Chemistry

Preliminary Course

Stage 6

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING

TAFE NSW

OPEN TRAINING AND EDUCATION NETWORK - DISTANCE EDUCATION

The chemical earth

Incorporating October 2002 AMENDMENTS

Acknowledgments

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- Board of Studies NSW 1999. *Chemistry Stage 6 Syllabus*. **Amended October 2002**. The most up-to-date version is to be found at http://www.boardofstudies.nsw.edu.au/syllabus_hsc/index.html

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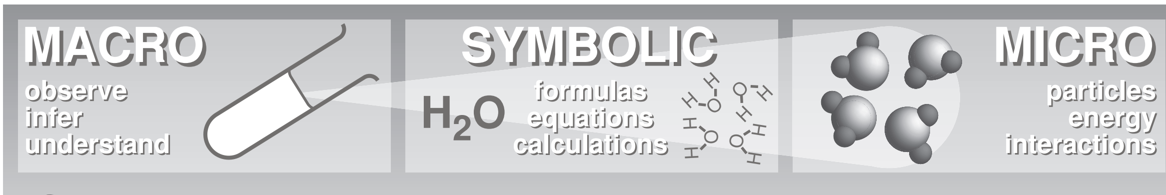
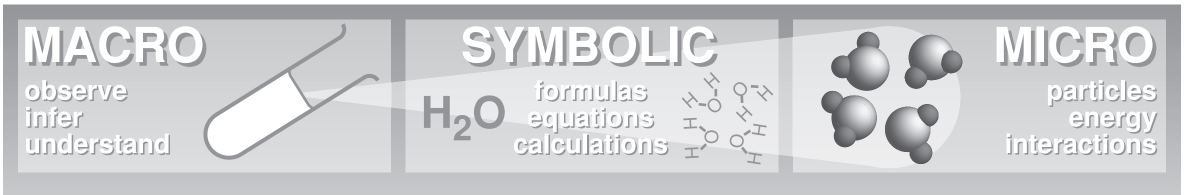


Contents of the chemical earth



Module overview

Chemistry is often called the central science since some knowledge of chemistry is needed for the study of Biology, Physics, Earth and Environmental Science and other sciences.

Practising chemists usually describe themselves according to the branch of chemistry that they specialised in after school. So, chemists might describe themselves as analytical, physical, organic, inorganic, pharmaceutical, agricultural, food or environmental chemists or as a biochemist or a geochemist. Other scientists who have included chemistry as a major part of their studies are material scientists, metallurgists, forensic scientists, biotechnologists, pathologists and genetic engineers. In your Stage 6 chemistry course you will study applications and uses of many of these branches of chemistry.

In the Preliminary modules the Assumed Knowledge of the Science 4–5 Syllabus will be briefly revised. You may find some of these sections of work easy as they could cover work that you already know and understand.

All of the modules in your chemistry course are made up of six parts. Each part needs a minimum of five hours of your time for completion.

The achievement of the outcomes, knowledge and understanding, skills, values and attitudes, will be assessed by:

- you, when comparing your answers to questions with suggested answers
- your teacher, using your send-in exercises at the end of each part.

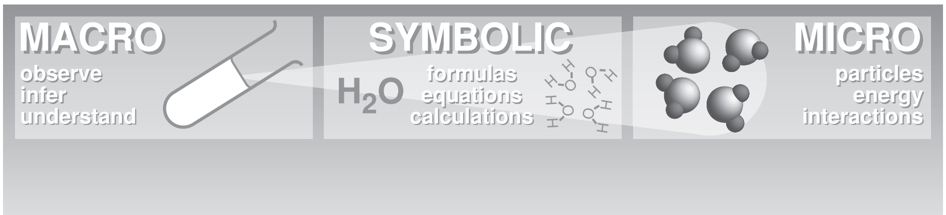
The best way to help your teacher to help you is by:

- attempting each of the questions and activities
- returning your send-in exercises regularly and on time.

This chemistry course will involve the study of chemistry at three levels:

- the macro level where you make observations on chemicals using your senses
- the micro level where you interpret and explain your observations using the model that matter is made up of particles with energy
- the symbolic level where symbols, formulas and equations are used to represent and communicate what you have observed at the macro level and wish to explain at the micro level.

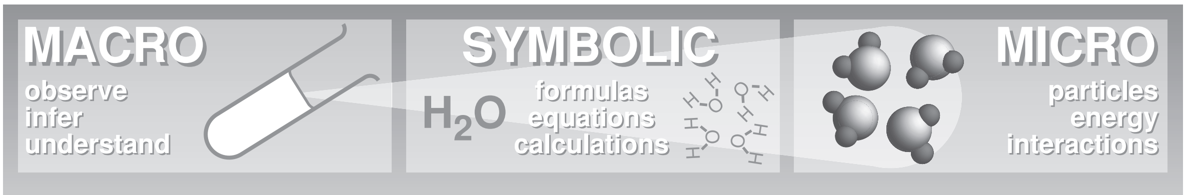
This banner heading should help you understand the three levels of your chemistry course and what each of these levels involves.



Practical experiences are an essential component of each module.

The Stage 6 Chemistry syllabus emphasises hands-on activities including:

- the use of appropriate computer based and digital technology
- research using the library
- research using Internet and digital technologies
- the use of computer simulations for modelling or manipulating data
- using and reorganising secondary data
- the extraction and reorganisation of information in the form of flow charts, tables, graphs, diagrams, prose and keys
- the use of animation, video and film resources to capture/obtain information not available in other forms.



