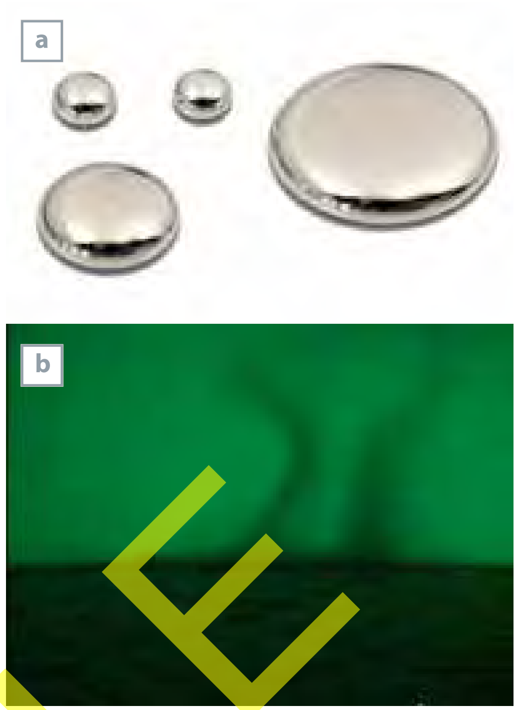

Figure 4.9 (a) Mercury is a toxic substance. (b) The dangerous fumes mercury gives off are easily seen using UV light but cannot be seen at all under normal lighting.

QUESTIONS 4.1.3: CHEMICAL AND PHYSICAL PROPERTIES

Remember

1. Recall the difference between a physical and a chemical property of a substance.
2. If copper is used in a saucepan for cooking, recall which physical property of copper are we trying to take advantage of.
3. If copper is used for electrical wiring in a house, recall which physical property of copper are we trying to take advantage of.
4. Recall why flammable substances are stored so they cannot come in contact with air.

Apply

5. Iron is the most commonly used element in the world. Identify whether each of the following are chemical or physical properties of iron:
   - **a** it is a grey, silvery solid at room temperature
   - **b** it will melt at temperatures of 3000°C
   - **c** it can conduct electricity
   - **d** it will rust
   - **e** it is needed by humans to help carry oxygen in the blood
6. Magnesium is a silvery metal but, when burnt in oxygen, magnesium will turn into a white powdery ash. With your understanding of the differences between elements and their compounds, explain why this is the case.
7. Outline the difference between rust and corrosion.
8. Explain why the dose of a substance is related to its toxicity.

Analyse

9. Elements and their compounds are very different. Water (H_2O) is made up of two explosive gases: hydrogen gas and oxygen gas, yet water itself is not explosive and is vital to all living things. From what you remember from the structure of atoms and compounds, suggest what may cause this difference.

METALS AND NON-METALS

One of the first steps to categorise elements is to determine whether they are a metal or a non-metal. Elements are grouped into one of these categories based on the properties they have in common.

EXPERIMENT 4.1.1: METALS AND NON-METALS

Aim

To determine the difference between metals and non-metals.

Predictions

Before you begin testing your materials, predict whether each substance is a metal or a non-metal. Include your predictions in your results table.

Materials

- 5 different types of elements (such as sulfur, copper, aluminium, carbon, magnesium)
- Transformer
- Light bulb
- Connection wires (and alligator clips)
- Hammer

Method

1. Observe and describe each element. Record your results in an appropriate table in the results section.
2. Test each element for ductility and malleability by hitting them with a hammer. Ensure you use the hammer outside on concrete. If a substance cracks or breaks when hit, it is non-ductile and non-malleable.
3. Test each element for electrical conductivity by connecting an appropriate circuit (refer to Figure 4.10).
4. Record the electrical conductivity of each element in the same table in your results.

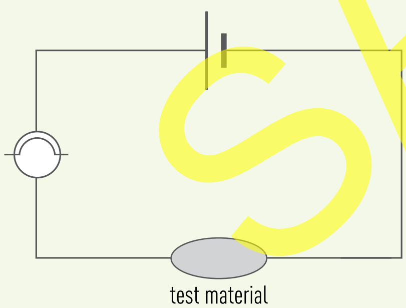

Figure 4.10 Substances that conduct electricity will allow the globe to light up.

Results

Design and draw an appropriate results table

Discussion

1. Your teacher will let you know which elements are metals and which are non-metals. Describe the trend you see with metals.
2. Describe the trend you see with non-metals.
3. Are there any exceptions to the trends you discussed in questions 1 and 2? Describe any exceptions noted.
4. Locate the metals and non-metals you tested on a periodic table. What do you observe?

Table 4.2 summarises the general properties of metals and non-metals, some of which you should have noticed in Experiment 4.1.1. Note that not all metals and non-metals necessarily have all of these features, but most do.

Table 4.2 A comparison of the properties of metals and non-metals.

Property	Metals	Non-metals
State at room temperature	solid	gas or liquid
Lustre (shine)	shiny surface	variable appearance
Colour	generally silver/grey in colour	various colours, or colourless as gases
Ability to conduct electricity	able to conduct electricity	not able to conduct electricity
Malleability (ability to be flattened)	malleable	not malleable
Ductility (ability to be drawn into a wire)	ductile	not ductile

There is also another group of elements called metalloids or semi-metals. As their name suggests, they have some properties like metals and some like non-metals.

The atoms that make up each element can explain the properties of that element. Atoms are not solid substances at all. Atoms are made up of three main subatomic particles: **electrons**, protons and neutrons. You will learn more about subatomic particles in *Oxford Insight Science 9 Student Book*; however, to understand some properties of substances you will need a basic understanding of them.

Subatomic particles and element properties

Protons and neutrons are about the same size as each other. They are both found in the centre of an atom, which is called the **nucleus**. Electrons are very small particles found orbiting around the nucleus. Protons are positive in charge, neutrons are neutral, and electrons are negative in charge.

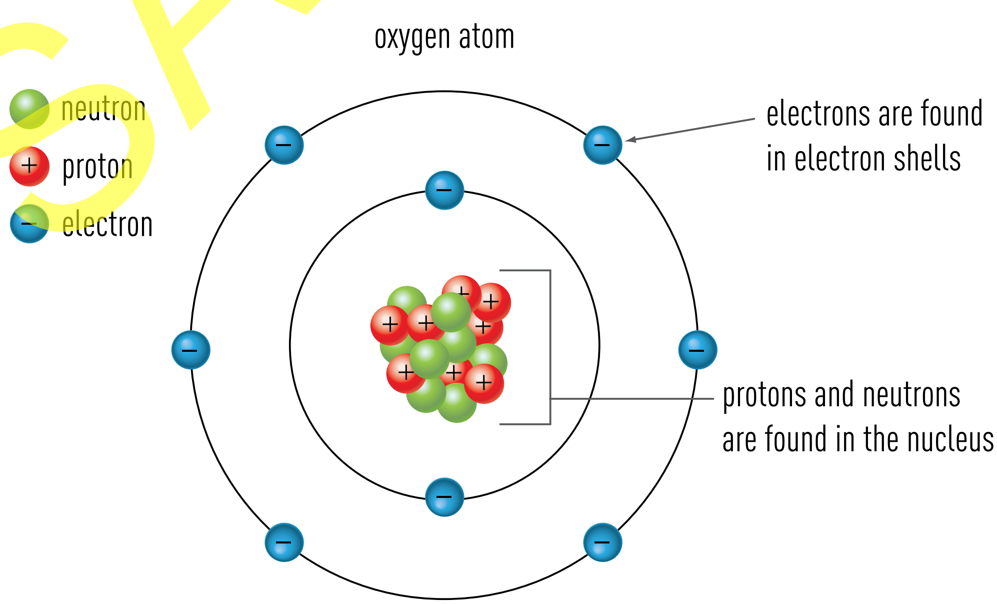

Figure 4.11 The structure of an oxygen atom.

DEEPER UNDERSTANDING

Subatomic particles such as protons, neutrons and electrons are extremely small. So how did we discover them and how do we know what the structure of an atom is like? Originally, scientists thought that atoms were small, indivisible particles. However, in 1897 a scientist called Joseph John Thomson discovered electrons within an atom using a piece of technology called a cathode ray tube. This meant the small, indivisible particle was actually made up of something smaller!

The nucleus was discovered in 1909 by a team of scientists (Ernest Rutherford, Hans Geiger and Ernest Marsden) that were working on gold foil. They were using radioactive particles to shoot through atoms when Rutherford realised that an atom was mostly empty space. Developments of the ability to use radioactive particles in such a way has increased our understanding of what the structure of an atom is like. You will learn about the Geiger–Marsden gold foil experiment in more detail in year 9.

Today, scientists are still looking at improving our understanding of the atom. Not only is an atom made up of protons, neutrons and electrons, even smaller particles known as quarks make up protons and neutrons.

Technologies such as the Large Hadron Collider are currently being used to help scientists probe even deeper into the atom.

The Large Hadron Collider is a powerful particle accelerator situated underground beneath the Swiss–French border near Geneva, Switzerland. It has been hailed as one of the most complex experimental facilities ever built, requiring collaboration between 10 000 scientists and engineers from over 100 countries. The Large Hadron Collider lies in a circular tunnel with a circumference of 27 kilometres,. So far, the Large Hadron Collider has detected the existence of three new particles found within an atom. Scientists are still analysing the results to further understand the nature of these particles.

Figure 4.12 A section of the Large Hadron Collider.

Metals

In the solid state, the atoms of a metal are in a **lattice** form. A lattice is a three-dimensional shape and it is most commonly seen in metallic elements. The positive nucleus and some electrons are attracted to each other, but they have electrons that tend to wander around the substance. For this reason, we say the structure of metals is a lattice of positive particles surrounded by a sea of free electrons.

The best way to imagine this structure is to consider a box of tightly packed

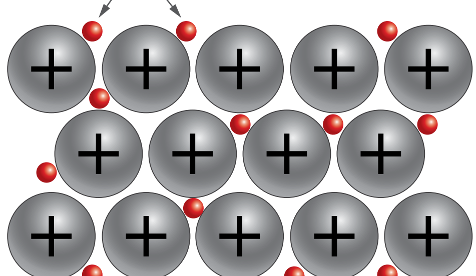

Figure 4.13 The subatomic structure of a solid metal substance.

Figure 4.14 A tightly packed box of oranges is similar to how positive metal particles are packed into a solid.

oranges. The oranges represent the positive particles of the metal. If you dropped marbles into the box, this would represent the electrons. The electrons can move around the substance independently of the positive particles, just like the marbles are able to move through the box of oranges independently of the oranges.

