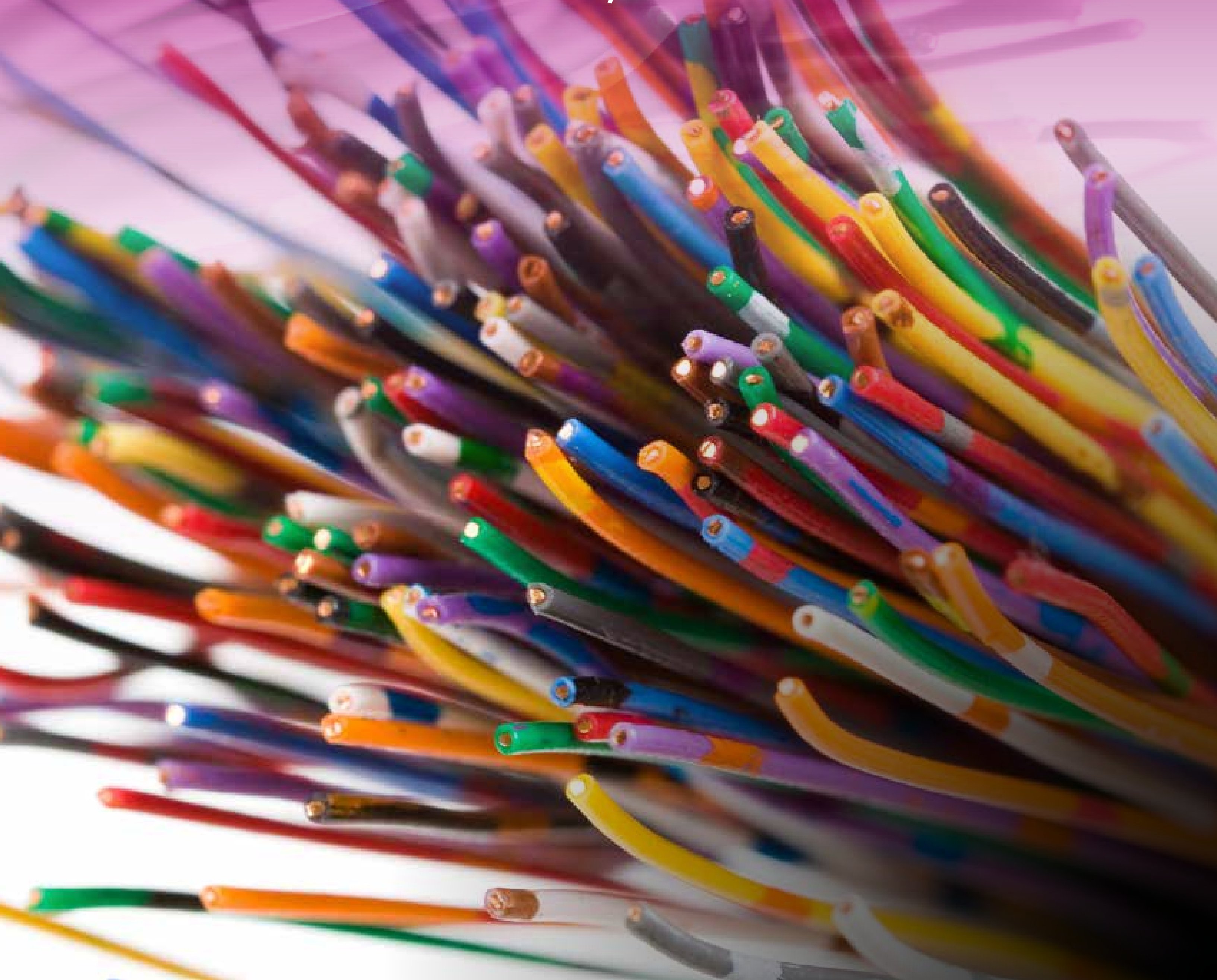
Surfing

VCE CHEMISTRY 1

Unit 1 How Can the Diversity of Materials Be Explained?

Marilyn Schell



Science Press
Bag 7023 Marrickville NSW 1475 Australia
Tel: (02) 9516 1122 Fax: (02) 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

Contents

Introduction

This book covers the Chemistry content specified in the Victorian Certificate of Education Chemistry Study Design. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