Particle theory

Indicative time

This module is designed to take a minimum of thirty hours. There are a number of and variety of practical activities. Organising materials and equipment for carrying out all these activities could take additional time but in doing so you will better understand the type of work chemists do. Some chemical reactions are complete in a matter of seconds while others will require observations over much longer lengths of time.

Contextual outline

The extracts below are from the Contextual Outline statements for The Chemical Earth from the Board of Studies NSW, *Chemistry Stage 6 Syllabus Chemistry*.

> 'The Earth includes a clearly identifiable biosphere, lithosphere, hydrosphere and atmosphere.'

In this module you will learn about chemicals in the parts of the earth where living things are found (the biosphere), where rigid rocks are found (the lithosphere), where water is found (the hydrosphere) and where gas is found (the atmosphere). You will also appreciate how the atoms that make up matter move between the spheres of the earth. The atoms of your body (biosphere) have come from the gases of the atmosphere, the liquid water of the hydrosphere and the solids of the lithosphere.

> 'All of these (spheres of the earth) are mixtures of thousands of substances and the use of this pool of resources requires the separation of useful substances.'

You will learn how these mixtures can be separated into useful pure substances (elements and compounds) by a variety of techniques.

> ‘The processes of separation will be determined by the physical and chemical properties of the substances themselves.’

You will learn to identify a substance using two sorts of properties:

- physical when the substance is by itself
- chemical when the substance reacts with another chemical and changes to a new substance.

> ‘In order to use the Earth’s resources effectively and efficiently, it is necessary to understand the properties of the elements and compounds found in mixtures that make up earth materials.’

Understanding the properties of chemicals requires you to learn about the particles that make up the chemicals, how the particles are arranged and the forces between the particles.

> ‘Applying appropriate models, theories and laws of chemistry to the range of earth materials allows a useful classification of the materials and a better understanding of the properties of substances.’

You will find that models to represent what you are studying, theories to explain your observations and laws or rules to provide predictions are all useful in sorting and understanding chemicals.

> ‘This module increases students’ understanding of the nature and practice and the applications and uses of chemistry.’

The emphasis in this module is on Prescribed Focus Areas 2 and 3.

Resources

Materials and equipment you need to carry out activities are listed below. Access to a computer and the internet are sometimes important for the study of modern chemistry. An important skill to develop in chemistry is planning ahead and thinking things through before carrying out the action. Make sure the resources you need are available when you start an activity.

For Part 1 you will require:

- a packet of coloured lollies such as Smarties®, M & Ms® or jellybeans
- two filter papers (coffee filter papers or 110 mm laboratory filter paper) or ink blotting paper
- a small clean paint brush or cotton wool buds
- a glass or transparent plastic container
- dry sand
- dry table salt
- weighing scales such as kitchen scales
- a container to hold water
- a funnel to hold filter paper (a funnel can be made by cutting off the top part of an empty plastic drink bottle)
- filter paper (if you have trouble finding filter paper for this filtration experiment try using tea bag containers - cut the top off then shake out all the tea leaves and tea dust)
- heat source for evaporating salty water, eg a stove and saucepan
- two spoons.

For the optional activity you will need:

- weighing scales
- blender or food processor
- containers
- filter such as an old handkerchief
- methylated spirits
- dried fruit such as apricots.

For Part 2 you will require:

- coloured pencils
- safety glasses, hammer
- fingernail, copper coin, iron nail, ordinary knife, hardened steel knife
- multimeter
- computer with a spreadsheet program eg. Excel.

For Part 3 you will require:

- table salt

- model making materials eg plasticine/ Blu-tack®/ play dough and popsticks/ ping pong balls and nail polish remover as glue/ polystyrene pieces and metal wire/ marshmallows and toothpicks.

For Part 4 you will require:

- matches and a candle, piece of cardboard, paper towel or tissues, small container half full of water, old steel bladed knife
- hundreds and thousands, small lollies eg. cachous (silver balls)
- copper carbonate, heat source (candle/spirit burner/Bunsen burner) and matches, small test tube/steel spoon/steel knife blade, limewater, safety goggles or glasses
- 9V battery, terminal connector, pencil graphite ('lead'), transparent plastic or glass container, small amount of table salt or vinegar
- soluble silver salt (silver nitrate or silver acetate), sodium chloride (table salt), two transparent glass or plastic containers OR internet access.
- magnet, breakfast cereal, water, bowl or container.

For Part 5 you will require:

- 5 cm length of magnesium ribbon, wooden peg or metal tweezers, matches and a candle
- round lollies such as orange jaffas®/white koolmints®/koolfruits®, tray or lid for holding the lollies
- crystals of a salt such as table salt

  graphite ('lead') pencil, multimeter

  sand grain and small hammer.

There is no equipment required for Part 6.

Additional resources

Balancing and Interpreting Chemical Equations. CDROM for Windows and Macintosh. Edith Cowan University, WA. ISBN 0 9585398 4 7 This includes a 16 page instruction booklet and software in three modules: molecular equations, ionic equations, interpreting equations. Each reaction used is presented as a video (macro), a particle representation (micro) and equation interpretation exercises (symbolic).

Elemental - Exploring the Australian Minerals Industry. A three CDROM set for Windows and Macintosh. Minerals Council of Australia and Board of Studies NSW. ISBN 0 7310 7552 8 Disc 2: *Minerals* is very good for bauxite and iron ore mining, processing and metal extraction.