Metals can conduct electricity because the electrons are able to flow through the solid, carrying the electrical charge with them. Free electrons also account for the shiny lustre of a metal. When light hits the metal, the electrons pick up a little bit of that energy and reflect the light back.

With the electrons loosely held, the metal atoms become positive particles as they lose some of their negative charges. These positive metal particles can slide quite easily over each other. This means the metal is malleable and ductile, as their positive particles will easily separate.

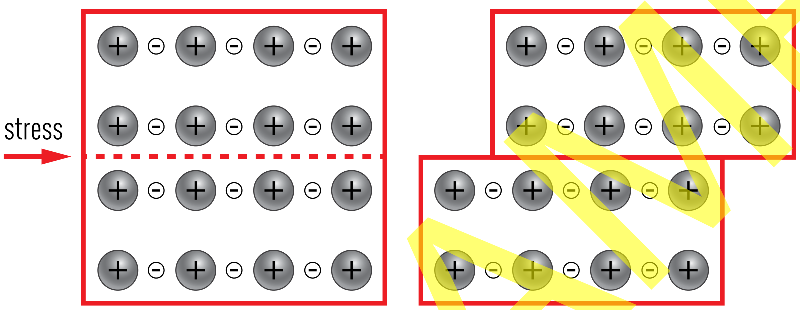

Figure 4.15 The positive particles in metal substances can slide over each other relatively easily. This allows for the metal to be malleable and ductile because it is easy to change its shape.

Non-metals

Non-metals are variable in their properties because their particles also differ greatly. Their electrons tend to be connected, either to other atoms or to each other, which is a key difference to metals. This means non-metals cannot conduct electricity as their electrons are all used up in connections rather than being free to wander.

Most non-metals are gases at normal temperatures. Some gases, such as helium, neon and helium, are **monatomic**. This means each gas particle is a single atom (mono means one). However, the atoms in other gases such as oxygen, hydrogen and nitrogen are **diatomic**. The atoms of these elements join together in pairs (di means two).

Figure 4.16 Helium is monatomic.

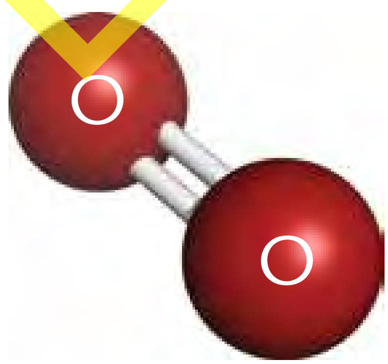

Figure 4.17 A molecule of oxygen. Oxygen gas has many of these molecules in it. Notice how each particle (red ball) is bonded to each other (white lines).

Figure 4.18 A mass of sulfur made up of many particles. The sulfur particles are all attracted to each other through electrostatic attraction (the positive parts are attracted to the negative parts). You can quite easily determine if an element is a metal or a non-metal simply by examining its position on the periodic table of elements.

QUESTIONS 4.1.4: METALS AND NON-METALS

Remember

1 Select four metals or non-metals and describe the appearance of each.

2 Fill in the following table with information about the subatomic particles found within an atom.

Name	Location	Size	Charge

3 Explain how metals are able to conduct electricity

Apply

4 From the periodic table, identify three metallic and three non-metallic elements

5 Draw a table to compare and contrast a metal and a non-metal you have examined. In the table, make sure the name and chemical symbol of the substances is included.

6 A new substance was discovered with the structure as shown in Figure 4.19.

a Do you think it is likely to conduct electricity? Justify your answer.

b The substance was found to be relatively soft. Explain why this may be the case (consider many of these ball structures together).

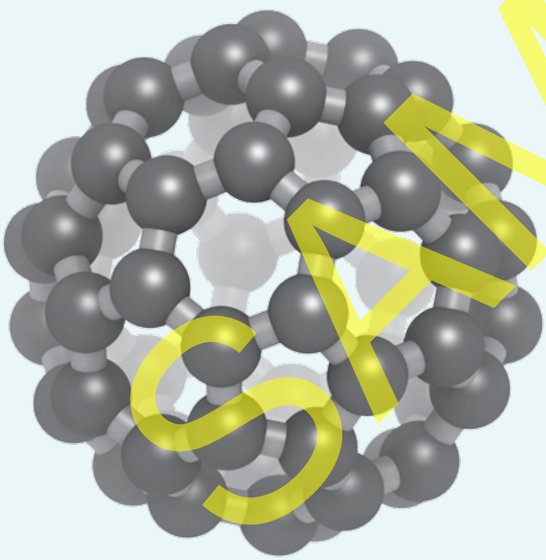

Figure 4.19 What can the structure of a substance tell you about its properties?

7 Graphite, a non-metal, is able to conduct electricity. What does this tell you about its structure? Explain your hypothesis.

Research

8 Research a semi-metal and explain its use in relationship to its properties.

USES OF ELEMENTS

The uses of elements are as different and varied as the elements themselves. Not all of the 90 naturally occurring elements can be found in their pure form. Many react with other elements and form compounds. But all substances can be purified into their base elements, even if they do not occur in their pure form.

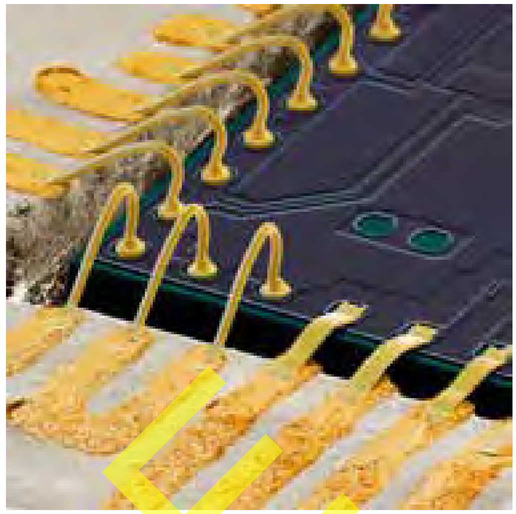

Figure 4.21 A coloured SEM image of the gold micro-wires connecting a microchip to a circuit board.

Gold (metal)

Gold is typically used for jewellery and ornaments. It has the chemical symbol Au, which stands for *aurum*, the Latin word for gold. In ancient times, gold was used as the currency in many countries. Its bright yellow colour and lustre (shine) made it irresistible to many cultures. Gold is also very unreactive. As a result, lumps of pure gold can be mined directly out of the ground.

Things that were made from gold thousands of years ago still have the same lustre – they have not tarnished or reacted with the air and moisture around them. Jewellery and other bodily ornaments need to be unreactive to reduce the chances of them reacting with your skin and possibly causing an allergic reaction.

Gold is also used in some electronic components. Transmission of electricity is easily interrupted by corrosion(see page XX), so components using low voltages or currents often contain gold because it does not tarnish or corrode easily. Devices that use gold components include mobile phones, GPS devices and computers.

Figure 4.20 A small part of the lattice structure of gold. The electrons are not shown in this diagram.

Iodine (non-metal)

Iodine is a brown solid that dissolves quite well in water. Iodine has antibacterial properties and is used largely as a disinfectant. When used in the antiseptic form, it is often diluted so that the solution is approximately 5–7% iodine.

Figure 4.22 Iodine being used as an antiseptic.

Helium (non-metal)

Helium is a gas that is often used in balloons. It is less dense than air, which is why helium balloons float. Helium is non-reactive and will not burn, making it safer to use in airships than highly reactive hydrogen. Helium is an element that only occurs in an atom form – it will not react with other elements to form compounds. It has the chemical symbol He.

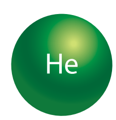

Figure 4.23 Helium is a monatomic gas.

Sulfur (non-metal)

Sulfur is a yellow substance, primarily used in the production of fertilisers as well as sulfuric acid. Historically, sulfur was used for medical purposes such as in Traditional Chinese Medicine. It was even mentioned in Egyptian scrolls dating back to 1500 BC as a treatment for particular eye infections. Sulfur is odourless in its pure form, but when combined with oxygen it forms a strong 'rotten egg' smell. Sulfur is a polyatomic molecule, meaning it is made up of many atoms, even though it is an element. It has the chemical symbol S.

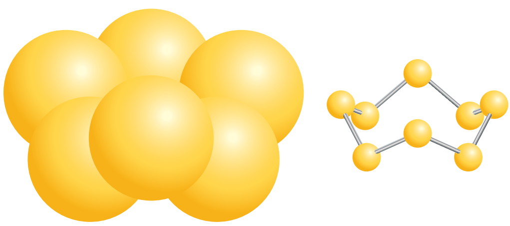

Figure 4.24 Two different representations of a sulfur molecule. How many atoms of sulfur are there?

Carbon (non-metal)

Carbon is a very interesting element as it occurs in many different forms (known as **allotropes**). The particles that make up the substance are all the same, but the structure of the atoms within the substance can be so different that it gives rise to different properties. Carbon can be found in many different allotropes, but the two main ones are diamond and graphite.

Diamond

Diamonds are the hardest substance in the world. Whilst most people often think of diamond jewellery, the main use for diamonds is actually in industry for cutting tools. Saws, drill bits and other cutting implements are often coated with diamonds, which helps the tools cut through even the hardest of steel or rock. But these diamonds will not ever be used for jewellery – the diamonds used in industry are not gem-quality.

Graphite

Unlike diamond, graphite is incredibly soft. It is so soft that it rubs off onto paper, and you use it as the 'lead' in pencils. When you write, you are leaving a trail of carbon on the paper.

Difference between diamond and graphite

The differences between the hardness of diamond and graphite, two forms of carbon, can be explained by the way the particles are arranged in the substance.

Graphite forms as sheets that separate from each other very easily. When you write with your pencil, sheets of carbon are being left behind onto the paper.

Diamond forms a three-dimensional lattice and is therefore very hard. It cannot be separated into sheets like graphite.