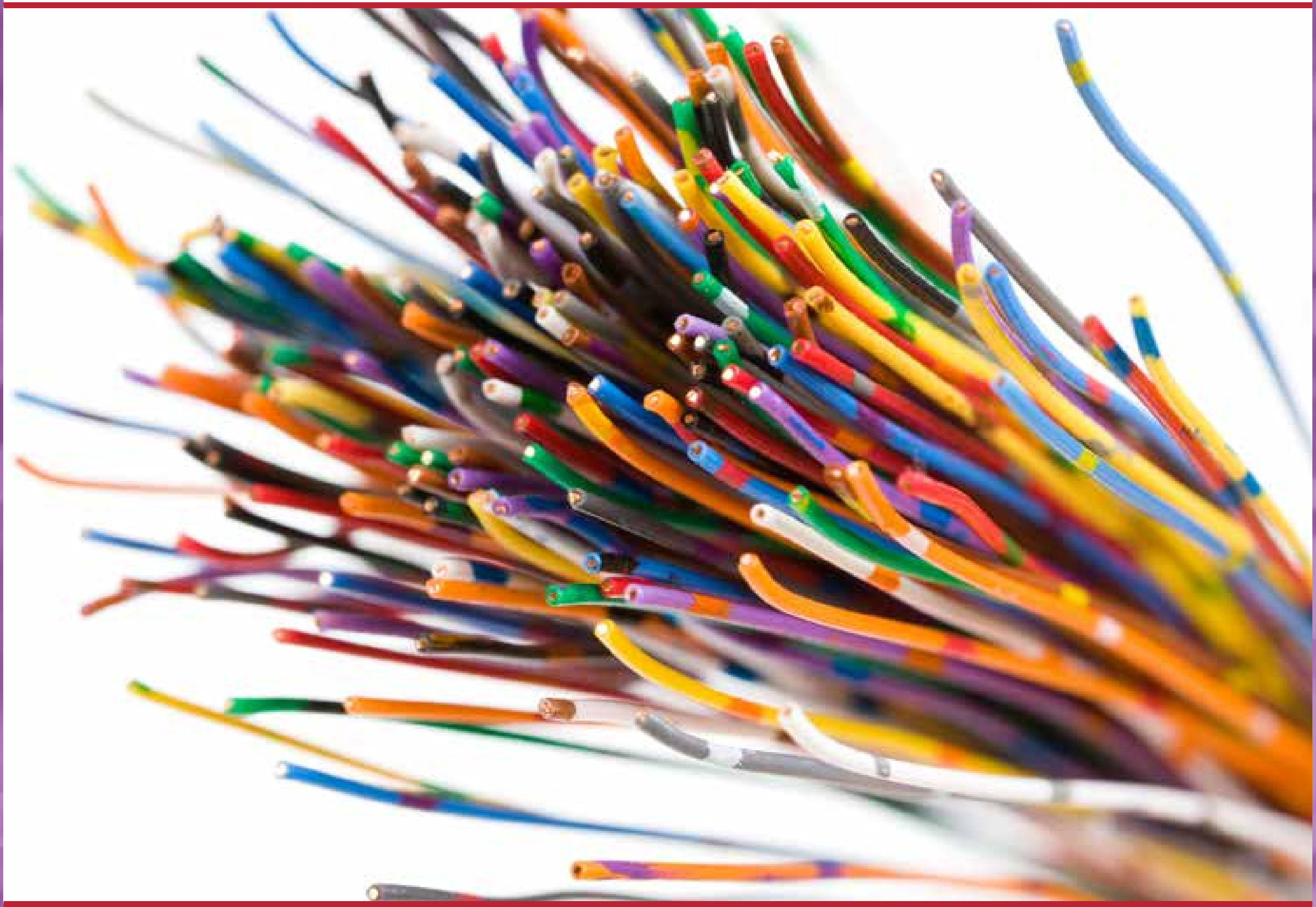
synthesise Combine various elements to make a whole.

Surfing

VCE CHEMISTRY 1

Area of Study 1

Elements and the Properties of Matter



1 Size of Particles

In chemistry, a **particle** is just a tiny amount of the matter. All matter consists of particles. Particles make up everything the Universe is made of and contains. Particles are all around us and even make up our own bodies.

Particles vary in size. Some particles are **visible**. A very small piece of rock that you pick up, a drop of water, a grain of sand, a spot of paint flicked by a paintbrush – all these could be described as particles which are visible to the unaided eye. We can see particles as small as about 40 micrometres (40 μm = 0.004 cm). Micrometres are also commonly called microns (μ), they are the same.

Some particles are too small to be seen without the help of a **magnifying glass or light microscope** – for example, a clump of pollen grains (10 to 100 μm), a dust mite (100 to 300 μm), a bacterium (0.5 to 1.0 μm), a red blood cell (6 to 8 μm).

Still others cannot be seen with a light microscope, but may be visible under an **electron microscope**. This uses a beam of electrons rather than light and can magnify objects up to about 2 million times. Some electron microscopes can see details as small as 0.2 nm (nanometres). A nanometre (nm) is 1000 times smaller than a micrometre (μm). **Viruses** can vary in size from about 5 to 400 nm, which is much smaller than bacteria. In comparison, macromolecules are around 10 μm and smaller molecules are only about 0.001 μm (1 nm) in size.

Nanoparticles are even smaller, they have one dimension between 1 and 100 nanometres wide. **Atoms** have no definite outer boundary so it is difficult to measure them, but they vary in size from about 0.1 to 0.5 nm. **Subatomic particles** include protons, neutrons and electrons which are all smaller than 0.1 nm, for example, a proton is about 0.8×10^{-6} nm in diameter.

Converting measurements

The different units used to measure particles of different sizes can be very confusing. In case you are not sure about units, here are some conversion factors to help you.

Table 1.1 Converting measurements.

1 km = 1000 m	1 cm = 10 mm
1 m = 1000 cm	1 mm = 0.1 cm
1 m = 1 000 000 μ (micron)	1 μm = 1 000 nm
1 μ =1 μm = 1×10^{-6} metre	1 nm = 10^{-3} μm
1 nm (nanometre) = 10^{-9} m	1 pm (picometre) = 10^{-12} m

QUESTIONS

1. What is the relationship between one metre and one:
   (a) Centimetre. (b) Micron.
   (c) Nanometre. (d) Picometre.
2. Place the following particles in order of size, starting with the largest.
   A nanoparticle, a proton, an atom, a water molecule, a bacterium, a red blood cell, a virus.
3. Explain why the substances listed in the table below are able to cause damage to the human body.