Separating Mixtures. Video (25 minutes). Classroom Video. This shows some interesting examples.

Selinger, B. 1998. *Chemistry in the Marketplace - A Consumer Guide*. 5th Edition. Harcourt Brace. ISBN 0 7295 3300 X. This book is world-renowned. The American Chemical Society have this as one of only four listings for high school chemistry teachers resources.

Look at the chemistry website page for further information on these and other additional resources.

http://www.lmpc.edu.au/science

Icons

The following icons are used within this module. The meaning of each icon is written beside it.

The hand icon means there is an activity for you to do. It may be an experiment or you may make something.

You need to use a computer for this activity.

There is a safety issue that you need to consider.

There are suggested answers for the following questions at the end of the part.

There is an exercise at the end of the part for you to complete.

Glossary

The following words, listed here with their meanings, are found in the learning material in this module. They appear bolded the first time they occur in the learning material.

AC (alternating current)	electric current alternating in direction
analysis	process of identifying parts of a sample
anion	a negative ion
atmosphere	layer of gas around the Earth
atomic number	unique number for each element; equal to the number of protons in the nucleus
atomic weight	weight of an atom compared with the weight of a carbon-12 atom taken to be exactly 12
binary	compound made up of two elements only
biosphere	parts of the Earth where life is found
boiling	liquid changing to gas rapidly
BP (boiling point)	temperature at which liquid changes to gas
bond energy	energy absorbed to break a bond or energy released when a bond forms
bonding	strong forces of attraction
brittle	cracks or breaks easily when deformed
catalyst	substance which, although not consumed, changes the rate of a chemical reaction
cation	positive ion
chemical change	chemical reaction; at least one new substance produced
chemical property	property of a substance reacting with another chemical
chemiluminescence	chemical reaction emitting light without heating
compound	pure substance formed by the combination of two or more elements in a fixed ratio
compressibility	ability to be pressed into a smaller space
condensation	change from gas to liquid

condenser	cooling equipment used to change gas to liquid
conductivity	ability to allow passage of electricity/heat
configuration	arrangement
covalent bond	bond formed by two atoms sharing a pair of electrons
crystal	piece of solid with some regular shape
crystallisation	separation of solid crystals from impurities and from solution
decomposition	reaction in which one substance forms two or more substances
density	mass of substance per unit volume
DC (direct current)	electric current moving in one direction only
distillation	process in which a volatile substance is separated from a less volatile substance
ductility	ability to be drawn into a wire without breaking; property of many metals
electrode	material transferring electrons to or from a liquid or a solution
electrolysis	chemical reaction requiring electrical energy
electrolyte	liquid or solution containing ions
electrolytic cell	arrangement of chemicals for changing electrical energy to chemical energy
electron	negatively charged subatomic particle
electron configuration	arrangement of electrons in shells going from innermost shell to outermost valence shell eg. 2.8.8.1 for potassium
element	pure substance made up of only one type of atom
empirical formula	formula giving the simplest whole number ratio of particles in a compound
enzyme	biological catalyst
evaporation	changing of liquid to gas below the BP
filtrate	clear solution that passes through a filter
galvanic cell	'battery'; arrangement of chemicals for changing chemical energy to electrical energy

gravimetric analysis	quantitative analysis using weighing
group	vertical column of the Periodic Table
hardness	ability to resist applied pressure
hydrocarbon	compound of hydrogen and carbon only
hydrosphere	layer of water around the Earth
inert	does not readily react with other chemicals
inference	what you think happens
inorganic	non-living origin
ion	charged particle formed from an atom or group of atoms (polyatomic ion)
ionic bond	bond formed between oppositely charged ions
IUPAC	International Union of Pure and Applied Chemistry
joule	unit of energy, symbol is J
justify	support an argument or conclusion
kelvin	unit of temperature = Celsius degree, symbol is K
lattice	arrangement of particles in a crystal
liquefaction	changing a gas to liquid eg. production of liquefied petroleum gas (LPG), compressed natural gas (CNG)
lithosphere	rigid outer layer of the Earth that includes the Earth's crust
malleability	ability to be shaped without breaking
mass number	total number of protons and neutrons in the nucleus of an atom
melting	changing of solid to liquid
MP (melting point)	temperature at which solid changes to liquid
mineral	useful element or compound from the earth
mixture	elements and/or compounds mixed together
mole	large number (6×10^{23}) of particles
molecule	particle that can move independently of other particles
neutron	neutral subatomic particle

nucleus	central core of an atom containing protons and neutrons
observation	what you detect with your senses
ohm	unit of electrical resistance represented by Ω
ore	matter from the earth worth extracting a mineral from
organic	from living things
phase change	change between states of matter
period	horizontal row of the Periodic Table
periodic	reoccurring at regular intervals
Periodic Table	arrangement of chemical elements in order of atomic number so that elements with similar properties occur at fixed intervals
physical change	change where the identity of the substance does not change eg. phase change or solution
physical property	property of a substance measured by itself
picometre	unit of length; 10^{-12}m; symbol is pm
prefix	part with a fixed meaning put at the beginning of a word eg. *bi* for two, *kilo* for thousand
proton	positive subatomic particle
qualitative analysis	finding out what elements are in a sample
quantitative analysis	finding out how much of each element is in a sample
radioactive decay	change involving protons and neutrons in the nucleus of an atom releasing energy;
reactive	tends to react with other chemicals
reciprocal	opposite in trend; reciprocal of a is $1/a$
reliable	trustworthy with results able to be repeated
residue	solid that collects on a filter
resistance (electrical)	resistance to flow of electricity
semiconductor	substance that is not a good conductor but conducts if small amounts of certain elements are added
semi-metal	element intermediate in properties between metals and non-metals