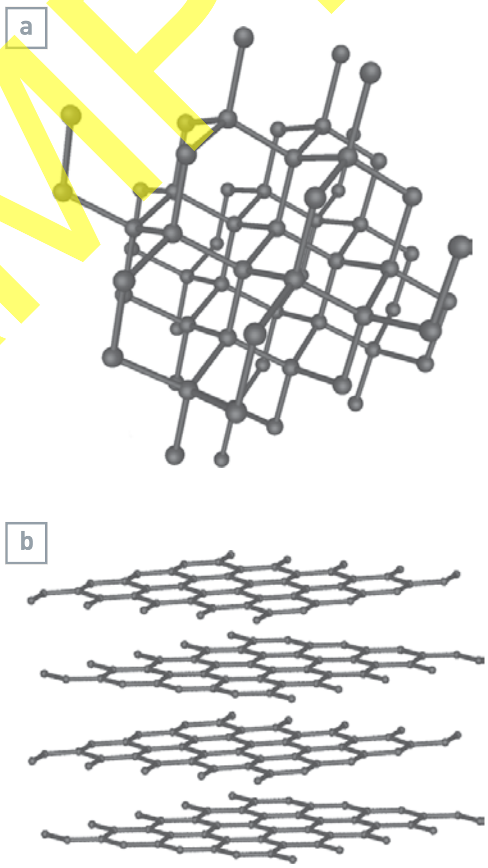

Figure 4.28 Two allotropes of carbon: (a) A three-dimensional crystal lattice structure of diamond. (b) Graphite forms in 2-dimensional sheets that slide easily over one another.

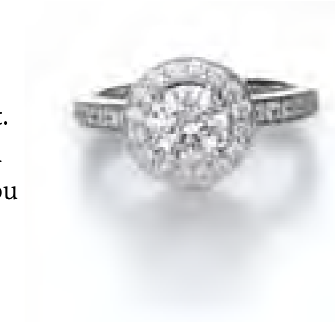

Figure 4.25 The hard crystal lattice structure of diamond is one of the reasons why it reflects light in a pretty and sparkling way.

Figure 4.26 A diamond-studded drill bit. These bits tend to be used in mining.

Figure 4.27 Graphite is the 'lead' in a grey-lead pencil.

Oxygen (non-metal)

Oxygen is a gas that is essential for most living things. We breathe in oxygen, and plants produce oxygen through photosynthesis. We use oxygen tanks in hospitals to help patients who have trouble breathing. Oxygen is also used in industry. Oxygen in liquid form is used as a fuel for space shuttles. It is also used in the process of making steel.

Oxygen can form diatomic or triatomic (three atoms) gases. Oxygen has the chemical symbol O. Oxygen gas is the diatomic form, which has the chemical formula O_2, while ozone has the chemical formula O_3. You may have heard of ozone in terms of the ozone layer. The ozone layer helps protect the surface of the Earth from UV rays. Ozone is also used to help purify air in tunnels and underground structures.

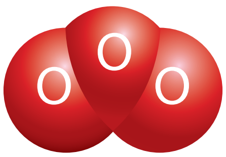

Figure 4.31 Oxygen forms a molecule with three oxygen atoms called ozone (O_3).

Figure 4.30 Molten iron being poured into a Basic Oxygen Steelmaking furnace.

In steel production, oxygen combines with carbon, which is found in the iron. This process is called 'Basic Oxygen Steelmaking' and involves blowing oxygen through the molten steel. The oxygen reacts with the carbon, decreasing the amount of carbon found in the steel, which makes the steel harder.

Oxygen can be used in all these different processes because of its chemical properties. It is used in rocket fuel for combustion (burning). It is impossible to light a fire without oxygen gas.

Figure 4.29 The first stage in a rocket launch usually uses liquid oxygen combined with other substances as fuel.

QUESTIONS 4.1.5: USES OF ELEMENTS

Remember

1. Recall the elements that exist as molecules rather than single atoms.
2. Molecules are often described as monatomic, diatomic or polyatomic. Suggest what the root words 'mono', 'di' and 'poly' mean.
3. Compare and contrast the following pairs of terms:
   a. 'atom' and 'element'
   b. 'molecule' and 'lattice'
4. Recall two common uses of gold.
5. Identify the term used to describe different substances made up of the same element but arranged in different forms to give different physical properties.
6. Explain why oxygen is used in steel making.
7. Recall why iodine is used as an antiseptic.

Apply

8. If the chemical formula for ozone is written as O_3, how would you write the formula for the polyatomic sulfur molecule?

ELEMENTS

4.1

CHECKPOINT

Remember and understand

1 Recall the three subatomic particles and where they are found in the atom. [3 marks]

2 Recall the chemical formula for a common element and describe its usage. [2 marks]

3 H, Ne and Cu are all common elements. Use the periodic table to identify their names. [3 marks]

4 Identify each of the following substances as a metal or non-metal: [5 marks]

- **a** sodium
- **b** iron
- **c** sulfur
- **d** nitrogen
- **e** chlorine

5 Account for the use of iron in society by the properties that it has. [2 marks]

Apply

6 Explain why we use models in science, giving at least one example where models have been used. [3 marks]

7 Explain the difference between monatomic and diatomic particles. [2 marks]

8 Explain why metals are malleable. Use a diagram in your answer. [2 marks]

9 Explain why non-metals do not conduct electricity. [1 mark]

10 Some metals, such as calcium, often appear white, whereas silver can often look grey. What do you think may be the cause of this? Explain your answer. [2 marks]

Analyse and evaluate

11 Compare and contrast chemical and physical properties. [3 marks]

12 Explain why the periodic table is arranged the way it is. Is this the best arrangement for it? Justify your answer. [3 marks]

13 Metalloids have features of both metals and non-metals. However carbon, in the form of graphite, also has features of a metal (it conducts electricity and is often shiny). Justify why carbon is classified as a non-metal and not a metalloid. [3 marks]

Ethical behaviour

14 While there are many uses of various elements, a lot of elements are non-renewable – they cannot be re-made within a human lifetime. Explain why recycling is a necessary process. [3 marks]

Critical and creative thinking

15 A new element has been found that is shiny and green, malleable, strong, non-reactive, ductile (but not very) and conducts electricity (but not well). Suggest a few uses for this element and explain your reasoning. [4 marks]

16 Based on the models you used in this section, evaluate the use of models in science. [4 marks]

TOTAL MARKS
[/45]

4.2 COMPOUNDS AND MIXTURES

Compounds are substances that are created when elements are chemically joined together, whereas mixtures are substances made up of compounds and/or elements that are not chemically bonded. The possibilities for the creation of materials from mixtures and compounds are endless. What are some uses for them? What properties do compounds and mixtures have that make them useful?

COMPOUNDS

You have seen that elements contain only one type of atom, however, there are far more substances than just the 90 naturally occurring elements. Many of the vast range of substances we see around us are formed when the atoms of different elements join together to form compounds.

A compound is any substance made up of more than one type of atom or element that are chemically bonded or joined together. Compounds can be broken down into smaller and lighter substances until the base elements are separated. This process is a type of chemical reaction called **decomposition** and involves breaking chemical bonds. Keep in mind that a specific element will not necessarily join with another specific element to form a compound.

Most of the substances we use are compounds. By altering the ratio of atoms of the different elements, chemists can alter the properties of these substances. Compounds are used because of their specific properties. Important compounds are made in factories or obtained from natural products. Artificially made compounds are commonly used in pharmaceuticals, fertilisers, **polymers** and food materials.

EXPERIMENT 4.2.1: DECOMPOSING A COMPOUND

Aim

To decompose copper carbonate.

Materials

- Copper carbonate
- Electronic balance
- Plastic beaker
- Test tube
- Spatula
- Bunsen burner
- Heatproof mat
- Matches
- Wooden tongs
- Tripod stand
- Paper towel

WARNING

> Wear safety glasses and lab coat, and tie long hair back when using a Bunsen burner.
> Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
> Never place hot objects on a balance.

Method

1 Place a plastic beaker and tare the balance so it reads zero.
2 Add an empty test tube to the beaker.
3 Using a spatula, add approximately 3 g of copper carbonate into the test tube. Record the combined mass of the copper carbonate and the test tube in grams.

Observe the copper carbonate and record your observations.

4 Set the Bunsen burner up on the heatproof mat. Light the flame, ensuring the hole is open and an orange (safety) flame is burning. Turn your Bunsen burner to the heating flame.
5 Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself. Make and record appropriate observations.
6 Allow the test tube and copper carbonate to cool. Wipe off any powder from the outside of the tube with paper towel.
7 Tare the plastic beaker and place the test tube into it to record the new combined mass of the test tube and the substance.
8 Collate results from your class to obtain averages for your class of mass of copper carbonate before heating, mass of substance after heating, and average change in mass.

Results

- Observations of copper carbonate before heating.
- Observations of substance after heating.
- Record your class results in the following table:

	Mass of original copper carbonate + test tube (g)	Mass of substance after heating + test tube (g)	Mass difference (g)
Your result			
Class average			

Discussion

1 What happened to the copper carbonate? Consider the colour and any change in mass.
2 What evidence is there that copper carbonate is a compound and not an element?
3 Identify any sources of error with this experiment.
4 Explain why you used the class average rather than just your results.

Conclusion

Write an appropriate conclusion that addresses the aim.

STUDENT DESIGN TASK

Chemical and physical properties of elements and compounds

Challenge

Your task is to design a series of experiments to determine the differences between chemical and physical properties of an element (copper) and its compound (copper sulfate).

Planning and conducting

- How do you test for electrical conductivity of a metal? You have done this in a previous experiment.
- Does copper sulfate conduct electricity in its solid form? What happens if you dissolve it in water?
- How do you test for chemical reactivity? How does copper react with a chemical called silver nitrate? What about when you place copper into water? How about copper sulfate – does it do the same thing?

- How can you find out physical properties such as the melting point of copper and copper sulfate? It is not feasible to heat and measure it.

When you have designed an experiment, show it to your teacher who will allow you to complete the experiment.

Processing and analysing

1. What were some differences between copper and copper sulfate? What were some similarities?
2. Research what copper is used for. How are its physical properties related to its use? How are its chemical properties related to its use?
3. Research what copper sulfate is used for. How are its physical properties related to its use? How are its chemical properties related to its use?
4. Does the compound of an element have the same properties as the element? Use evidence from your experiment to answer this question.

Communicating

Write your experiment as a proper experimental report. Ensure you include the aim, materials, method, an appropriate discussion as well as a conclusion.

Types of compounds

When models are used in science, atoms are generally represented by individual spheres. Spheres of the same size and colour represent the same element. Molecules are represented in models by two or more spheres joined together. They may be of the same atom (of the same size and colour for molecular elements like O_2) or of different atoms.