Type of particle	Size (microns)
Fibreglass Insulation	1 to 1000
Coal dust	1 to 100
Asbestos	0.7 to 90
Insecticide dust	0.5 to 10
Tobacco smoke	0.01 to 4
Pesticides	0.001

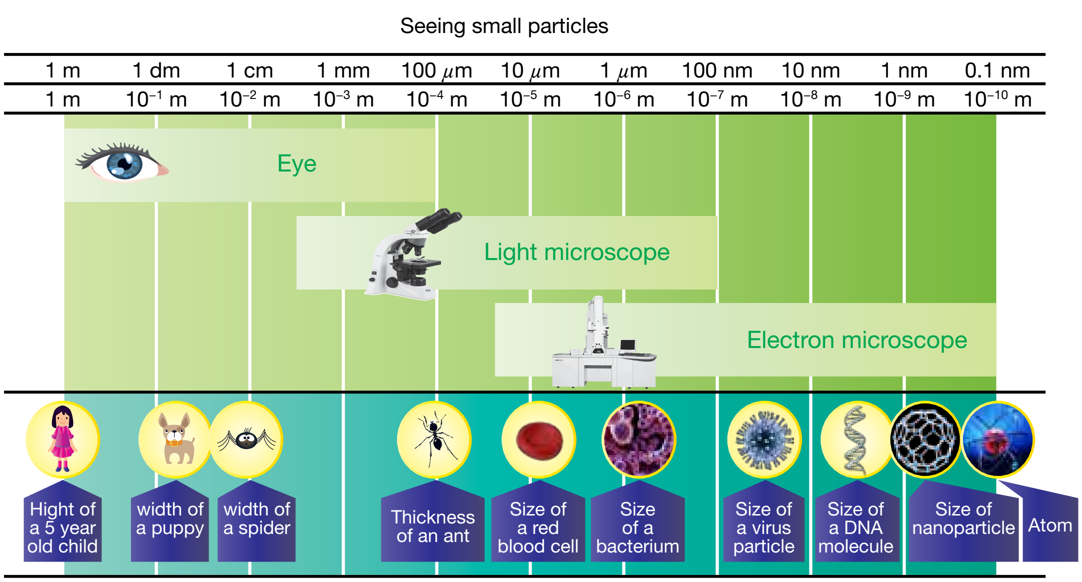


Figure 1.1 Seeing particles.

2 Kinetic Particle Theory

You may recall learning about the kinetic particle theory which states that everything – all the matter in the Universe – is made of **many tiny particles that are continuously in random motion and able to interact with each other**. Revising this theory here will help with your understanding of the concept of particles of different sizes and how these relate to elements and compounds and their chemical reactions.

The particles referred to in the kinetic particle theory can be **atoms**, **molecules or ions**. The types and arrangement of particles in a substance tell us if it is an element, compound or mixture.

Elements, compounds and mixtures

Matter can be classified as elements, compounds or mixtures based on their particles.

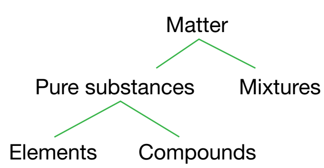


Table 2.1 provides some examples of elements, compounds and mixtures.

Table 2.1 Examples of elements, compounds and mixtures.

Pure substances		Mixtures
Elements	Compounds	
Calcium Ca	Hydrochloric acid HCl	Fried rice
Sodium Na	Calcium hydroxide $Ca(OH)_2$	Air
Magnesium Mg	Sodium chloride NaCl	Ocean water
Aluminium Al	Calcium oxide CaO	Blood
Oxygen O		Nail polish

Elements and compounds are referred to as **pure substances** because they each consist of particles which are all the same. Mixtures are not pure substances because their particles vary.

A **pure substance** (element or compound) has properties that are always the same. These can be physical properties such as melting point, boiling point, density, hardness, conductivity, malleability; or they can be chemical properties such as whether it is stable or will decompose on heating and whether it reacts with water, acids and bases.

Particles in elements

The particles in an element are all the same. They may be single atoms, or molecules made of groups of identical atoms. You can see this in Figure 2.1.

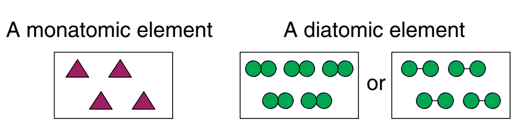


Figure 2.1 Particles in elements.

There are 92 elements that occur naturally and these are all listed on the periodic table. Each element has its own symbol and its own distinctive properties – both physical and chemical.

Particles in compounds

The particles in any compound are all the same. Each particle is made of two or more different atoms chemically combined together, always in the same ratio. Each compound also has its own distinctive physical and chemical properties. We can illustrate compounds as in Figure 2.2.

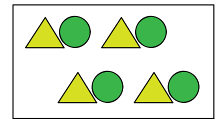


Figure 2.2 Particles in compounds.

Particles in mixtures

The particles in mixtures are *not* all the same. Mixtures may contain particles of different elements, different compounds, or elements and compounds, as shown in Figure 2.3. Because the composition of a mixture can vary, mixtures cannot be represented by symbols and they do not have distinctive physical or chemical properties.

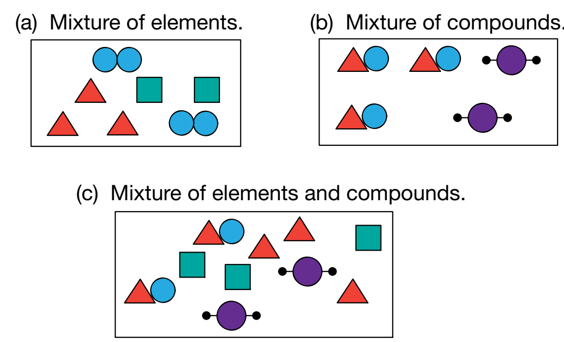
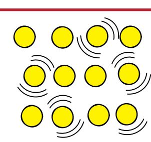
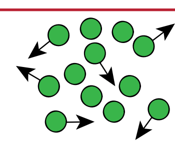
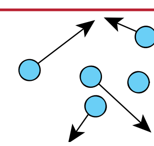


Figure 2.3 Particles in mixtures.

Particles and the states of matter

Table 2.2 States of matter and particle theory.