solidification	freezing; liquid changes to solid
solute	substance that dissolves
solution	mixture of solute and solvent
solvent	liquid able to dissolve another substance
spreadsheet	computer program for processing numbers arranged in table form
subatomic	smaller in size than an atom
supernova	explosion that occurs towards the end of a large star's life; the star collapses to a dense core then explodes creating heavier atoms
synthesis	building up a substance from simpler substances
synthetic	made by synthesis
thermal	heat
URL	uniform resource locator; the address of a document on the internet
valence/valency	used to describe the outer electrons of an atom that determine reactivity and bonding with other atoms
valence/valency shell	outer electron shell of an atom
valid	leading to effective results and worthwhile conclusions
volatile	describing something that easily becomes vapour
voltameter	equipment used to measure electrolytic decomposition
volume	amount of space
volumetric analysis	quantitative analysis using volumes

Chemistry
Preliminary Course
Stage 6

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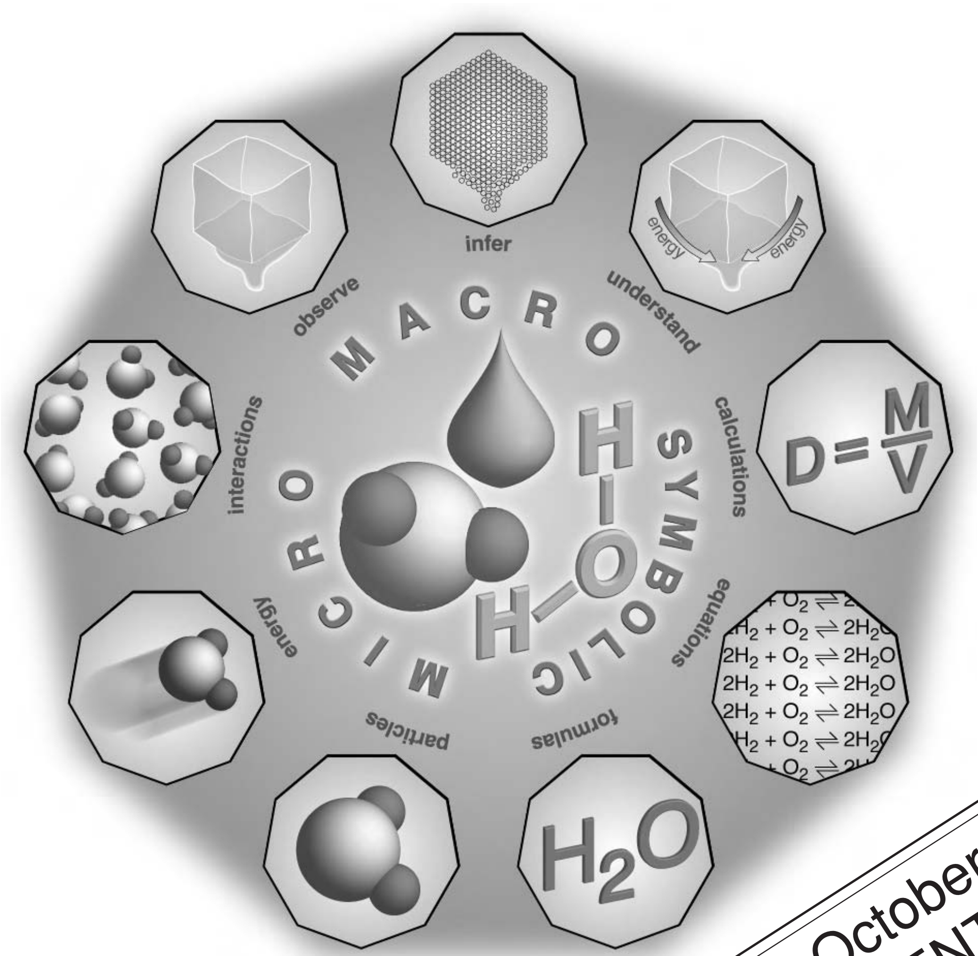
The chemical earth

