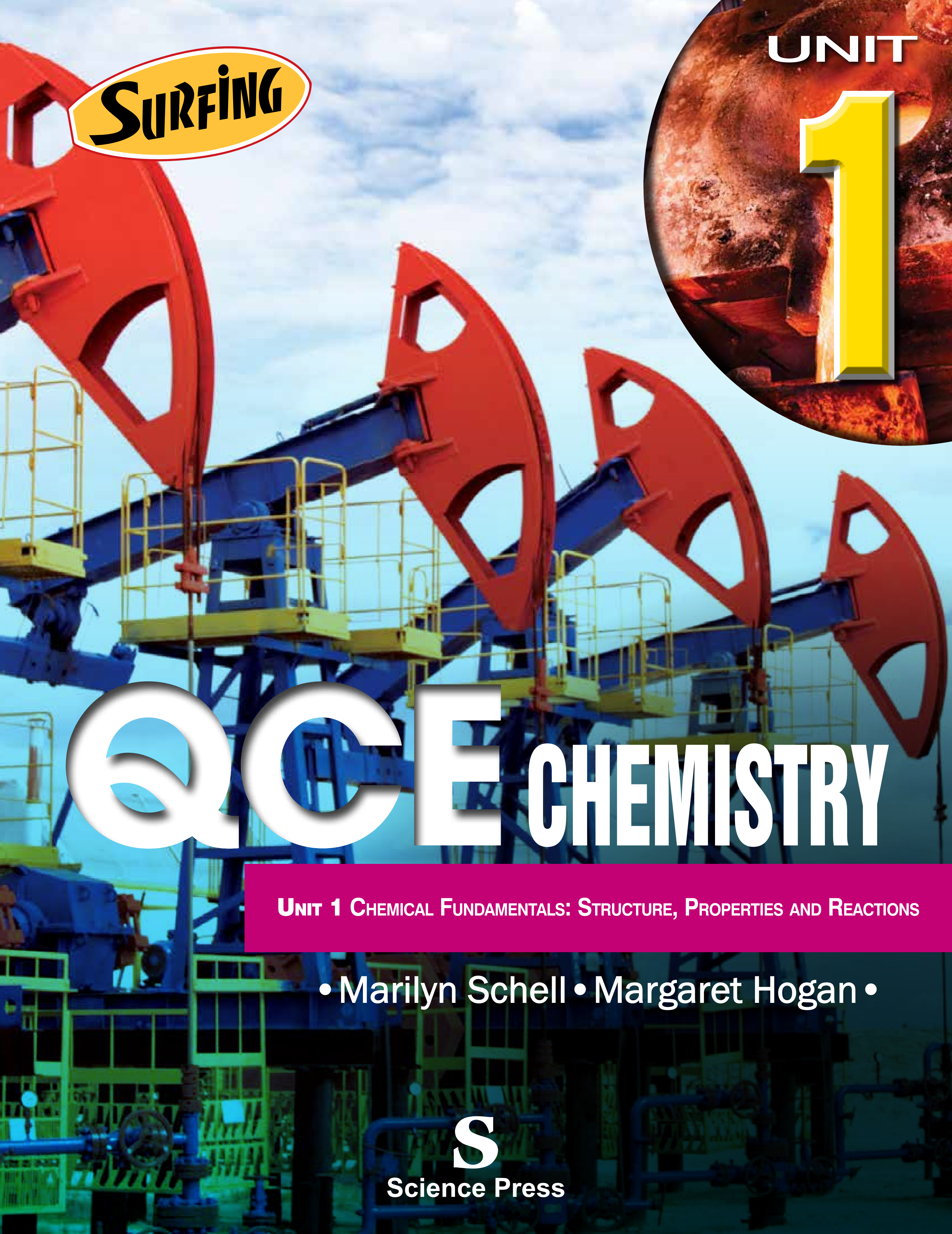

SURFING

UNIT 1

QCE CHEMISTRY

UNIT 1 CHEMICAL FUNDAMENTALS: STRUCTURE, PROPERTIES AND REACTIONS

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Introduction

This book covers the Chemistry content specified in the Queensland Certificate of Education Chemistry Syllabus. 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 each topic 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 QCE CHEMISTRY