Solid	Liquid	Gas
Particles are close together and vibrating in fixed positions	Particles are close together and moving more freely	Particles are far apart and moving very freely
		
Definite shape	Shape depends on container	Shape depends on container
Definite volume	Definite volume	Fills all available space
Cannot be compressed	Cannot be compressed	Can be compressed
Cannot diffuse (spread through other substances)	Can diffuse	Can diffuse

In different states (solid, liquid and gas), the particles of a substance move differently. The energy of the particles controls their movement and thus the state of the substance. When particles of a substance change speed, this may cause a change in state of the substance. The particles themselves do not change their state. Heating a solid may make its particles move faster and more freely, and break apart from each other, so that the substance becomes a liquid. Cooling a substance causes its particles to slow down. Experiments predict that zero kinetic energy of the particles in matter will occur at a temperature of –273°C, which no one has yet been able to achieve. This is known as absolute zero and is the basis for the Kelvin temperature scale.

Particles and physical change

In a physical change, such as melting or boiling, the particles are rearranged. During any change of state, the particles stay the same, but they move differently and change their distance apart.

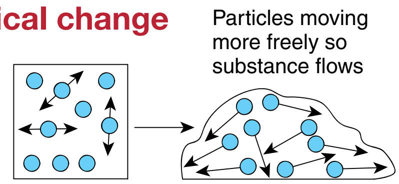


Figure 2.4 Particles during a change of state.

Particles and chemical change

In a chemical change, such as burning or electrolysis, the atoms are rearranged. For example, Figure 2.5 shows water particles split and rearrange when it is decomposed by electricity passing through it (electrolysis).

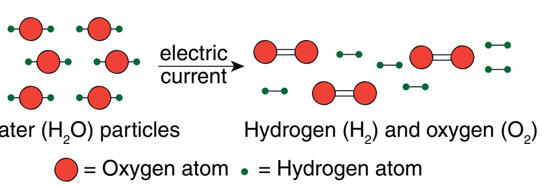


Figure 2.5 Particles in a chemical reaction.

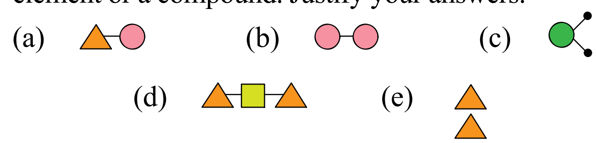
The differences between physical and chemical changes are summarised in Table 2.3

Table 2.3 Physical and chemical changes.

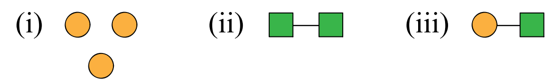
Factor	Physical change	Chemical change
New substances	No new substance is formed.	A new substance is formed.
Particles	Particles stay the same (they just move differently).	New particles are formed (atoms have been rearranged).
Reversal	Usually easy to reverse by physical changes.	Usually difficult to reverse.
Energy involved	Small energy changes usually involved.	Energy changes are usually large.
Examples	Filtration, centrifuging. Change of state, e.g. melting, boiling, evaporation, condensation.	Combustion (burning). Acids on metals. Decomposition by heat or by electrolysis.

QUESTIONS

1. The following diagrams illustrate a number of particles. Deduce whether each of these diagrams represents an element or a compound. Justify your answers.



2. The following diagrams show a series of molecules.

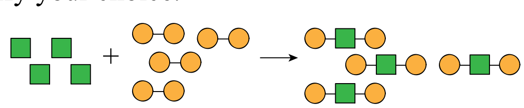


Identify which diagram represents:
(a) An element that has diatomic molecules.
(b) A compound.
(c) An element that has monatomic molecules.
Justify your answers.

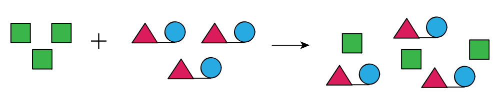
3. Draw diagrams of:
(a) A molecule of a compound which has three different types of atoms.
(b) A molecule of a compound which has four atoms of three different types.
(c) A molecule of an element that is diatomic.
(d) A molecule of an element that is monatomic.
(e) A mixture of an element which has diatomic molecules and a compound with two different types of atoms.

4. Identify which of the following diagrams show a physical change and which show a chemical change. Justify your choice.

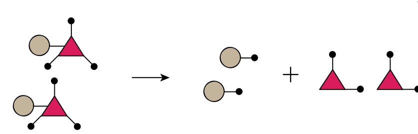
(a)



(b)



(c)



5. (a) How is the theory that all matter is made of particles helpful in chemistry?
(b) In terms of particles, what is the difference between a physical and a chemical change?

6. (a) Identify three types of particles.
(b) Name the theory that states – all matter is made of moving particles.
(c) If the particles in a substance are identical then it must be a(n) .... or ....
(d) Which state(s) of matter can be compressed?
(e) Name and state the symbol of five elements.
(f) Name five common mixtures.
(g) Name five compounds and state a formula for each.

3 Introduction to Elements

Before you get started on your study of elements and the periodic table, you should check that you remember and understand this revision of some junior science. If anything is not clear you should speak to your teacher immediately.

- Each element is a pure substance containing only one type of atom.
- There are 92 elements that exist naturally and make up the entire Universe. Some other elements have been made in nuclear reactors or particle accelerators, but most of these have unstable atoms and only exist for a fraction of a second.
- The periodic table lists all the elements in order of their atomic numbers (the number of protons in the nucleus of their atoms).
- Elements are classified, according to their properties as metals, non-metals and metalloids (or semi-metals).
- On the periodic table, metals are on the left and non-metals on the right. There are a lot more metals than non-metals.

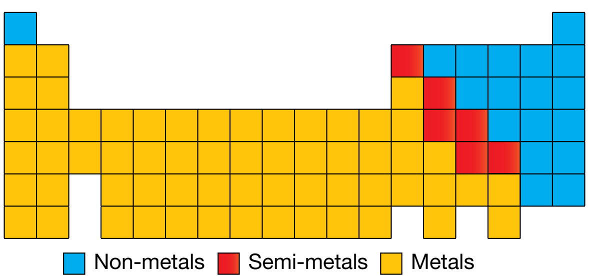


Figure 3.1 Periodic table.