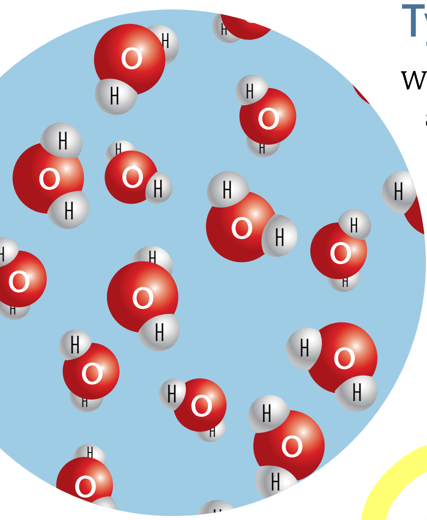

Figure 4.32 Water is a molecular compound. How many different atoms does it have? How many atoms does it have in each molecule?

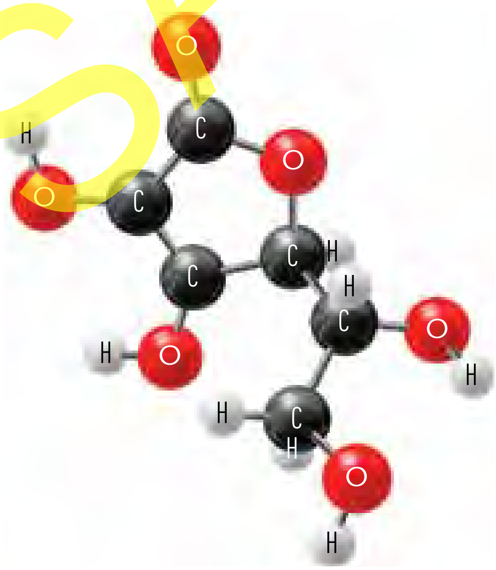

Figure 4.33 Vitamin C is also a molecular compound, although more complex than water. How many different atoms does it have? How many atoms does it have?

Some compounds are **molecular**, such as water and carbon dioxide. Molecular compounds form discrete units that are made up of a set ratio of elements. For example, water (H_2O) is made up of two hydrogen atoms joined together with one oxygen atom. Every water molecule has this same structure. The molecules can be collected together loosely to form water vapour, more closely to form liquid water, or in a three-dimensional structure to form solid ice.

Some compounds are called **polymers**. The molecules in polymers are made of groups of atoms in a pattern that repeats over and over like the beads of a necklace. Plastics are examples of polymers. Other polymers include chemicals found in plants and animals, such as starch and proteins.

Other compounds do not contain molecules but exist in a **lattice** arrangement, with atoms held together in three-dimensional networks. Lattices often form when metallic and non-metallic elements bond together.

Compounds do not necessarily have any of the properties of the elements that go into making them. For example, sodium chloride is the scientific name for common table salt. It is made up of sodium, an explosive metal, and chlorine, a poisonous colourless gas. Yet

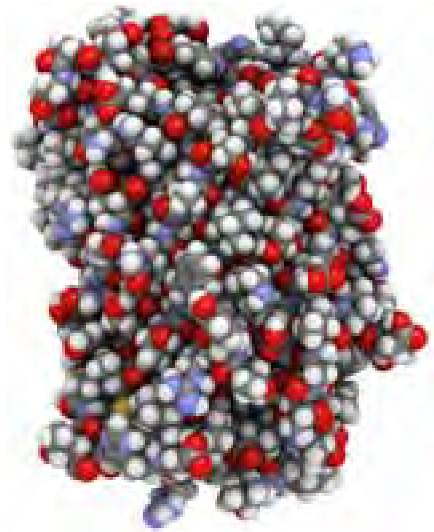

Figure 4.34 This protein is called 'Green Fluorescent Protein'. It is usually used in microbiology and genetics to make things glow in the dark. It is a very complex compound, which is a polymer made up of repeating units called amino acids. How many different atoms are in this compound?

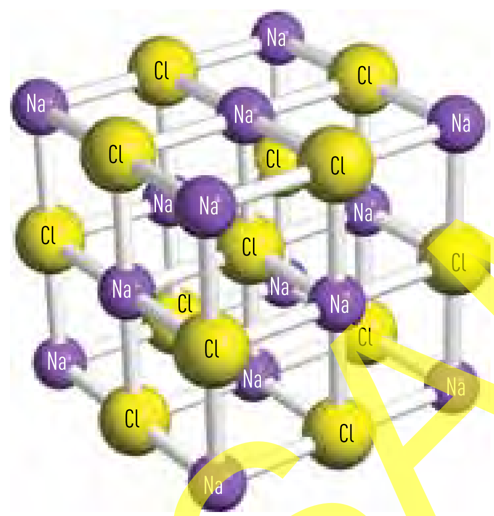

Figure 4.35 Sodium chloride (NaCl), common table salt, is an example of a compound that has a lattice structure. Notice the repeating three-dimensional pattern. How would you extend this model so that it becomes 5 × 5 × 5 atoms?

sodium chloride (the compound made up of sodium and chlorine) is colourless, a solid, and is so safe that we regularly eat it.

Elements and compounds are both pure substances. The particles within a pure substance, whether they are atoms or molecules, must all be the same. Figure 4.36 shows the different types of elements and compounds.

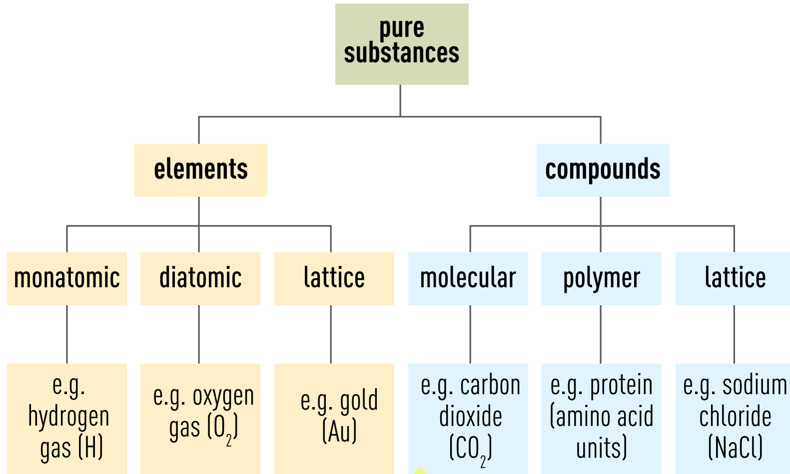

Figure 4.36 Elements and compounds are both pure substances because each particle in the substance is the same, but both elements and compounds come in different forms.

Common compounds

Many compounds form in nature, but many are manufactured artificially to have desired properties.

Water (H_2O)

Water is one of the most common substances in the world, and we depend heavily on it. Water is a versatile compound vital for all life on the Earth. It is also sometimes called the universal solvent because so many other substances will dissolve in it.

Carbon dioxide (CO_2)

Carbon dioxide is breathed out during respiration, and plants use carbon dioxide to photosynthesise. Carbon dioxide in the atmosphere helps to trap heat against the surface of the planet, preventing it from freezing solid. It is also commonly used in fire extinguishers because fire cannot burn in carbon dioxide. Carbon dioxide has the chemical formula CO_2, which means it has 1 carbon atom and 2 oxygen atoms.

Iron oxide (FeO)

Iron is a metal element that conducts electricity well. While it is rarely used in its pure form, iron is commonly used in lots of different **alloys** (mixtures of metals) and

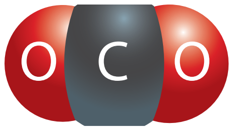

Figure 4.37 A molecule of carbon dioxide. How is this different to a water molecule?

compounds used largely in construction. Iron has the chemical symbol Fe, based on its historical Latin name of *ferrum*. Pure iron forms a lattice like all metallic elements.

There are several different forms of iron oxide, but they are commonly known as rust. Iron oxide forms when iron reacts chemically with oxygen, usually from the air. Rust does not conduct electricity, nor is it a gas. The reaction to form iron oxide will be covered further in chapter 5.

Iron oxide forms a lattice structure. One form of iron oxide has the chemical formula FeO. Lattice structures can be any size, so the actual number of atoms involved cannot be accurately listed in the formula. Instead, the formula states the ratio that the different elements appear in the lattice. In this case, there is an oxygen atom for every iron atom in the lattice.

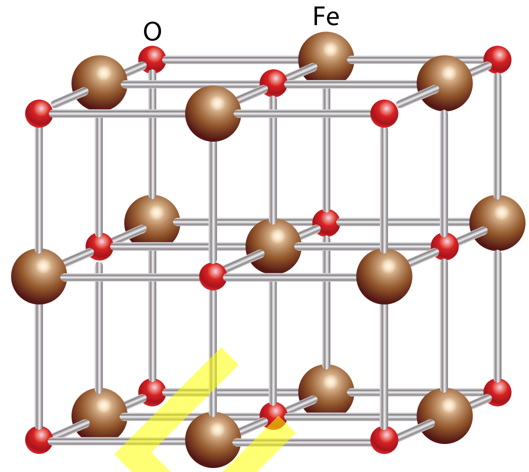

Figure 4.38 The lattice structure of iron oxide.

QUESTIONS 4.2.1: COMPOUNDS

Remember

1 Define the term 'decomposition'.

2 Compare and contrast the following pairs of terms:
  - a 'element' and 'compound'
  - b 'compound' and 'molecule'
  - c 'molecule' and 'lattice'

3 Recall which compound features in both respiration and photosynthesis.

4 Compare and contrast iron, oxygen and iron oxide.

5 Recall the chemical formula for:
  - a water
  - b carbon dioxide
  - c iron oxide

Apply

6 Explain, using appropriate examples, the difference between a polymer and a molecule.

7 Classify the substances in Figure 4.39 as elements or compounds. Justify your classification.

8 For all the common compounds given in this section, construct a table that provides their scientific name, their chemical formula, the different elements, the number atoms of each element and ONE common use.

Analyse

9 From the table constructed in question 8, identify the relationship between the number of capital letters in a formula and the number of elements involved in the compound.

10 A scientist discovered a new substance, but found she could not decompose it into simpler substances. Is this new substance an element or a compound? Use your understanding of elements and compounds to justify your answer.

Figure 4.39 Identify these models as elements or compounds.

MIXTURES

Mixtures are not pure substances. They are substances made up of two or more different pure substances, elements and/or compounds that are not chemically bonded together. Mixtures are different from compounds (different elements chemically bonded or joined together).