UNIT 1

UNIT 1

CHEMICAL FUNDAMENTALS: STRUCTURE, PROPERTIES AND REACTIONS

In this unit you will:

- Relate matter and energy in chemical reactions to the breaking and forming of bonds as new substances are produced.
- Compare models of the atom and the evidence for their development.
- Investigate patterns in the properties and composition of materials.
- Use models to show the relationships between bonding and properties of materials.
- Use the mole concept to quantify matter.
- Investigate chemical structure, properties and reaction enthalpy.
- Participate in experiments and investigations to improve your science inquiry skills.

SURFING QCE CHEMISTRY

UNIT 1

TOPIC 1

Properties and Structure of Atoms

In this topic you will:

- Describe and explain trends in the elements of the periodic table across periods and down groups.
- Relate ionisation energy data to electron configuration of atoms and show that this is the basis of the structure of the periodic table.
- Apply the Aufberg principle, Hund's rule and the Pauli exclusion principle to write electron configurations for atoms and ions up to $Z = 36$, using s, p, and d orbitals and recognise the electron configurations of Cr and Cu as exceptions.
- Recognise the importance of the stability of the valence electron shell in the formation of chemical bonds and understand that bonds form when electrostatic attractions occur as electrons are lost, gained or shared.
- Determine formulas of ionic compounds and Lewis structures of molecules and ions.
- Understand that isotopes of an element have the same chemical properties but different physical properties and these determine their uses.
- Show that radioisotopes must be monitored to prevent harm to humans and the environment.
- Understand the concept of relative atomic mass of an element and calculate relative atomic mass of elements and percentage abundance of isotopes of an element.
- Investigate analytical techniques including mass spectrometry, flame tests, atomic absorption spectroscopy.
- Compare absorption and emission spectra and show how the emission spectrum of hydrogen provides evidence for the Bohr model of the atom.

1 Revision – 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 and is represented by a unique symbol.
- 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 physical and chemical properties and their position in the periodic table.
- Elements can be classified as metals, non-metals and metalloids (semi-metals). On the periodic table, metals are on the left and non-metals are on the right. There are a lot more metals than non-metals.
- Semi-metals (also called metalloids) are between the metals and non-metals).

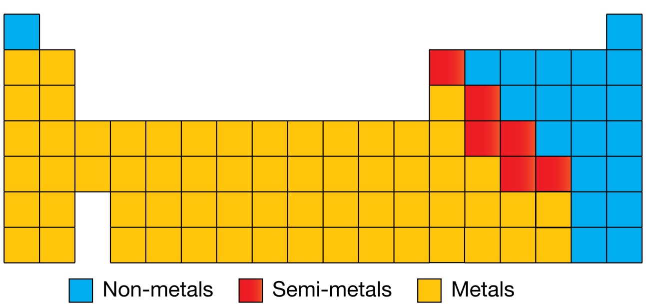


Figure 1.1 Periodic table.

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 1.2 Non-metals – bromine, carbon, phosphorus and sulfur.

Figure 1.3 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, O_2.

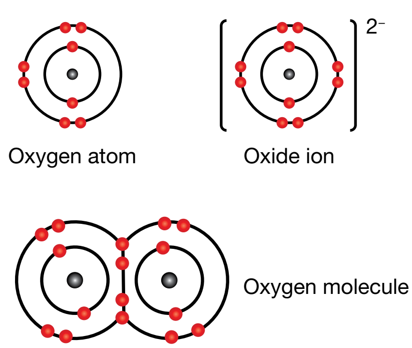


Figure 1.4 Oxygen as an atom, ion and molecule.

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.

Each atom consists of even smaller particles, called **subatomic particles**. There are three main types of subatomic particles, which are summarised in Table 1.1. Most of the mass of an atom is due to the protons and neutrons in its nucleus, each orbiting electron being almost 2000 times lighter than a neutron or a proton.