Metals, non-metals and metalloids

Metals tend to melt and vaporise at much higher temperatures than non-metals. Because of this, most metals are hard, shiny solids at room temperatures, whereas non-metals tend to be gases or soft solids. Only two elements occur naturally as liquids – the metal mercury (Hg) and the non-metal bromine (Br_2).

Metals are better conductors of heat and electricity than non-metals. One exception to this is graphite, a form of the non-metal carbon that is used in 'lead' pencils.

Metals are malleable (can be bent and hammered into shapes) and ductile (can be stretched into wires). Non-metals are neither malleable nor ductile.

Metalloids (also called semi-metals) include boron, silicon, germanium, antimony and arsenic. They are found on the periodic table between the metals and non-metals. Like metals, they are crystalline solids with high melting points. However, they do not conduct electricity as well as metals. Some semi-metals/metalloids are used as semiconductors.

Figure 3.2 Non-metals – bromine, carbon, phosphorus and sulfur.

Figure 3.3 Metals – iron, copper, aluminium, silver, lead, and gold.

Elements as particles

Elements are made of particles, which can be atoms, ions or molecules.

An **atom** is the smallest amount of an element that can take part in a chemical reaction, for example the oxygen atom, O.

An **ion** is an atom which has lost or gained one or more electrons, for example the oxide ion O^{2-}.

A **molecule** is the smallest part of a substance that can exist independently. For example, oxygen exists as a molecule made of two oxygen atoms linked together.

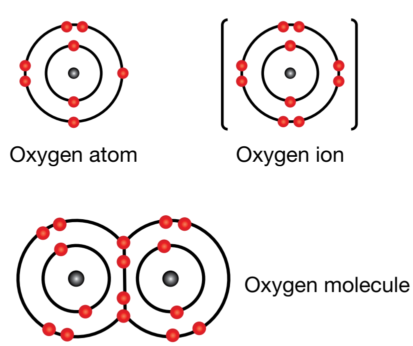


Figure 3.4 Oxygen as an atom, ion and molecule.

When oxygen reacts with another substance, the molecule splits and individual atoms react by sharing or donating electrons.

Each element has unique atoms, so a sample of any element consists of billions of identical atoms. These are different from the atoms of all other elements.

Each atom has a tiny central nucleus with electrons orbiting around this nucleus. The atom is more than 10 000 times bigger than its nucleus, and most of an atom is just empty space. Even in the nucleus there is empty space. There is no air inside atoms, only tiny particles and empty space.

The atom consists of even smaller particles, called **subatomic particles**. There are three main types of subatomic particles, which are summarised in Table 3.1. Most of the mass of an atom is due to the protons and neutrons in its nucleus, each orbiting electron being almost 2,000 times lighter than a neutron or a proton.

Table 3.1 Subatomic particles in atoms.

Particle	Where it is found	Symbol	Relative charge
Proton	Nucleus	p^+	+1
Neutron	Nucleus	n	0
Electron	Orbiting the nucleus	e^-	−1

QUESTIONS

1. Using the positions of elements in the periodic table, classify each of the following elements as a metal, non-metal or semi-metal.

Element	Classification	Element	Classification
Sodium		Germanium	
Chlorine		Carbon	
Gold		Boron	
Nickel		Mercury	
Oxygen		Hydrogen	

2. Name four semi-metals and account for their classification.
3. Describe how you could test the electrical conductivity of an element. Use a circuit diagram in your answer.
4. Copy and complete the table below to summarise differences between physical properties of metals and non-metals.

Physical property	Metals	Non-metals
Melting and boiling points		
Conductivity of heat		
Conductivity of electricity		
Malleable		
Ductile		
Lustre		
State at room temperature		

5. (a) What is an atom?
   (b) Outline the structure of an atom.
6. Use the information in the table below to classify each of the elements P, Q, R and S as a metal or a non-metal.

Element	Melting point (°C)	Boiling point (°C)	Conductivity
P	1490	2900	Good
Q	−7	58	Poor
R	1540	3000	Good
S	114	183	Poor

7. Something is wrong with each of the following statements. Rewrite them as scientifically accurate statements.
   (a) An element is a pure substance containing only one atom.
   (b) Most elements are non-metals.
   (c) Compounds are made of elements mixed together in any ratio.
8. Colour in the periodic table below to illustrate which elements are solids, liquids and gases at room temperature (25°C).

						H											He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Ru	Db													

☐ Gases ☐ Liquids ☐ Solids

9. Check your knowledge with this quick quiz. Identify each of the following.
   (a) An inert non-metal.
   (b) Five metals and their symbols.
   (c) Five non-metals and their symbols.
   (d) The most common element in the Universe.
   (e) A non-metal that is a good electrical conductor.
   (f) Particles found in the atomic nucleus.
   (g) Particles that orbit the atomic nucleus.
   (h) The smallest atom that exists.
   (i) Number of elements that occur naturally.
   (j) The smallest part of an element that can take part in a chemical reaction.
   (k) The term which means 'can be stretched into wires'.
   (l) Which are better conductors of heat and electricity, metals or non-metals?

4 Distribution of Elements

There are 92 elements that occur naturally and make up the entire Universe. Most of these 92 elements are chemically reactive, so they combine in fixed ratios with other elements to form compounds. For example:

- Sodium and chlorine occur as sodium chloride ($NaCl$), the main salt in sea water.
- Carbon occurs in many compounds including carbon dioxide (CO_2) and glucose ($C_6H_{12}O_6$).
- Hydrogen occurs as water (H_2O) and in many carbon compounds such as methane (CH_4) in natural gas.

The less reactive elements occur uncombined as the element. For example:

- Gold and silver occur in the Earth's crust as elements.
- Inert gases such as neon, argon and krypton occur as elements.