Table 4.3 highlights some of the main differences between compounds and mixtures.

Table 4.3 Some key differences between compounds and mixtures.

	Compound	Mixture
Components	contains two or more elements	contains two or more elements or compounds
Bonding between particles	the elements are chemically bonded together	the elements/compounds are not chemically bonded together
Ratio of different particles	elements occur in a strict ratio to each other, e.g. water is always H_2O (not H_3O or H_4O)	substances within the mixture can occur in different ratios

Varying the composition of a mixture will not change the name or type of the mixture. For example, your grandmother's chocolate cake may be different to how you make a chocolate cake (different amounts of chocolate, different amounts of butter), but it is still chocolate cake. The properties will change slightly as the proportions of each component of the mixture changes. Grandma's cake might taste better than yours but not significantly different, as opposed to when the ratio of elements is altered in a compound. O_2 is an odourless gas that is vital for our survival, while ozone O_3 is toxic if breathed in and has a distinct metallic smell.

Just as elements and compounds can be classified by their structure, so too can mixtures.

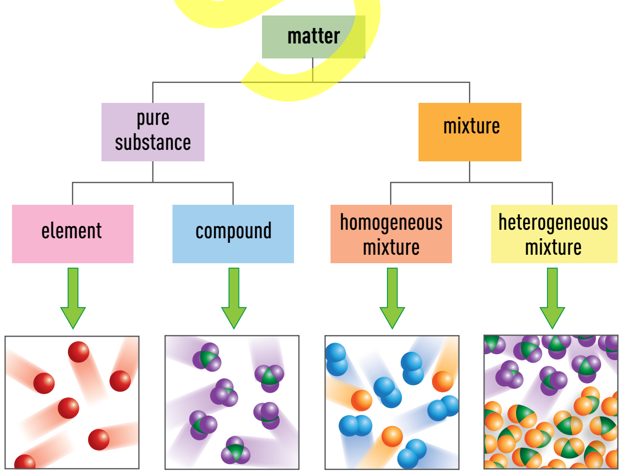

Figure 4.41 The key differences between elements, compounds and mixtures.

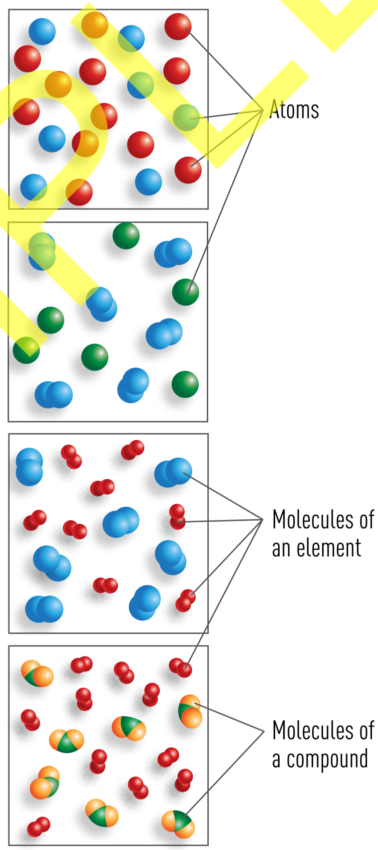

Figure 4.40 Mixtures can contain different elements, different compounds or a combination of elements and compounds. The key is that the different particles are not bonded together.

Figure 4.42 Chocolate cake is a homogenous mixture. Each spoonful of chocolate cake will contain the same 'stuff' because all the ingredients (particles) have been spread evenly throughout the substance.

Figure 4.43 Medicine is another homogenous mixture.

Homogenous mixtures

A **homogenous** mixture looks the same throughout the substance. Each type of particle in the mixture is distributed evenly throughout the substance. Common homogenous mixtures include air, milk, seawater and most medications. Chocolate cake is also a homogenous mixture.

Figure 4.44 Plain cookie dough is a homogenous mixture but chocolate chip cookie dough is heterogeneous, as you will get different amounts of chocolate chips throughout the dough.

Heterogeneous mixtures

A**heterogeneous** mixture does not look the same throughout the substance. Sand is an example of a heterogeneous mixture – the composition of sand varies from beach to beach, and often between different spots on the one beach. Other heterogeneous mixtures include rocks and chocolate chip cookie dough. The amount of chocolate chips in the cookie dough will change depending on which spoonful you take.

Figure 4.45 This type of sedimentary rock is called conglomerate rock. Each different part of the rock contains different substances with visibly different make up. Is this considered a homogenous mixture or a heterogeneous mixture?

Figure 4.46 Sand often looks like it's uniform, but if you inspect it up close it is actually made up of many different types of substances.

ACTIVITY 4.2.1: MODELLING THE STRUCTURES OF ELEMENTS, COMPOUNDS

overmatter

What you need: items for modelling (such as polystyrene balls, molecular kits, marbles, stones), camera

1 Use the equipment provided to model the following elements, compounds and mixtures:
- an monatomic element
- a diatomic element
- a compound made up of two elements
- a compound made up of four elements
- a mixture containing at least two different substances.

2 Take a photo of each of your models.

3 Using your models, explain the different particle arrangements in elements, compounds and mixtures.

4 Explain why the use of models is important in science.

Sandy mixtures

We see sand on beaches and in sandstone buildings all the time, but what exactly is it? 'Sand' is a general term given to any granular substance (a substance containing grains) between 2 mm and 0.0625 mm in size. As a heterogeneous mixture, the composition of sand varies – not only between parts of a beach, but also between locations. The most common substance found in sand is quartz, which is also known as silicon dioxide (SiO_2), but it is the other substances that make up sand that often give it a unique colour.

White sand

White sand often occurs in tropical locations where there is a high percentage of seashells, corals and a single-celled organism known as a foraminifera. The whiteness of the sand comes from a compound called calcium carbonate ($CaCO_3$), which these organisms produce to build their hard exoskeletons and shells.

Red sand

Australia is famous for the red sand that occurs in Central Australia, often called the Red Centre. The red of the sand is from iron oxide (FeO).

Black sand

Black sand is usually found on beaches that are close to active volcanoes. Maui in Hawaii has black sand beaches, as do some beaches in New Zealand. The black colour comes from a mineral called magnetite, which can be found in high concentrations in volcanic rocks such as basalt and obsidian.

Yellow sand

The most common type of sand seen on the beaches of Australia is yellow sand. The yellow in the sand is due to a combination of impurities in the quartz, which causes a yellow colour, as well as the high number of shell fragments found in the sand.

Figure 4.48 Red sands of the Australian Outback.

Figure 4.47 (a) White sand is often seen in tropical regions where foraminifera are common. (b) Foraminifera are microscopic single-celled organisms.

Figure 4.49 Black sand beaches of New Zealand.

Figure 4.50 The yellow sand of Bondi Beach is a similar mixture to the sand on most beaches of Australia.

QUESTIONS 4.2.2: MIXTURES

Remember

1 Recall the difference between a mixture and a compound.
2 Compare and contrast a heterogeneous mixture with a homologous mixture.
3 Identify two common components of sand.

Apply

4 Identify whether fruitcake is a heterogeneous mixture or a homologous mixture. Explain your answer.
5 In Figure 4.51, identify which diagram models a mixture and which models a compound. Justify your answer.

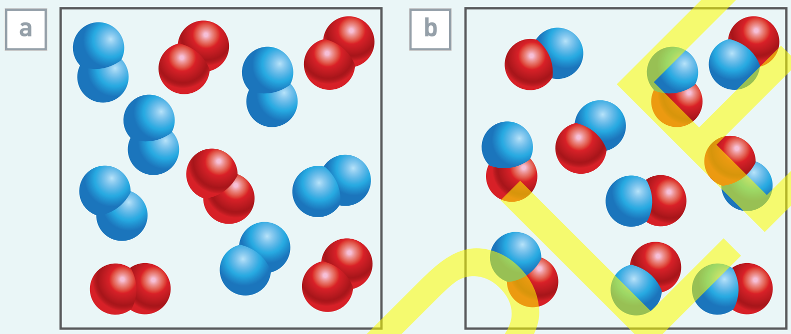

Figure 4.51 Can you explain which diagram is showing a compound and which is showing a mixture?

COMPOUNDS AND MIXTURES

4.2 CHECKPOINT

Remember and understand

1 Recall the difference between an atom and a molecule. [1 mark]

2 Explain the difference between an element and a compound. [1 mark]

3 Identify the term used to describe when a compound has been broken down into simpler components. [1 mark]

4 Recall the chemical formula for a common compound and describe its usage. [2 marks]

5 Relate the usage of a common compound to its properties. [1 mark]

6 Describe the difference between a homogenous mixture and a heterogeneous mixture. [2 marks]

7 Identify an example of a homogenous mixture. [1 mark]

Apply

8 Examine Figure 4.52 and identify each diagram as showing an element, a compound or a mixture. Explain your reasoning. [4 marks]

9 Methane is a gas produced by cows. It's highly flammable and has the chemical formula CH_4.

a Is methane an element or a compound? Justify your answer. [2 marks]

b Explain what the chemical formula tells you about the number of different types of atoms methane contains. [2 marks]

c Explain what the chemical formula tells you about the number of atoms methane contains. [2 marks]

Analyse and evaluate

10 'If it is possible to separate two things from a chemical, it means it is a mixture.' Analyse this statement and explain where it is correct and where it is not. [4 marks]

Critical and creative thinking

11 Draw a series of your own diagrams to depict the differences between an atom of an element, a molecule of an element, a molecule of a compound, a homogenous mixture and a heterogeneous mixture. [5 marks]

12 When atoms and elements were shown in this section, usually solid balls were used to represent individual atoms. Can you think of a better model? If yes, explain why your model is better. If not, explain why the model used is good. [3 marks]

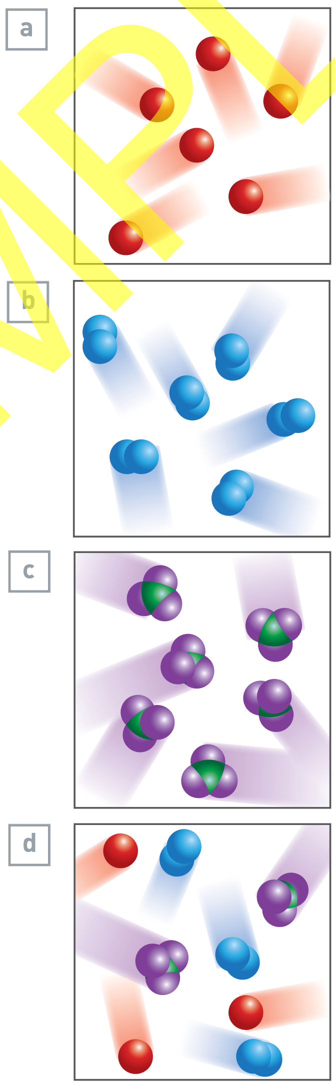

Figure 4.52 Can you explain what each of these diagrams is showing?