Part 1: Mixtures



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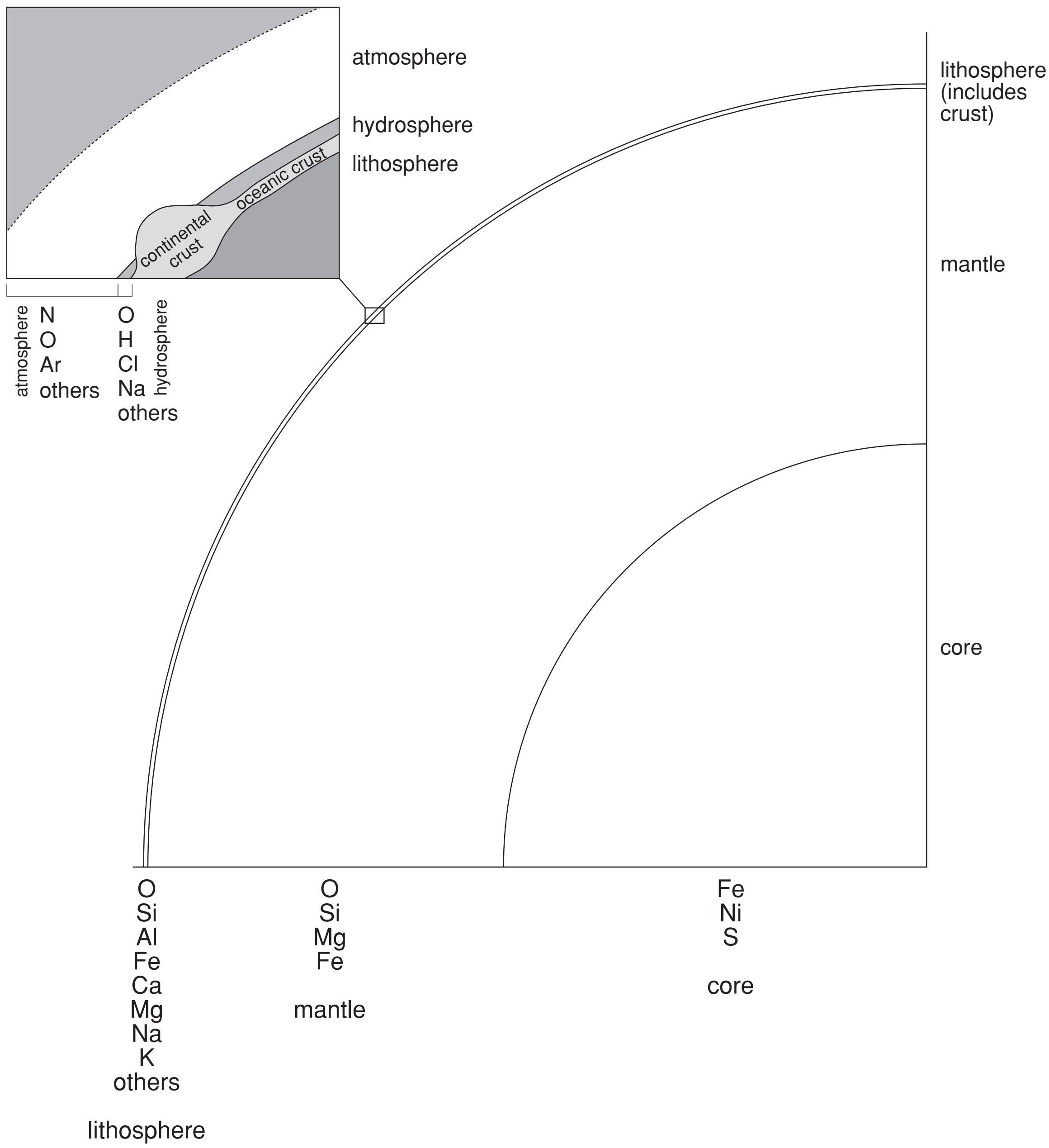
atmosphere
hydrosphere
lithosphere
oceanic crust
continental crust
atmosphere
N
O
Ar
others
O
H
Cl
Na
others
hydrosphere
lithosphere (includes crust)
mantle
core
O
Si
Al
Fe
Ca
Mg
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lithosphere
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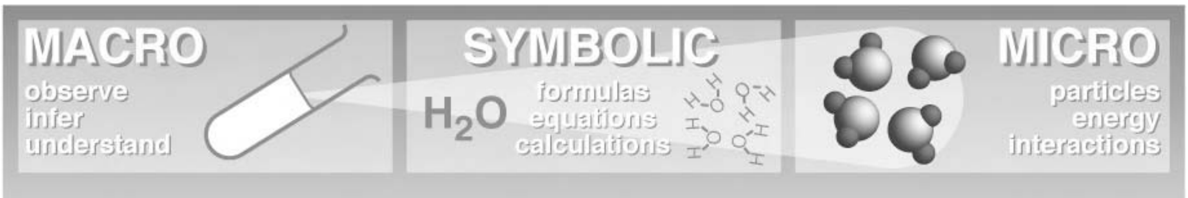
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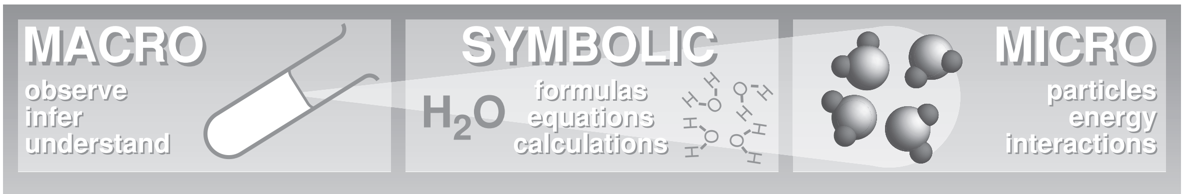
Contents



Introduction

During Part 1 you investigate the mixtures that make up the living and non-living components of the Earth.

Don't be concerned that this Part 1 is much longer than the other parts of the module. Part 1 revises much of the chemistry covered in the Stage 4 and 5 Science course that is required for the Stage 6 chemistry course.