Some elements occur both in compounds and also as the element. For example:

- Oxygen occurs as a gas in the atmosphere and in many compounds such as water, carbon dioxide (CO_2) and calcium carbonate ($CaCO_3$).
- Nitrogen gas (N_2) makes up approximately 78% of the atmosphere and it also occurs in compounds such as in proteins.
- Sulfur occurs in the crust as deposits of the element. It also occurs in the ocean as sulfur compounds such as magnesium sulfate.

The origin of elements

The Big Bang theory, which is believed to have started our Universe about 15 billion years ago, led to the creation of the smallest atoms, e.g. hydrogen, helium and lithium. All other elements have been created by nuclear fusion reactions in stars and supernovas as the nuclei of smaller atoms combined together. Fusion reactions release a great deal of energy.

Composition of the Universe

Hydrogen is the most common element in the Universe, followed by helium. The composition of the Universe is believed to be similar to that of stars such as our Sun. The Sun is mostly hydrogen and helium, although it does contain about 67 elements and Table 4.1 lists those that are most abundant.

Table 4.1 Abundance of the most common elements in the Sun.

Element	Composition by total number of atoms (%)	Composition by mass (%)
Hydrogen	91.2	71.0
Helium	8.7	27.1
Oxygen	0.08	0.096
Carbon	0.04	0.40
Nitrogen	0.01	0.096
Silicon	0.0045	0.099
Magnesium	0.0038	0.076
Neon	0.0035	0.058
Iron	0.030	0.014

Composition of the Earth's crust

The composition of the **Earth's crust** differs from that of the whole Universe. The main elements in the Earth's crust are shown in Table 4.2.

Table 4.2 Composition of the Earth's crust.

Element	Composition by mass (%)
Oxygen	46.6
Silicon	27.7
Aluminium	8.1
Iron	5.0
Calcium	3.6
Other elements	9.0

The most common atoms in the crust are oxygen atoms – they occur combined in many compounds. Most of the elements in the crust occur as compounds, e.g. silicon dioxide (SiO_2). Silicon dioxide is the main component of sand and quartz. The largest group of rock-forming minerals are silicate compounds – compounds containing silicon and oxygen combined together with metals such as aluminium. Calcium occurs in compounds such as calcium carbonate which is found in marble and limestone.

The **Earth's core** consists of mainly iron and nickel with smaller amounts of the lighter elements such as sulfur and oxygen.

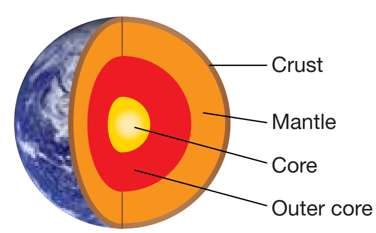


Figure 4.1 The Earth's structure.

Carbon-based life forms

Life on Earth is carbon based and all living things have similar composition. They are largely made of water and carbon compounds such as carbohydrates, proteins and lipids (fats and oils). For example, compare the elements present in humans and bacteria shown in Table 4.3.

Table 4.3 Elemental composition of humans and bacteria.

Element	Composition by mass (%)	
	Humans	Bacteria
Oxygen	64.00	68.00
Carbon	19.00	15.00
Hydrogen	9.00	10.20
Nitrogen	3.00	9.00
Calcium	1.50	0.25
Phosphorus	0.80	0.83

Techniques used to analyse the elements that make up the structure of objects include:

- **Neutron diffraction** is used to analyse crystalline material without destroying it, e.g. determining the chemical structure of historical artefacts such as ceramics and paintings.
- **Spectral analysis** is a technique which allows scientists to look at the colours of light (spectra) or wavelengths of other forms of radiation (e.g. infra-red, ultraviolet) which are released or absorbed by a substance. This technique has been used to determine the composition of stars, as each star emits a unique spectrum of radiation.

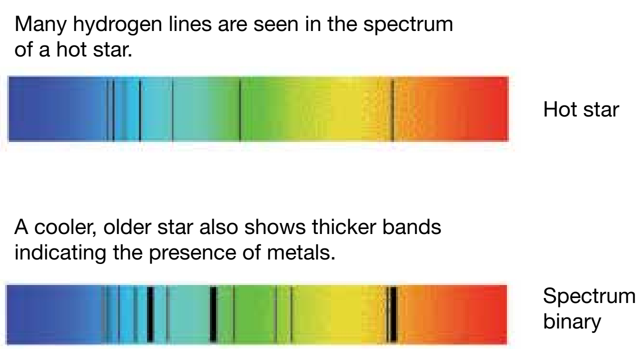


Figure 4.2 Spectral analysis of stars.

The absorption or emission of specific wavelengths is the basis of flame tests and atomic absorption spectroscopy, both of which will be dealt with in more detail later.