TOTAL MARKS
[/30]

4.3 THE IMPACT OF ELEMENTS AND COMPOUNDS ON SOCIETY

Humans have long had a close relationship with elements and compounds found naturally. These elements and compounds have given huge advantages to the societies that had access to them and who knew how to use them, and have helped shape human history. New developments enabling us to utilise elements and compounds that were previously inaccessible, and the creation of completely new materials, are continuing to shape our society.

TRADITIONAL USES OF ELEMENTS AND COMPOUNDS

The development of human society throughout history has been linked with our understanding of the uses of elements and compounds. Metals, in particular, have significantly changed the way humans have lived, both in ancient and modern times.

Archaeology is the study of human activity in the past. Its study is usually a combination of history and science. Humans have left artefacts throughout history, from the very large such as the Pyramids in Egypt and Stonehenge in England, to the very small such as shells, weapons stores and burial plots.

The materials used in particularly settings have been important to archaeologists as this helps them to understand how human society and culture have evolved. The three basic ages of prehistoric human development are the Stone Age, the Bronze Age and the Iron Age.

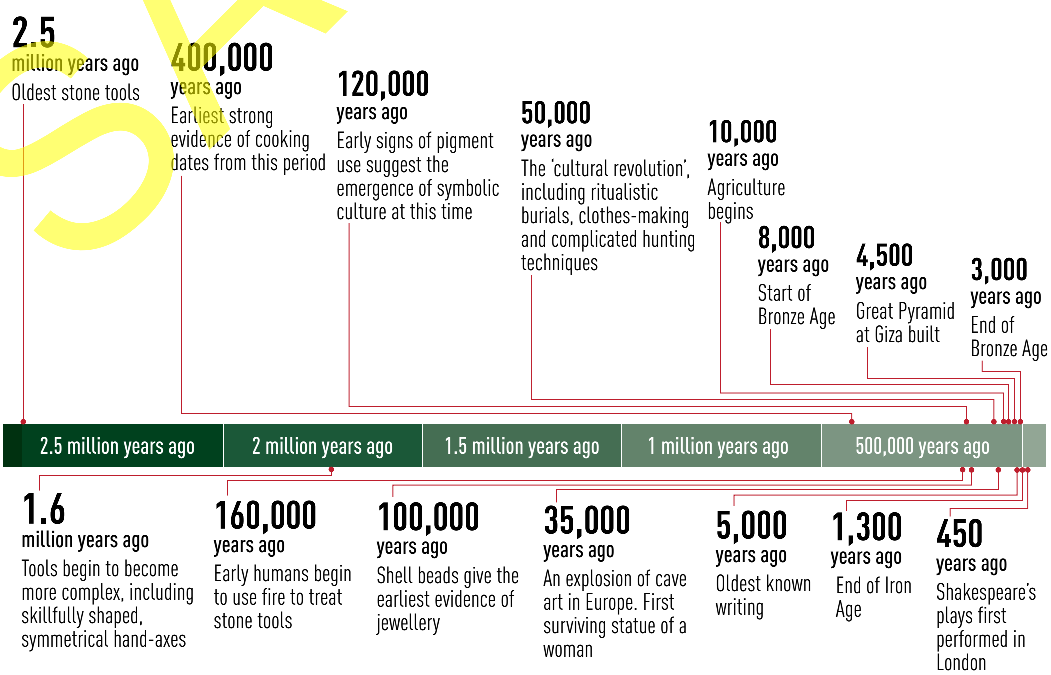

Figure 4.53 The development of human society is closely linked to resources and technological development.

Figure 4.54 A stone axe made from flint. The glassy shine to the rock comes from the high content of quartz in the rock itself.

Figure 4.55 A bone tool. A tool like this is likely to be used as an arrowhead or some sort of piercing weapon.

The Stone Age

The start of the Stone Age, one of the oldest of the ages, is always being pushed back in time through new discoveries. It is likely to have lasted around 3.4 million years and ended around 6000 to 2000BC.

The Stone Age is characterised by the use of stone tools; however, bone tools were also made and used in this time. The stones used are a type of compound. Typically, flint and chert (quartz, SiO_2) were used as cutting tools and weapons. They could be sharpened to a point, allowing them to be used as cutting devices.

Basalt (volcanic rock) and sandstone were used to grind and shape stone tools. Basalt and sandstone are hard, and they themselves cannot be sharpened.

Additionally, wood, bone and shell were also used in the Stone Age for utensils and weapons. Wooden handles of stone axes are not preserved very well, but they are occasionally found. Clay was used as pottery to hold water and other substances.

The Bronze Age

The start of the Bronze Age can be identified through the beginnings of **metallurgy** – the extraction and processing of metals. At the beginning of the Bronze Age, a transitional period often called the Copper Age was occurring. Metals were superior to stone as it was less time consuming to work them yet they held their shape just as well as stone. Additionally, damaged metal implements could easily be melted down and re-worked into new implements. Stone did not have that advantage.

The Copper Age

In places where copper was found naturally, melting copper to create different shapes would have been very easy. In many ways, copper is easier to work with than stones. To make pins and other small objects, copper is soft enough to be 'cold-hammered' – it can be hit with a hammer into the desired shape. For larger objects, all copper requires is very high temperatures for it to be melted and a mould of some sort for it to be poured into. However, copper is very soft and cannot keep a sharp edge. This makes copper a poor material for tools and weapons. The supply of native copper (naturally formed lumps or nuggets) also decreased as the demand for it increased.

As a relatively abundant metal in the Earth's crust, copper appears in many different types of metal ores. Ores are minerals that contain metal elements.

It is not yet known exactly how or why copper ores were first used to extract copper. Temperatures of above 1000°C are required to extract copper from its ores. This process of extraction is known as **smelting**. Copper ores such as malachite and azurite were used in powdered form to decorate vases in times that predate the start of the Bronze Age.

Figure 4.56 Native copper was one of the first metal elements to be mined and refined.

Figure 4.57 A model of Los Millares based on current excavations.

However, when the first smelting occurred, the consequences of it were enormous. For the first time, large stable cities were built around sites where copper ores were found. Trading routes were established through settlements that started to specialise what they produced. Los Millares, a Copper Age city in modern Spain, looked like it supported around 1000 people at its peak.

It was found, towards the end of the Copper Age, that copper smelted with tin made a much stronger metal alloy – a homogenous mixture of metals called bronze.

Figure 4.59 Bronze-Age spearheads. The bronze spearheads remain, while the wooden shafts decomposed over time.

Bronze

Bronze is classified as an alloy. An alloy is a mixture of two or more substances that produce a new substance with metallic properties. Copper on its own is very soft, but with the addition of tin the physical properties of the substance change. Items made from bronze are harder and more durable than stone and copper items.

The ores that give rise to copper and tin are rarely ever found together. When it came to first working with bronze, proper trade had to occur between settlements and cultures. For example, a lot of tin was mined in Cornwall in England. Trade routes were established and it was found that some of the Cornwall tin was traded as far as modern day Lebanon, Syria and Israel.

The Bronze Age was also when written language became more widespread and formalised. Scientists and archaeologists believe the written language was likely to have developed further due to the need to communicate between traders.

It is unknown exactly why bronze gave way to iron in the next 'Age'. Iron in its natural form is softer than bronze and harder to work with. Bronze was still commonly used during the Iron Age – bronze swords were given to officers in the Roman army, although soldiers received iron swords. The current theory for the transition to iron is that there were decreasing supplies and increasing prices of tin.

Figure 4.58 A bronze vessel from 1600 to 1046 BC, China. The Chinese used bronze largely as a ritual material – these vessels were designed to be used by the spirit of the dead.

EXPERIMENT 4.3.1: EXTRACTING COPPER FROM COPPER ORE

You have already heated copper carbonate and observed the reactions in Experiment 4.2.1 (page XX), but is it possible to obtain solid copper from this reaction?

Aim

Read the method of this experiment and write a suitable aim that starts with 'To ...'

Materials

- Heatproof mat
- Bunsen burner
- Tripod
- Gauze mat
- Crucible
- Beaker
- Spatula
- Powdered copper(II) carbonate
- Powdered charcoal

WARNING

> Copper carbonate is a respiratory irritant. In some parts of this practical, heating a powder may give off sparks or heated powders. Wear safety glasses and ensure that all care is taken and flammable material is moved away from the experimental space.

Method

1. Set up equipment as shown in Figure 4.60.
2. Place 1 spatula of copper(II) carbonate into a crucible.
3. Heat the crucible and contents, being very careful of the hot powder.
4. When there is no further change in appearance of the mixture, allow the crucible and contents to cool.
5. Add 2 spatulas of powdered charcoal to the crucible.
6. Mix well while holding the crucible.
7. Add a thin layer of powdered charcoal to cover the surface of the mixture.
8. Heat the apparatus for a few minutes. Be careful of any hot powder or sparks.
9. Allow mixture to cool.
10. Tip the powder from the crucible into a beaker half-filled with water.
11. Swirl the contents of the beaker around. Any copper you have made will fall to the bottom of the beaker.
12. Pour off the water and charcoal mix, add fresh water and swirl again.

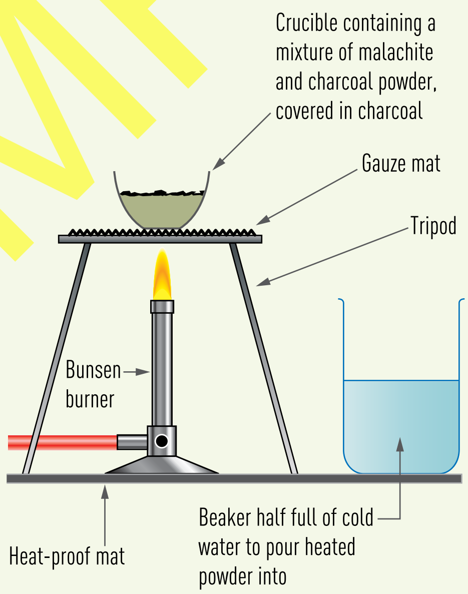

Figure 4.60 Experimental set-up.