Table 1.1 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															

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 element with symbol H.
   (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) The 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?

2 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 in air 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, 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 when 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 2.1 lists those that are most abundant.

Table 2.1 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 2.2.

Table 2.2 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.

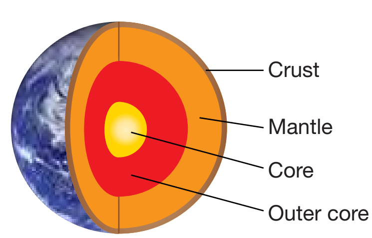


Figure 2.1 The Earth's structure.

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 2.3.

Table 2.3 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.

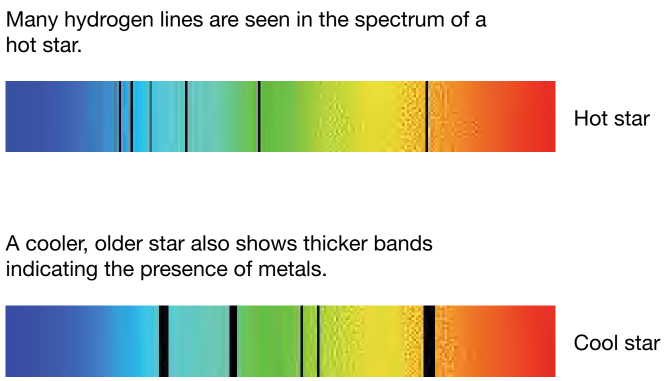


Figure 2.2 Spectral analysis of stars.

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 of the Earth. 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.

3 Elements and the Periodic Table

It is easy to tell whether or not a substance is an element – just look at a periodic table. Every element is there. If it is not there, it is not an element.

The periodic table provides a tool to organise elements, making it easy to see similarities and differences in their structure, properties and reactivity. Elements are listed in the periodic table, in order of their **atomic number** (Z) which is the number of protons in the atoms of an element. For example, the atomic number of oxygen is 8 – it has 8 protons in each of its atoms.

The structure of the periodic table is based on the atomic number and properties of the elements and trends in their properties can easily be seen. In the periodic table, the elements are arranged in periods and groups and trends in their properties are evident across periods and down groups.

A Russian scientist, **Dmitri Mendeleev**, developed the modern periodic table in 1869. He based his table on observed physical and chemical properties of the elements known at that time, including atomic masses.

He predicted the existence of some undiscovered elements (e.g. germanium, gallium and polonium) and left places for them on the table. At that time nobody knew that the noble gases of group 8 existed, so they were not included in his periodic table.

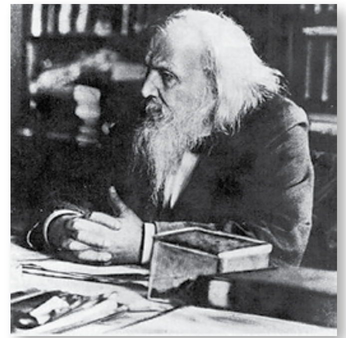


Figure 3.1 Dmitri Mendeleev.

The periodic table can be divided into the **main block** and the **transition block** elements. The lanthanides and actinides are subgroups of the transition elements.

The **transition metals** are in the middle of the table. They have strong metallic bonds so are generally hard, dense metals with high melting points. They include unreactive precious metals and many form coloured compounds.

Vertical columns of the periodic table are called **groups** and the rows are called **periods**.