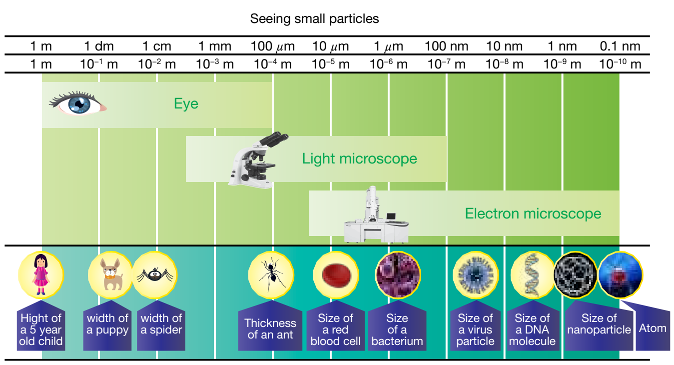
QUESTIONS

1. It is interesting to compare the relative abundance of elements in different areas. From the data provided in the text, identify the most commonly occurring:
   (a) Element in the Universe.
   (b) Metal in the Earth's crust.
   (c) Non-metal in the Earth's crust.
2. From data provided in the text:
   (a) Identify the four elements that are most common in the Earth's crust.
   (b) Use a pie graph to illustrate the composition of the Earth's crust. Include a heading and a key.
3. (a) Hydrogen makes up 90% of the atoms in our Sun, but it only makes up 71% of the mass of the Sun. Explain.
   (b) How does the composition of the Earth's crust differ from the composition of the Universe?
4. Research the composition of the Earth's atmosphere to identify the three most common gases present.
5. The composition of the human body is given in one source as mainly oxygen, carbon and hydrogen. Another source claims it is made of mainly carbohydrates, proteins and fats.
   (a) Account for this apparent conflict.
   (b) Name three elements that are present in almost identical concentrations in humans and bacteria.
6. Research to identify some elements and compounds present in the atmosphere, lithosphere and hydrosphere. Tabulate your answer.
7. (a) Name two techniques used to analyse the elemental composition of objects.
   (b) Outline a theory to account for the existence of elements with larger atoms than helium and lithium.
8. Outline ways in which advances in scientific understanding of elements has impacted on one of the following.
   (a) Developments in two other areas of science.
   (b) Society and the environment.
9. Life on Earth is carbon based and yet carbon is not one of the six most common elements in the Earth's crust. Outline the main sources of carbon on Earth.
10. Check your knowledge with this quick quiz.
   (a) Identify the most common element in the Universe.
   (b) Name the most common element in the atmosphere.
   (c) All known life is based on which element?
   (d) Name the technique used to analyse which elements are present in stars.
   (e) Name the three main elements in all living organisms.

Answers

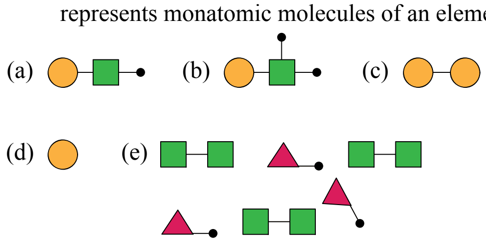
1 Size of Particles

1. (a) A centimetre is 100 times smaller than a metre (1 m = 100 cm).
   (b) A micron is a million times smaller than a metre (1 m = 1 × 10^6 µm). A micron is the same as a micrometre.
   (c) A nanometre is a thousand million times smaller than a metre (1 m = 10^9 nm).
   (d) A picometre is 1 000 000 000 000 (a million million) times smaller than a metre. (1 m = 10^{12} pm).
2. Red blood cell, bacteria, virus, nanoparticle, water molecule, atom, proton.
3. These substances can all have particles which are smaller than many cells, including blood cells. They can be breathed in, invade the lungs and do damage there. They can also get into the bloodstream and reach other organs where they can cause further damage.



2 Kinetic Particle Theory

1. (a), (c) and (d) are compounds – each consists of two or more different particles joined together. (b) is an element – two identical particles are joined to make a diatomic molecule of an element. (e) is an element – two identical particles are present but they are not joined – they represent two monatomic molecules of an element.
2. (a) A diatomic element is represented by diagram (ii). Two identical particles are joined.
   (b) A compound is represented by diagram (iii). Two different types of particles are joined together.
   (c) A monatonic element is represented in diagram (i). There are three identical particles, but they are not joined – so this represents monatomic molecules of an element.
3.



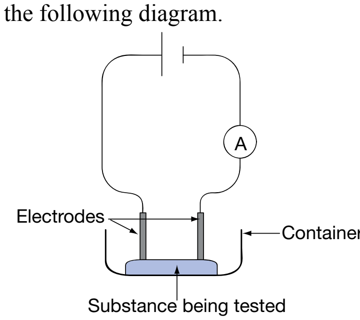
4. (a) Chemical – new particles are formed.
   (b) Physical – particles simply mix, no new particles are formed.
   (c) Chemical – new particles are formed.
5. (a) The particle theory provides a model which helps us to visualise what is happening within matter. It helps us to explain many things about solids, liquids and gases, e.g. their shape, what happens when you try to compress them, and why liquids and gases can diffuse but solids cannot.
   (b) In a *physical change* the particles remain the same, they just move differently, e.g. faster or slower. In a *chemical change*, new particles are formed – we see this when atoms are rearranged during a chemical reaction.
6. (a) Atoms, molecules, ions.
   (b) Kinetic particle theory.
   (c) Element or compound.
   (d) Gas.
   (e) Various, e.g. sodium Na, oxygen O, hydrogen H, aluminium Al, mercury Hg. (Any name on the periodic table is correct for this question.)
   (f) Various, e.g. air, sea water, ink in a pen, nail polish, paint, bread, cosmetics, soil, rocks, soup.
   (g) Various, e.g. water H_2O, sodium chloride NaCl, sodium hydroxide NaOH, hydrochloric acid HCl, ammonia NH_3.

3 Introduction to Elements

1.

Element	Classification	Element	Classification
Sodium	Metal	Germanium	Semi-metal
Chlorine	Non-metal	Carbon	Non-metal
Gold	Metal	Boron	Semi-metal
Nickel	Metal	Mercury	Metal
Oxygen	Non-metal	Hydrogen	Non-metal

2. Semi-metals are boron, silicon, germanium, arsenic, antimony and tellurium. They are classified as semi-metals as they have properties of both metals and non-metals. Like metals they are crystalline solids with high melting points, but they also resemble non-metals, for example they are poorer conductors of electricity than metals.
3. *Note:* Any diagrams you draw in chemistry should be in pencil, large enough to clearly see how the apparatus is connected and used, and they must always be fully labelled.
   Set up a circuit as shown in the following diagram.
   Place each element to be tested in the container, one at a time, and touch the ends of the sample with the electrodes. If the element conducts electricity, the ammeter will show a current is flowing (you could also use a light globe in the circuit).