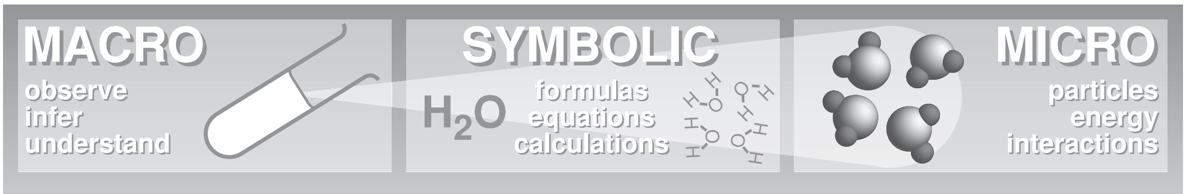
In Part 1 you will be given opportunities to learn to:

- identify the difference between elements, compounds and mixtures in terms of particle theory
- identify that the biosphere, lithosphere, hydrosphere and atmosphere contain examples of mixtures of elements and compounds
- identify and describe procedures that can be used to separate naturally occurring mixtures of:
  - solids of different sizes
  - solids and liquids
  - dissolved solids in liquids
  - liquids
  - gases
- assess separation techniques for their suitability in separating examples of earth materials, identifying the differences in properties which enable these separations
- describe situations in which gravimetric analysis supplies useful data for chemists and other scientists
- apply systematic naming of inorganic compounds as they are introduced in the laboratory
- *identify IUPAC names for carbon compounds as they are encountered.*

  (This content statement shown in italics will largely be covered in later modules of the Preliminary and HSC courses).

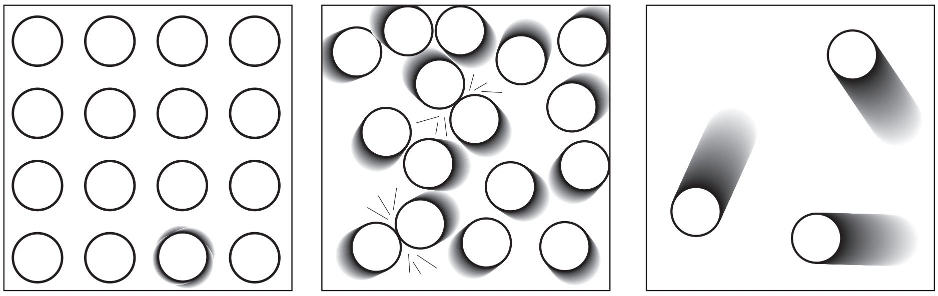
In Part 1 you will be given opportunities to:

- gather and present information from first-hand or secondary sources to write equations to represent all chemical reactions encountered in the preliminary course
- identify data sources, plan, choose equipment and perform a first-hand investigation to separate the components of a naturally occurring or appropriate mixture such as sand, salt and water
- gather first-hand information by carrying out a gravimetric analysis of the mixture to estimate its percentage composition
- identify data sources, gather, process and analyse information from secondary sources to identify the industrial separation processes used on a mixture obtained from the biosphere, lithosphere, hydrosphere or atmosphere and use the evidence available to:
  - identify the properties of the mixture used in its separation
  - identify the products of separation and their uses
  - discuss issues associated with wastes from the processes used.



Particle theory

In chemistry, we study the properties of chemicals using the particle theory. The particle theory is the idea that everything around and in us is made up of particles. The particles are usually found in one of three states of matter – solid, liquid or gas.



solid	liquid	gas
particles vibrate to and fro but do not move	particles move or slide freely with frequent collisions	particles move at high speed and are much further apart

Use the words solid, liquid and gas to complete the sentences below:

In a _______ the particles are close together and have fixed positions. The particles are lined up in rows and columns like eggs in an egg carton or the oranges in a fruit box.

In a _______ the particles have ‘empty space’ between one another and move randomly at high speed. The particles bounce off the walls of the sealed container.

In a _______ the particles are close together but can move freely over one another.

Check your answers.

Using the particle theory

The particle theory that states that all matter is made up of particles is very useful. It can explain properties or characteristics such as the shape and the volume of solids, liquids and gases.

The particle theory can, for example, be used to explain:

- why solids have a fixed shape and a fixed volume – the particles are in fixed positions so the shape and volume (amount of space taken up) do not change
- why liquids have a shape that fills the bottom of the container that the liquid is held in – the particles can move freely over one another
- why gases fill the whole of their container and escape when the lid of the container is removed – the particles are moving at high speed.

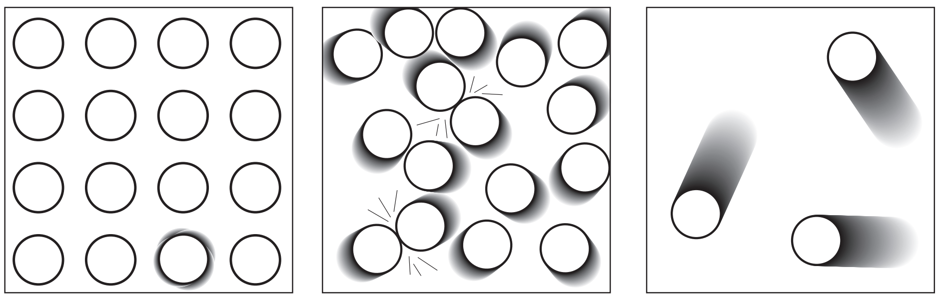
Compressibility is a property which can be explained by using the particle theory.

One of the three states of matter is easy to compress. It is easy to squeeze the space taken up by the particles into a smaller volume. The particles do not change in size as this state is compressed. Only the amount of space in which the particles move becomes smaller.

Which of the three states of matter do you think is easy to compress?

Check your answer.

Note that the particles do not change in size between solid, liquid and gas. The amount of space taken up by all the particles can change but not the size of each particle.



solid liquid gas

Explaining changes of state

Gain of energy or loss of energy can cause matter to change its state.