Discussion

1. How successful were you at making copper?
2. Compare the amount of copper you have made to how much copper carbonate you used.
3. Explain why technology had to be more advanced to extract copper from its ores compared with using native copper.

Conclusion

Write a suitable conclusion for your experiment that addresses your aim.

Figure 4.61 Forging of steel.

Figure 4.62 Pure iron is too soft to make effective weapons, but steel is strong and can be honed to form sharp edges. These Iron-Age weapons and chains are made from steel.

The Iron Age

Similarly with the Bronze Age, scientists and archaeologists do not know how iron started to be made. Iron is more easily obtained than bronze, but by itself it is softer than bronze and cannot hold a sharp edge. This makes iron unsuitable for weapons and sharp tools.

However, sometime during the Iron Age, the process of alloying iron with carbon was discovered. This produced an alloy called steel, which was much stronger than bronze. The best steel was produced with approximately 0.3% to 1.2% carbon. However, the best steel weapons often fetched a very high price as the method of producing steel was difficult. Wrought iron (fairly pure iron) was often used, as it was cheaper. Steel could not be cold hammered – it had to be forged. Forging is a process of heating the steel until it is red hot before hammering it into the desired shape. It is likely that the saying 'to strike while the iron is hot' came from forging.

The Iron Age also led to times of better agriculture. The use of iron ploughs increased the speed at which a field could be ploughed and allowed for soils to be turned over more regularly. This increased the nutrient levels in the soils and allowed crops to be planted year-round rather than needing to rotate through plots of farmland.

It has also been suggested that civilisations with access to steel were able to dominate over civilisations that still used bronze in times of war. The Hittites, an empire of people from the Hattusa region (now part of Turkey, Syria and Lebanon) had dominated much of current-day Europe through their ability to forge and create iron weapons.

Eventually, as with all ages, the Iron Age gave way to the Middle Ages, or the medieval times.

STUDENT DESIGN TASK

Comparing properties of iron and steel

Aim

To compare the physical and chemical properties of iron and steel.

Planning and conducting

- Consider where you are going to get iron and steel samples. Wrought iron may be good to use as iron; stainless steel is a good example of steel.
- Some chemical properties and physical properties cannot be tested easily (e.g. melting point). You will need to consider where or how you can obtain reliable information for these chemical and physical properties.
- Some physical properties you can measure (e.g. electrical conductivity). How are you going to measure these? What is the best way to examine this?
- How do you make your experiment a fair test?

Processing and analysing

- Consider how you are going to summarise your findings.
- Consider how you can check the reliability of your data.
- What inferences can you make about the differences in properties between iron and steel?

Communicating

- How are you going to present your findings? You may choose a report format, a poster, or perhaps another suitable way.
- How will you cite your research resources?

QUESTIONS 4.3.1: TRADITIONAL USES OF ELEMENTS AND COMPOUNDS

Remember

1 Define the term 'alloy'.

2 Name two alloys and identify the components involved in each alloy.

3 Explain why bronze was used instead of copper during the Bronze Age.

Apply

4 Suggest a reason why wooden handles for axes and spears are not usually well preserved.

5 Complete the following table to summarise the types of stones used in the Stone Age, their usages and the reason for their usage.

Stone type	Usage	Reason

Analyse

6 Each 'Age' in prehistory had a defining element or compound used in many of the tools of the day. What do you think you would call our age now? Explain how and why you came up with your answer.

Research

7 In many parts of the world, archaeological artefacts such as spears, stone tools

MODERN USES OF ELEMENTS AND COMPOUNDS

Figure 4.63 Copper is commonly used to make electrical wiring and water pipes.

Our current dependency on elements and compounds is incredibly high. Every material object we use or touch comes from raw materials somewhere in the production line. We still use the materials we had in prehistoric times, though in a slightly different way.

Copper

Copper is a great electrical conductor and is used as wiring in most electrical circuits. While gold is a better electrical conductor, copper is much cheaper. Copper is also commonly used to make water pipes.

Due to our reliance on copper, copper ores with a high percentage of copper are decreasing. As a result, we no longer extract copper in the same way that prehistoric people did – we now use electricity to extract copper in a process called electrolysis. However, because there is less copper available to make new products, it is becoming more and more expensive.

EXPERIMENT 4.3.2: ELECTRICAL EXTRACTION (ELECTROLYSIS) OF COPPER

Aim

To extract copper from a copper sulfate solution using electricity.

Materials

- Power pack
- Electrical leads
- 0.1 M copper sulfate solution
- 2 carbon electrodes

Method

1 Set up the equipment as shown in Figure 4.64.

2 Set the power pack onto 6V DC and switch it on.

3 Leave the reaction for 20 minutes, ensuring that you make and record observations every 2–3 minutes.

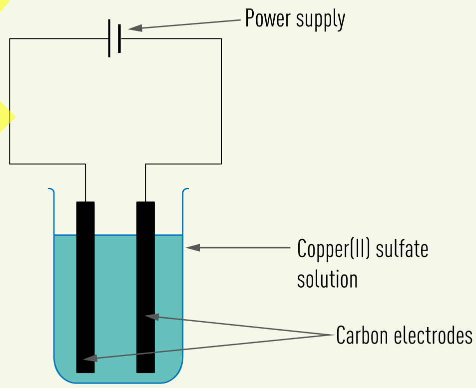

Figure 4.64 Electrolysis set-up.

4 Switch off the power supply and record any observations for a further 2 minutes.

Results

Record your observations in an appropriate way.

Discussion

1 One of the electrodes should be covered with a thin layer of copper. Was this electrode attached to the positive or negative terminal of the power supply?

2 Where does the solid copper come from come from? Justify your answer.

3 Electroplating is an application of this process. Research what electroplating is and how we can use this equipment to do it. If time permits, you may be able to electroplate some of your own items.

4 This reaction will also work if copper electrodes are used in place of carbon. Carbon electrodes were used because it makes the copper deposit on the electrodes easier to see. Suggest a way to measure if this reaction has taken place if copper electrodes were used.

Figure 4.65 The chassis and frame of cars is usually made from steel.

Iron

Nowadays, iron is largely used in the form of steel. Steel is a versatile material used in many items, most notably in building construction and car manufacturing. Steel is a relatively cheap material, very durable, strong, and can be formed into many different shapes.

One problem with steel is that it corrodes (rusts) very easily. The iron in the alloy reacts with water and oxygen in the air in a process known as oxidisation. You will learn more about corrosion and rusting in chapter 5.

Aluminium

Aluminium is the second-most widely used metal in the world (iron is the first). It is a highly reactive metal and is very difficult to extract from its ore. Electrolysis is used to extract the metal. Aluminium is extremely lightweight and malleable. Because it is so reactive, aluminium is almost always alloyed with other substances.

Figure 4.66 Bauxite, the ore of aluminium.

Household aluminium foil and aluminium drink cans usually contain only 92–99% aluminium.

The combination of strength and lightness means aluminium is often used in the manufacturing of cars, aeroplanes and trains. It is also used in window and door frames in many households.

Carbon dioxide

Carbon dioxide has many uses, the most familiar being to provide the 'fizz' in carbonated drinks. It is used in this manner because carbon dioxide is cheap to obtain and does no harm when consumed. Carbon dioxide also produces a slightly sour taste as it makes carbonic acid when placed in

Figure 4.67 A carbon dioxide fire extinguisher.

water, which contributes to the flavour of many soft drinks.

Carbon dioxide is also used in types of fire extinguishers as it can 'smother' the oxygen required for fires.

Sulfuric acid

Sulfuric acid is one of the most important chemicals in the chemical industry. Its use is only second to water.

Approximately 60% of the sulfuric acid used in the chemical industry goes into making fertilisers. Whilst some of the sulfur from sulfuric acid is required for plant growth, sulfuric acid is largely used to help increase the amount of fertiliser produced. It has been estimated that 50% of the world's population consumes food grown with the aid of fertilisers. Because of this high reliance on fertilisers, the volume of sulfuric acid used in fertiliser production is also very high.

Of the sulfuric acid used in industry, 20% goes towards the production of medicines, detergents, resins, water treatment and aluminium production. Another 6% is used to produce pigments including paints, printing inks and fabrics. The remainder goes into the production of cellophane plastic, cleaning metals, batteries and explosives.

Mainly, it is the chemical properties of sulfuric acid that dictates its use, rather than its physical properties.

ACTIVITY 4.3.1: OUR LIMITED RESOURCES

It is important to recognise some of the problems we face as a society. Our current resources of natural substances, such as minerals from which we extract compounds and elements, are running out due to increased consumption of them. We cannot create any more.

Research a piece of technology you use regularly (such as a mobile phone, game console or computer), and identify some of the elements that go into making it. Find out approximately when these elements are expected to run out with our current demand for them. Once completed, suggest some ways that may be required to conserve our use of these elements. You may wish to present your findings as a verbal report or a written report.

QUESTIONS 4.3.2: MODERN USES OF ELEMENTS AND COMPOUNDS

Remember

1 Recall some properties of carbon dioxide that make it suitable for use in carbonated drinks.

2 Identify whether the properties named in question 1 are chemical or physical properties.

Apply

3 Suggest a reason why extraction of aluminium did not occur until the mid 1800s compared with the prehistoric uses of copper and iron.