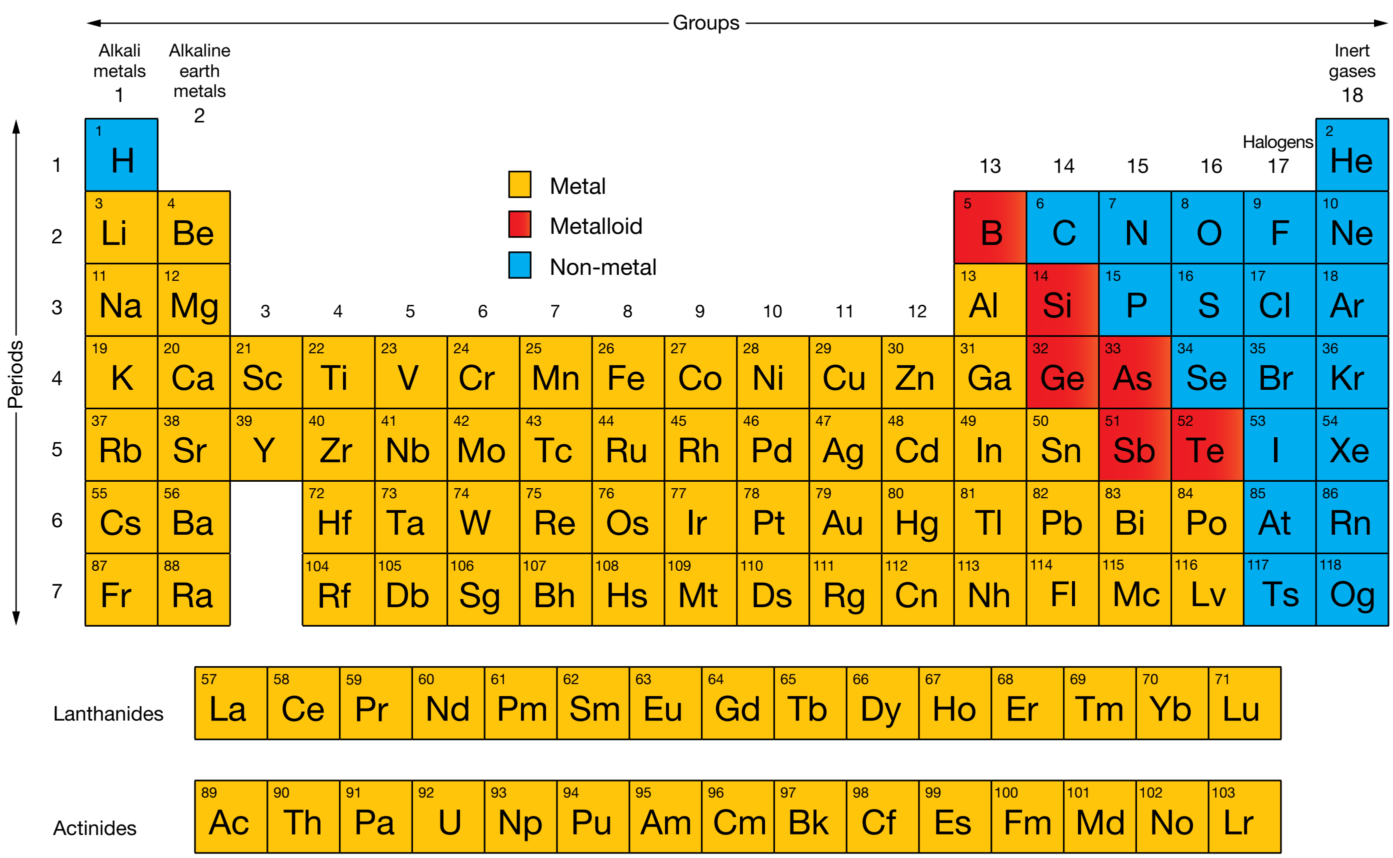


Figure 3.2 The parts of the periodic table.

Groups of the periodic table

In Figure 3.2 you can see that the elements are divided into 18 groups. All the elements in each group have similar chemical properties.

Group 1 (**alkali metals**) and **group 2** (**alkaline earth metals**) are all active metals, and they are mostly shiny, silver solids at room temperature. They have higher melting and boiling points than non-metals and their hydroxides are strong alkalis. Their activity increases down each group.

Elements in **groups 13 to 16** become increasingly metallic as you move down the group, e.g. group 5 varies from non-metal to semi-metal to metal.

The elements in **group 17** (**halogens**) are active non-metals.

Group 18 elements are all non-metals, they are inert (unreactive) gases and have low melting and boiling points so they are gases at room temperature.