Gain of heat energy can cause particles to move more freely. This can lead to **melting**, **evaporation** and **boiling**.

Loss of heat energy can cause particles to slow down. This can lead to condensing (**condensation**) and freezing (**solidification**).

1 Can you use the processes melting, evaporation and boiling, condensation, solidification to label this diagram?

solid $\rightleftharpoons$ liquid $\rightleftharpoons$ gas

2 Ice, water and steam are the solid, liquid and gas states of matter for the chemical water. Can you fill in the missing words about water in the sentences below?

Ice melts to form liquid _________which boils to form _________.

_________ condenses to liquid water which solidifies to form _____.

Check your answers.

Temperature and changes of state

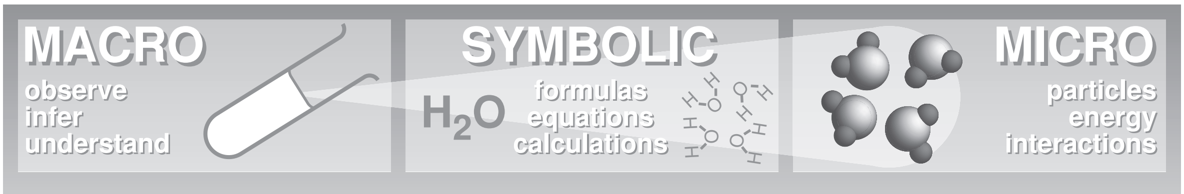
The temperature at which a solid changes to a liquid is called the **melting point (MP)**.

Ice melts, that is changes from solid to liquid, at zero degrees Celsius (0°C). This temperature of 0°C is sometimes written using the kelvin scale as 273K.

The temperature at which a liquid changes to a gas rapidly, that is boils, depends on the atmospheric (air) pressure. At normal atmospheric pressure the boiling point of water is 100°C which is the same as 373K.

Note that each Celsius degree is the same size as each **kelvin**.

Water can change slowly from liquid to gas at temperatures below the boiling point. This slow change is called evaporation. The rate of evaporation increases as temperature rises because more heat energy is available for the particles to move away from one another.



Elements

An **element** is made up of one type of particle only. The particles making up an element are called atoms. Atoms may be joined or be single atoms.

Consider the mixture of elements which make up the Earth's atmosphere:

The element oxygen is made up from oxygen atoms only. These oxygen atoms may be joined or be single atoms. In the atmosphere (the thin layer of gas around the earth) the element oxygen can consist of:

- two oxygen atoms joined (diatomic oxygen O_2) – the main form of oxygen near the earth's surface
- three oxygen atoms joined (triatomic oxygen O_3) – a form called ozone that is common 25 km above the earth's surface in the ozone layer
- single oxygen atoms (monatomic oxygen O) – a common form 50 km above the earth's surface.

Mon- or mono-, di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, nona- and deca- are **prefixes** used to represent numbers in chemical names and descriptions. Can you work out the numbers for each prefix? If you can, write the numbers above the corresponding prefix.

Check your answers.

The element nitrogen is the most common gas in the Earth's atmosphere and exists as two nitrogen atoms joined together (N_2).

Two elements which are only found in the Earth's **atmosphere** in very small amounts because their particles are so light that they drift out into space are:

- the element hydrogen which exists as two hydrogen atoms joined together (H_2).
- the element helium which only ever exists as single atoms (He).

How many elements are there?

There are 92 elements that occur naturally on Earth. More than twenty other elements have been made artificially since 1937. Each element, and therefore, each type of atom, has its own chemical symbol. The symbols of all known chemical elements can be seen in the **Periodic Table** on the next page.

The symbols for some elements consist of a single capital letter such as O for oxygen, H for hydrogen and N for nitrogen. Other elements are represented by two letters; the first of the two letters is always a capital letter while the second of the two letters is always lower case.
For example He for helium, Ca for calcium and Co for cobalt.

A small number of the recently made elements are given three letter symbols. These three letter symbols are used until the organisation known as the International Union of Pure and Applied Chemistry (**IUPAC**) agrees on the names and symbol it will give to newly made elements. For example, Uuu is the symbol for element number 111, called unununium [*pronounced un-un-OON-ium*].

Look at the periodic table shown below and on the next page. This style of periodic table shows the atomic number, the symbol and names of 115 known chemical elements.

The periodic table is the most useful summary of information in chemistry. All the atoms that chemicals are made up from are represented on this table.

1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium						1 H Hydrogen	Atomic number Symbol Name				5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Caesium	56 Ba Barium	57-71 LANTHANIDES	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89-103 ACTINIDES	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnilium	111 Uuu Unununium	112 Uub Ununbium	113	114 Uuq Ununquadium	115	116 Uuh Ununhexium	117	118 Uuo Ununoctium

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

You will be provided with a periodic table like this to use in all your major chemistry examinations. These periodic tables will have the atomic weight as additional information. You will learn how to use atomic weights in the second module about metals.

1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium						1 H Hydrogen	Atomic number Symbol Name				5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
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87 Fr Francium	88 Ra Radium	89-103 ACTINIDES	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnilium	111 Uuu Unununium	112 Uub Ununbium	113	114 Uuq Ununquadium	115	116 Uuh Ununhexium	117	118 Uuo Ununoctium

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

1 In the table provided list the elements that are represented by a single capital letter. (Hint: your table will be complete when you have a list of 14 symbols and 14 elements)

Symbol	**Element**
H	hydrogen
B	
	carbon

2 How many elements in the periodic table have three letter symbols?

____

(Hint: Was your answer a number? If it wasn't then read the question again.)