4.

Physical property	Metals	Non-metals
Melting and boiling points	High	Low
Conductivity of heat	Good	Poor
Conductivity of electricity	Good	Poor (except graphite)
Malleable	Malleable	Not malleable
Ductile	Ductile	Not ductile
Lustre	Shiny lustre	Dull, no lustre
State at room temperature	All solids except mercury which is liquid.	Mostly soft solids or gases except bromine which is liquid.

5. (a) An atom is the smallest part of an element that can take part in a chemical reaction.
   (b) The central part of an atom is called the nucleus and it contains positively charged particles called protons and neutral particles called neutrons. Most of the mass of an atom is in the nucleus. Tiny, negatively charged particles called electrons orbit the nucleus of the atom in shells.

6. P – metal, Q – non-metal, R – metal, S – non-metal.
7. (a) An element is a pure substance containing only one type of atom.
   (b) Most elements are metals.
   (c) Compounds are made of elements chemically combined together in a fixed ratio.
8.

						H											He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Ru	Db													

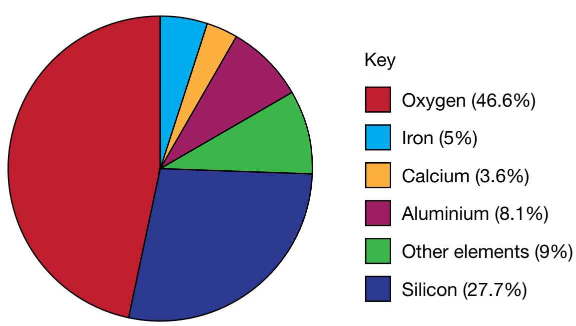
Gases   Liquids   Solids

9. (a) Any element in group 8, e.g. helium.
   (b) Various, e.g. sodium Na, calcium Ca, iron Fe, tin Sn, cobalt Co.
   (c) Various, e.g. chlorine Cl, argon Ar, nitrogen N, sulfur S, fluorine F.
   (d) Hydrogen.
   (e) Carbon (in the form of graphite).
   (f) Protons and neutrons.
   (g) Electrons.
   (h) Hydrogen.
   (i) 92
   (j) An atom.
   (k) Ductile.
   (l) Metals.

4 Distribution of Elements

1. (a) Hydrogen
   (b) Aluminium
   (c) Oxygen
2. (a) Oxygen, silicon, aluminium, iron.
   (b) (*Note*: Graphs should be drawn in pencil, and always have a title and a key.)

Composition of the Earth's crust



3. (a) There are lots of hydrogen atoms, but each hydrogen atom is tiny (hydrogen atoms have the lowest mass of all atoms).
   (b) The Universe is made almost entirely of hydrogen and helium gas. The most common elements in the Earth's crust are oxygen, silicon and aluminium.
   (Hydrogen and helium gases have presumably been lost to space from the Earth's atmosphere and crust due to their low densities. But some hydrogen has remained, combined with oxygen in water (H_2O) and also combined in other compounds such as carbohydrates and hydrocarbons.)
4. The Earth's atmosphere is composed of mainly nitrogen 78.1%, oxygen 21% and argon 0.9%.
5. (a) The human body does consist of mainly the elements carbon, hydrogen, and oxygen (19%, 9% and 64% by mass). However, these are active elements, so they occur in the body not as elements but combined together as compounds such as water, carbohydrates, proteins and fats. The compounds carbohydrates, proteins and fats are mostly made of the elements carbon, hydrogen and oxygen.
   (b) Three of the following – oxygen, carbon, hydrogen, phosphorus. (Not nitrogen as it is present in a 3 times greater percentage in bacteria than in humans, and not calcium as bacteria do not have shells or bones.)
6. (*Note:* When drawing a table, make sure that you always rule the vertical lines, the lines between sections and the line at the end of the table.) Various, e.g.

Sphere	Elements	Compounds
Atmosphere	Nitrogen Oxygen Argon	Water Carbon dioxide Sulfur dioxide
Lithosphere	Carbon (coal) Gold Copper	Aluminium silicate Silicon dioxide Iron oxide Calcium carbonate
Hydrosphere	Oxygen (dissolved in water)	Water Sodium chloride Magnesium chloride Calcium chloride

7. (a) Various, e.g. spectral analysis and neutron diffraction.
   (b) The Big Bang theory – Hydrogen, helium and lithium were formed in stars during the Big Bang when the Universe originated. Nuclear fusion of these small atoms in stars and supernovas eventually formed all the elements with larger atoms.
8. (a) Various – outline any two areas. For example:
   Biology:
   - Calcium is a major element in the Earth's crust and its abundance helps explain the evolution of its use in the shells and bones of multicellular animals. Calcium was excluded from bacterial cells and hence accumulated in ancient seas.
   - Our understanding of isotopes has led to the use of C-14 dating of fossils. The study of fossils (palaeontology) provides evidence for the theory of evolution.

   Cosmology:
   - Our knowledge of elements has led to the use of spectral analysis to determine the composition of stars and changes in their life cycles. In turn this enables the age of a star to be determined and the fate of a star to be predicted.

   Archaeology:
   - Artefacts are objects from past civilisations. They provide historical information about past societies. The elemental composition of artefacts can be determined by analysis and matched to the composition of the crust. This allows scientists to identify the source of the artefact and provides information about the technology of the society that used the artefacts.

   (b) Various, for example:
   Our knowledge of the composition of the Earth's crust has enabled the extensive mining of minerals and their uses in modern society, e.g. metals used in construction, uranium for nuclear power, titanium in artificial joints used by surgeons to replace damaged joints. However, mining has also resulted in environmental damage such as loss of vegetation, habitats for flora and fauna and pollution of air and water.