Periods of the periodic table

The **periods** of the periodic table are the horizontal rows. They are numbered from 1 to 7, starting from the top and going down.

The first period contains only two elements, hydrogen and helium, which are both non-metals. The elements in every other period show a range of properties. For example, in period 2, lithium and beryllium are metals, boron is a semi-metal, and carbon to neon are non-metals.

The **activity of metals** decreases across the periodic table. For example, group 1 metals (e.g. sodium and potassium), are more active than group 2 metals (e.g. magnesium and calcium) which are more active than group 3 metals (e.g. aluminium).

Electrical conductivity decreases across the table; metals are good conductors, non-metals are poor conductors.

Melting and boiling points increase and then decrease across the table; high for metals, very high for group 4, then lower for non-metals.

As you study each example of trends in the periodic table in the following chapters, you should consider how these characteristics are determined, how they are interrelated and how you can study them in the laboratory.

QUESTIONS

1. (a) Group 1 elements are called the alkali metals. Use a periodic table to identify the names and symbols for each of the elements in group 1.
   (b) Explain why metals from groups 1 and 2 are never found existing as free elements.
2. (a) Name three elements classified as halogens and state the symbol used for each.
   (b) Research the origin of the term ‘halogen’.
3. (a) Outline the meaning of the term ‘inert’.
   (b) Identify the group of elements on the periodic table that are inert.
   (c) Name and write symbols for these elements.
   (d) Explain why these elements exist as elements rather than compounds.
4. Name and state symbols for four transition metals.
5. Based on their position in the periodic table, predict which element in each of the following pairs of elements would be more active.
   (a) Strontium or magnesium.
   (b) Strontium or potassium.
   (c) Lithium or rubidium.
6. For each of the following elements, write its symbol, then identify the period and group to which it belongs.
   (a) Magnesium.
   (b) Silicon.
   (c) Chlorine.
   (d) Aluminium.
   (e) Lithium.
   (f) Oxygen.
7. Name three elements which you would expect to have very similar chemical properties to chlorine. Justify your selection.
8. Outline the change in melting point across periods of the periodic table.
9. Check your knowledge with this quick quiz. Identify each of the following.
   (a) The group to which argon belongs.
   (b) The group to which carbon belongs.
   (c) The period to which sodium belongs.
   (d) The group of the periodic table in which the most active metals occur.
   (e) The number of naturally occurring elements.
   (f) The characteristic that determines the order of elements on today’s periodic table.
   (g) What we call vertical columns of the periodic table.
   (h) What we call horizontal rows of the periodic table.
   (i) On the periodic table, where would you find the least active elements?

4 Development Of the Periodic Table

Early scientists believed that the Universe was made of four elements – earth, wind, fire and water. Over the last two centuries scientists have discovered the 92 elements whose atoms are the building blocks of everything around us. As knowledge about elements increased, scientists tried to classify them in ways that would show patterns and trends in the structures of their atoms and their properties. This chapter provides a short summary of some of these attempts, leading to a summary of our modern periodic table, which you will be studying in more detail.

Antoine Lavoisier (1743-1794)

Lavoisier was a Frenchman. He is most famous for his discovery of the role that oxygen plays in combustion. Lavoisier was one of the first to realise that there were simple substances that could not be broken down any further – today we call them elements. In his list he included oxygen, nitrogen, hydrogen, phosphorus, mercury, zinc and sulfur. In 1787, Lavoisier classified the elements known at that time into metals and non-metals, based on their physical and chemical properties. Lavoisier was one of the many people in France beheaded by the guillotine – but not because of his beliefs about chemistry.

(a) Antoine Lavoisier. (b) Johann Dobereiner.

Figure 4.1 Chemists associated with the periodic table.

Johann Wolfgang Dobereiner (1780-1849)

Dobereiner was a German chemist. In 1829 he noticed similarities between some sets of three elements, which he called **triads**. For example, he pointed out the similarities in physical and chemical properties between the metals lithium, sodium and potassium and also between the non-metals chlorine, bromine and iodine.