Analyse

4 Draw a pie chart to show the various uses of sulfuric acid.

5 Choose one element or compound and explain how its chemical and/or physical properties relate to its use.

THE IMPACT OF ELEMENTS AND COMPOUNDS ON SOCIETY

4.3 CHECKPOINT

Remember and understand

1 Recall the three main periods in archaeological history. [1 mark]

2 Select a chemical element and identify one chemical property and one physical property of it. [2 marks]

3 Explain why the stones such as chert and flint used in tools needed to be hard. [2 marks]

4 Explain why trading was necessary in prehistoric times. [2 marks]

5 Explain what an alloy is and identify two different alloys and their uses in modern society. [3 marks]

Apply

6 Phosphorus a flammable solid that is stored in oil. Paper is also a flammable solid, but it does not need to be stored in oil. Propose why these two flammable solids need to be stored in different ways. [3 marks]

7 Suggest a reason why the Copper Age was relatively short compared to the Bronze Age. Justify your answer. [2 marks]

8 Steel bridges, such as the Sydney Harbour Bridge, must be frequently painted to ensure the metal is not exposed to salt water, moisture and oxygen so it does not rust. Propose a reason why bridges are not made out of another material that does not require such care. [2 marks]

Analyse and evaluate

9 In ancient times, metals such as gold and silver were only used by the very rich. Stones such as turquoise and lapis lazuli were also highly prized. Suggest a reason why these substances were particularly sought after. [3 marks]

10 'We should use gold instead of copper in our homes for electrical wiring as gold is a better conductor of electricity than copper.' Evaluate this statement based on what you know about gold and copper. [2 marks]

11 Bronze was used for many purposes by our ancestors, such as for weapons, tools and fittings on ships, but bronze is rarely used for these purposes today. Suggest reasons why we no longer use bronze for these purposes. [2 marks]

12 Investigate some common solders used. What are solders? What properties do they have? Explain how their properties relate to their uses. [3 marks]

TOTAL MARKS
[/30]

4 CHAPTER REVIEW

1 Fill in the gaps, using the words in the Word Bank below:

The ____________________ model of matter describes that all substances are made up of small components. The ways these particles behave determine the ____________________ of the substance. We can separate all substances into elements, ____________________ and mixtures. The arrangement of particles is ____________________ between them.

We use substances in different ways because of their different ____________________ properties and ____________________ properties. For example, ____________ is used in electrical wiring because it is ductile and can ____________________ electricity. It also doesn't react with ____________________ , which means we can also use it to make pipes.

Historically, humans have used substances to their advantage. Archaeological ages can be separated into the ______________ Age, the ______________ Age and the ______________ Age. As we have developed as a culture, our uses of substances have become more ____________________.

WORD BANK

bronze	copper	physical	water
chemical	different	properties	
conduct	iron	sophisticated	
compounds	particle	stone	

Describe the properties and uses of some metal and non-metal elements

1 Identify some physical differences between a metal and a non-metal. [2 marks]

2 Describe the properties and uses of copper. [2 marks]

3 Describe the properties and uses of oxygen. [2 marks]

4 Compare and contrast the properties of a metal and a non-metal element. [2 marks]

5 Carbon is often found as an allotrope. Explain what this term means and outline why carbon is classified as a non-metal. [3 marks]

6 Explain how the property of an element relates to its use, using an example. [2 marks]

Identify that our understanding of the structure and properties of elements has changed due to technological advances

7 Our understanding of the structure of elements has changed due to technological advances. Explain how a specific technological advancement has changed our understanding of the structure of an element. [2 marks]

8 Explain how a specific technological advancement has changed our understanding of the properties of an element. [2 marks]

9 Suggest a reason why scientists persisted with building the Large Hadron Collider, and recall the outcomes of the research so far. [2 marks]

Explain why element symbols are used in science

10 Recall the chemical symbol for:

- **a** hydrogen [1 mark]
- **b** carbon [1 mark]
- **c** copper [1 mark]

11 We often use symbols and chemical formulas to describe substances in science. Explain why this is the case. [2 marks]

12 The chemical symbols used in science are often derived from ancient names. For example, gold has the symbol Au, which comes from *aurum*, the Latin word for gold. Explain why less reactive elements are more likely to have their Latin names. Hint: How does the reactivity of an element relate to how easily it could be discovered? [3 marks]

Describe the differences between elements, compounds and mixtures in terms of type and arrangement of particles

13 Describe how particles are arranged in an element. [1 mark]

14 Recall the definitions of an element, a compound and a mixture. [2 marks]

15 Compare and contrast the particle arrangements in a compound and a mixture. [2 marks]

Identify some common compounds

16 Identify two common compounds used in everyday life and recall their chemical formulas [2 marks]

17 Sodium bicarbonate ($NaHCO_3$) is a common compound also known as baking soda. Identify the elements baking soda contains, including the element names and their symbols. [1 mark]

Investigate how people in different cultures in the past have used certain substances to their advantage

18 The development of human society has been closely linked to the availability of metals and materials. Using your understanding of one material used in prehistoric times, explain why this

material was used, what it was used for and what we use to perform that function today. [3 marks]

19 Explain how our understanding of elements and their properties has helped to shape history. [2 marks]

20 Explain how technology affected the development of a particular culture. [3 marks]

4 CHAPTER REVIEW

TOTAL MARKS
[/50]

Investigate how the chemical properties of a substance help determine its use (additional content)

21 Gold is not chemically reactive, while nickel is. Explain why gold is more ideal to use in jewellery instead of nickel. [2 marks]

22 Water pipes used to be made from lead before copper became the preferred material. Plastics are now commonly used to make water pipes. Investigate these three substances and suggest reasons why lead was replaced by copper, and then why plastic replaced copper. [5 marks]

RESEARCH

Choose one of the following topics for a research project. Your job is to discover a little more about how materials are used in society, both historically as well as in present day.

Emerging technologies

There are many new technologies available for use in touch technology and smart phones. Investigate some of the compounds and elements used in these technologies. How do we obtain these elements and compounds? What does the demand and supply look like? Are there any estimates as to when these materials may run out?

Steel structures

The I-beam is the strongest form of steel beam used in construction. It is a much stronger than a single beam of steel. Research why this may be the case. You will need to look at the applied forces in all directions as well as some of the physical strengths that iron has (such as compressional strength and tensile strength).

Beaker people

The Beaker People were a movement during archaeological history that came after the Iron Age. The Beaker People are known for using a particular kind of vessel to carry liquids. Investigate the Beaker People culture including why and how they moved through Europe and took over from the Iron Age.

REFLECT

4 CHAPTER REVIEW

Me

1 How has my understanding of elements, compounds and properties of substances changed?

2 What did I find difficult in this topic?

My world

3 What elements and compounds do we typically use in everyday life?

4 Why do we use certain materials in technology? What is it about those materials that make them suitable for their usage?

My future

5 What are some future limitations to how we use materials?

6 How will we tackle problems of limited supply of certain materials?

KEY WORDS

allotrope	flammability	metalloids	polymers
alloy	groups	metallurgy	pressure
compound	heterogeneous	mixture	reactivity
corrosion	homogenous	molecular	refractive index
decomposition	kinetic theory	non-metals	smelting
diatomic	lattice	nucleus	toxicity
electrons	monatomic	particles	
element	metals	periods	

4

MAKING CONNECTIONS

Use of elements and compounds by traditional Indigenous Australians

Australia is one of the oldest and flattest countries in the world. Australia lies in the middle of a continental plate. There are no active volcanoes on the mainland, and it has been a long time since the extinct volcanoes were active. There are a few interesting geological features because of this.

Australia has low nutrient soils

Nutrients come from the recycling of organic matter such as decaying trees or animals, but also come from new rocks made by volcanoes. Over many thousands of years, the nutrients found in new rocks are leached further down into the soil. Australia, being a very 'old' country, means there are very few new rocks – Australia has the oldest rocks in the world! However, this also leads to very poor soil quality.

Australia has very little volcanic rock

Another result of Australia's location and long extinct volcanoes means that harder volcanic rocks were weathered and eroded away long before the arrival of Indigenous Australians.

When looking at Stone Age technology, Australia lacked the flint and chert that other continents had access to.

Influences of geology

The geology of the region meant the tools that Indigenous Australians used were very different to others around the world. As a result of different tools, the lifestyles of Indigenous Australians tended to be quite different compared with their European or Asian counterparts.

Indigenous Australian tools

As Australia is such a vast country, the materials available to make tools and implements varied greatly depending on location. Different groups produced their tools and implements differently depending on the purpose of the tool and the location of the group. Knives, spears, digging implements and vessels for eating and drinking were common among all communities. Coastal communities would use fish bones as spears, whereas communities with no access to the ocean would use stones or fire-hardened wood for this same purpose.

Figure 4.68 Blades made by chipping away at the edges of stones. These kinds of blades were often used for ceremonial purposes, but also for cutting up meat and other food.

Weapons

A lot of tools such as boomerangs, clubs and spears were made of materials that decay easily, such as wood and fibre. Very few ancient examples remain. Spears tended to be made from light wood that grew tall and straight. This meant little work was required to shape the spear. Lighter wood also meant that spears took less energy to throw.

Boomerangs tended to be made of heavier wood, as more force was required to hunt larger prey such as kangaroos. Lighter boomerangs existed, but they were still made out of wood that was heavier than the wood used for spears.

Carriers

Nets, baskets and bags were used for hunting and fishing as well as for carrying multiple objects. The weaves in some baskets were so tight that they were capable of carrying honey! Bags were usually made from a plant called cordyline, as well as grass stalks and bush string. Twined bark fibres, swamp reeds, flax and seagrasses were also used to weave baskets. Basket weaving is very intertwined with Indigenous folklore. Often stories are passed on from generations during sessions of basket weaving.

Watercrafts and canoes

Watercrafts were relatively fragile. They were often made from bark and left to rot after a few uses. Watercrafts were typically used to help hunt bird eggs and fish. Rivers were used to travel quickly through regions. There are often trees around riverbeds that still show 'canoe scarring' – a region of bark that has been peeled from the tree to make a canoe.

Figure 4.69 An assortment of Indigenous tools: coolamon (wooden carrying bowl), stone axe, wooden shield, dilly bag, grinding stone, fire sticks and woomera (spear-throwing device).

Figure 4.70 A tree showing a typical canoe scar.

Research tasks

1. Research some other tools used by traditional Indigenous Australians. You may wish to look at items such as digging sticks, seed-grinding stones, spear throwers, shelters and message sticks. Examine the materials these tools and implements were made from, and suggest a reason why these materials were selected.
2. Research the cultural surroundings of traditional Indigenous Australians. Ceremonial wear, body paint and rock painting were all common. What were used for these special purposes? How were the materials used different to those used for everyday items?
3. Traditional Indigenous Australians also had established trading routes to exchange items available in one region but not another. Ochre, grinding stones, shields and weapons were all traded. Research some of these trade routes. How did traditional Indigenous Australians communicate with each other when languages between communities were so different? Where were these trade routes found? What items were traded?
4. Consider the following statement: 'Human development was largely influenced by the geology of their surroundings. For example, in Australia, traditional Indigenous Australians lived a largely nomadic life due to the poor soil quality and the lack of easy access to metals such as copper.'

Research the geology of Australia and the lifestyle of traditional Indigenous Australians compared with places like Europe, and evaluate the statement. Present your information as an annotated poster, multimedia presentation or another format of your choosing. You must supply a bibliography of your sources.