H						
Li	Be	B	C	N	O	F
Na	Mg	Al	Si	P	S	Cl
K	Ca	Ga	Ge	As	Se	Br
Rb	Sr	In	Sn	Sb	Te	I
Cs	Ba	Tl	Pb	Bi	Po	At

Figure 4.2 Dobereiner's triads.

John Newlands (1837-1898)

John Newlands had Scottish and Italian parents but he lived in England. In 1863, he put forward a '**law of octaves**'.

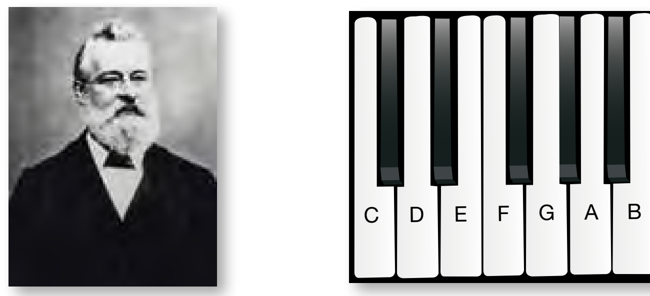


Figure 4.3 John Newlands and an octave on the piano.

He noticed that if the known elements were placed in order of increasing atomic mass, then every eighth element had similar properties. This is referred to as **periodicity of the chemical properties** of elements. He likened it to the eight notes in an octave of music.

H	F	Cl	Co/Ni	Br	Pd	I	Pt/Ir
Li	Na	K	Cu	Rb	Ag	Cs	Tl
Gl	Mg	Ca	Zn	Sr	Cd	Ba/V	Pb
Bo	Al	Cr	Y	Ce/La	U	Ta	Th
C	Si	Ti	In	Zn	Sn	W	Hg
N	P	Mn	As	Di/Mo	Sb	Nb	Bi
O	S	Fe	Se	Ro/Ru /Ag	Te	Au	Os

Figure 4.4 Newlands' octaves.

These classifications worked for some elements, but unfortunately not for all of them, and more were discovered that did not fit.

Dmitri Mendeleev (1834-1907)

Dmitri Mendeleev was a Russian chemist. In 1869 he proposed ideas that formed the basis of our modern periodic table. Mendeleev put forward the **periodic law**. He said that if the elements were arranged in order of increasing **atomic mass**, then those with similar physical and chemical properties (including valency) would occur at regular or periodic intervals.

Mendeleev's table was successful because he placed elements where he thought they should go, making allowances for possible inaccurate measurements of atomic mass, and he left gaps for elements he thought would be discovered later. Being able to make predictions from a theory is a very important aspect of the scientific method. Mendeleev went further and predicted the properties of those elements still to be discovered.

Table 4.1 compares the predictions of Mendeleev about an element not yet discovered at that time. Mendeleev predicted in 1869 that an element would be found to fit this position in the table and he called it Eka-silicon because he thought it would have properties similar to silicon and fit just below it in the table. This element, which we now call germanium, was discovered by chemists in 1886 and its properties were found to be very similar to those predicted by Mendeleev.

Table 4.1 Comparison of predicted and discovered element.

Property	Eka-silicon	Germanium
Atomic mass	72	72.3
Melting point	High	937°C
Density	5.5 g mL^{-1}	5.36 g mL^{-1}
Formula of oxide	EkO_2	GeO_2
Density of oxide	4.7 g mL^{-1}	4.7 g mL^{-1}
Formula of chloride	$EkCl_4$	$GeCl_4$
Boiling point of chloride	Just below 100°C	86°C
Density of chloride	1.9 g mL^{-1}	1.88 g mL^{-1}

Henry Mosely (1887-1915)

Mosely was an English physicist. It was Mosely who realised that arranging the elements by atomic number (rather than atomic mass or weight) produced a better repeating pattern of properties. For example, using atomic mass, potassium (39.10) would come before argon (39.5). This would put potassium in group 8 and argon in group 1. Using atomic number, these two elements fit much more logically into the periodic table with potassium in group 1 with other active metals, and argon in group 8 with other inert gases.

Figure 4.5 Henry Mosely.

The **modern table** places the elements in horizontal periods, forming vertical groups of elements with similar chemical properties. It includes the noble gases (group 18) which were discovered around 1895 and slotted into the table between group 17 and group 1 elements.

Many other scientists were then involved in working out theories as to why the elements behave in this periodic fashion and it was realised that this requires an understanding of the electronic structure of the elements' atoms.

QUESTIONS

1. Explain the following terms as associated with the periodic table of elements.
   (a) Group.
   (b) Period.
   (c) Atomic number.
2. Name four scientists who contributed to the development of the modern periodic table – listing them in order of their contributions, from earliest to latest.
3. The form of the periodic table most universally accepted is the one based on the work of Dmitri Mendeleev.
   (a) State the periodic law put forward by Mendeleev.
   (b) Explain why Mendeleev's table was adopted by other chemists.
   (c) What change was Mosely responsible for making in Mendeleev's periodic table?
4. 'Science is a global enterprise.' Discuss this statement with reference to the history of the development of the periodic table.
5. Check your knowledge with this quick quiz.
   (a) Lavoisier divided the elements into .... and ....
   (b) The sets of similar elements, like lithium, sodium and potassium, were called .... by Dobereiner.
   (c) The periodic law of Mendeleev states that similar elements occur at periodic intervals when the elements are placed in order of increasing ....
   (d) In his periodic table, Mendeleev left .... for elements yet to be discovered.
   (e) The modern periodic table is based on placing the elements in increasing order of atomic ....
   (f) In the periodic table, the vertical columns are called ....
   (g) The horizontal rows of the periodic table are called ....

Answers

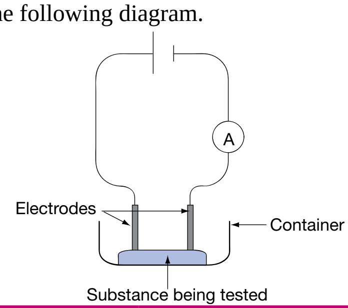
Topic 1 Properties and Structure Of Atoms

1 Revision – 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

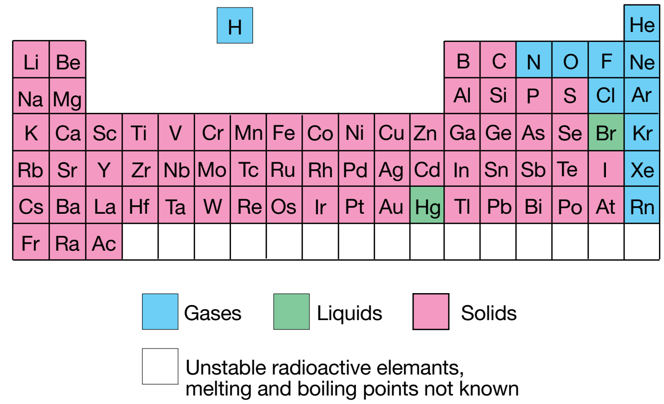
2. Semi-metals include boron, silicon, germanium, arsenic, antimony and tellurium. They are classified as semi-metals because they have properties of both metals and non-metals. Like metals they are crystalline solids with high melting points, but they also resemble non-metals, for example they are poorer 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.

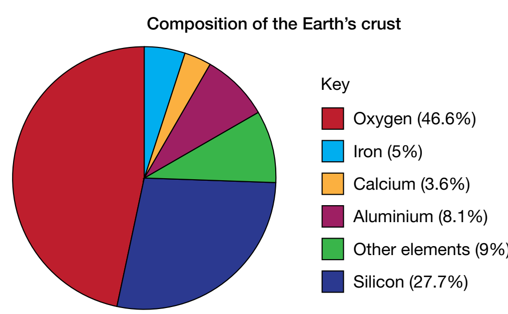
5. (a) An atom is the smallest part of an element that can take part in a chemical reaction.
(b) The central part of an atom is called the nucleus and it contains positively charged particles called protons and neutral particles called neutrons. Most of the mass of an atom is in the nucleus. Tiny, negatively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



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.

2 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.)



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%.