3 The periodic table shown has 115 elements listed. Of these 23 have been artificially made since 1937. Calculate, by subtraction, the number of elements that are represented by two letter symbols.

(Did you read the question carefully, use your answers from questions 1 and 2, and didn't spend time counting all the elements with two letter symbols.)

Check your answers.

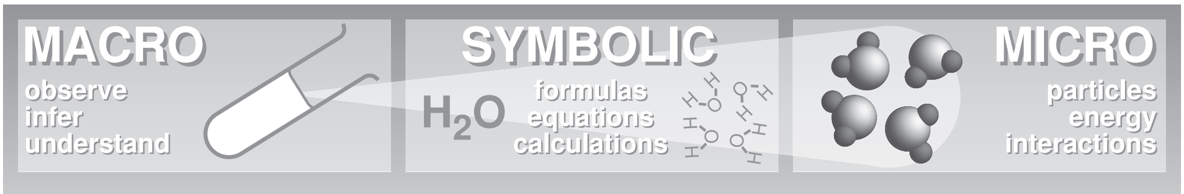
At present elements with **atomic numbers** above 109 are given names using the prefixes nil, un, bi, tri, quad, pent, hex, sept, oct and enn for 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. Because these elements are metals their names all end in -ium.

In June 1999 a team of scientists at the Lawrence Berkeley Laboratory in the United States announced the discovery of the elements 116 and 118. **Radioactive decay** of these elements produced element 114. In July 2001 the same team of scientists retracted its discovery of element 118 after several confirmation experiments failed to reproduce the original results.

This incident illustrates how scientific research is scrutinised. When scientists announce a discovery they are expected to give sufficient detail so that other laboratories can repeat the experiment and check the results. German and Japanese laboratories as well as the US laboratory were unable to reproduce the original results. The announced discovery of element 118 was retracted.

If you have internet access find out more about newly discovered elements or the periodic table by looking at the chemistry website page.

http://www.lmpc.edu.au/science



Compounds

A compound is made up of two or more different types of atoms joined together.

The names of the elements in a compound and the number of different atoms can often be worked out from the name. In this section you will concentrate on naming **binary** compounds – compounds made up of two elements only.

The common name for many compounds, such as water, is not of much use if you want to work out the types of atoms in the compound. A name like dihydrogen oxide, or the formula, H_2O, gives much more information about what atoms water is made up of.

Compounds of two elements only usually end in -ide.

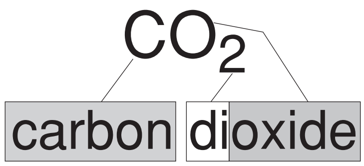
For example, sodium chloride (NaCl), calcium oxide (CaO), sulfur trioxide (SO_3).

Note that when you write a formula:

- the symbol of the element are written on top of the lines of a page
- the numbers are written as subscripts across the lines of a page.

Some names contain prefixes- which show the number of atoms.

The diagram below shows how different parts of the name refer to different parts of the formula.



The compound carbon dioxide is made up of one carbon atom and two oxygen atoms in each molecule.

The prefixes used in naming compounds are:

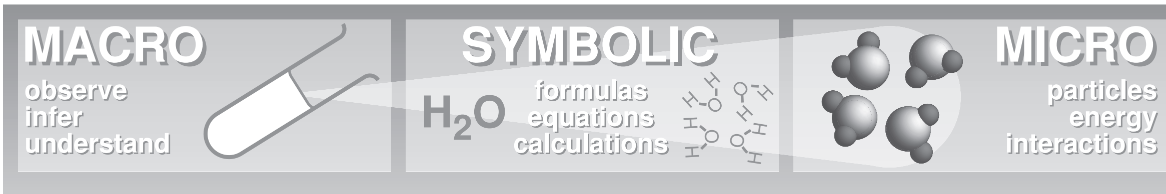
Name	**means**	**Example**	
mono	one	carbon monoxide is	CO
di	two	sulfur dioxide is	SO_2
tri	three	sulfur trioxide is	SO_3
tetra	four	carbon tetrachloride is	CCl_4
penta	five	phosphorus pentafluoride is	PF_5
hexa	six	uranium hexafluoride is	UF_6

Note that the 'a' ending of tetra, penta and hexa are dropped before the letter 'o' as in P_2O_5 diphosphorus pentoxide and N_2O_4 dinitrogen tetroxide.

Can you complete this table?

Name of compound	**Formula of compound**
nitrogen monoxide	
	N_2O_3
dinitrogen pentoxide	
	CS_2
diphosphorus pentoxide	

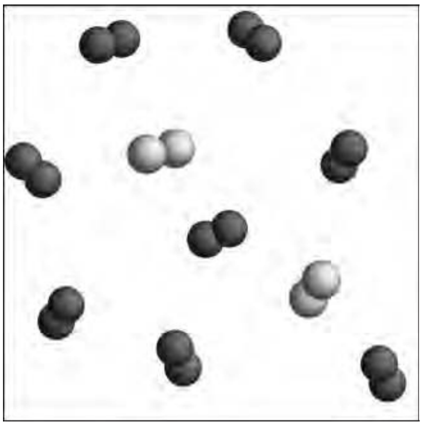
Check your answers.



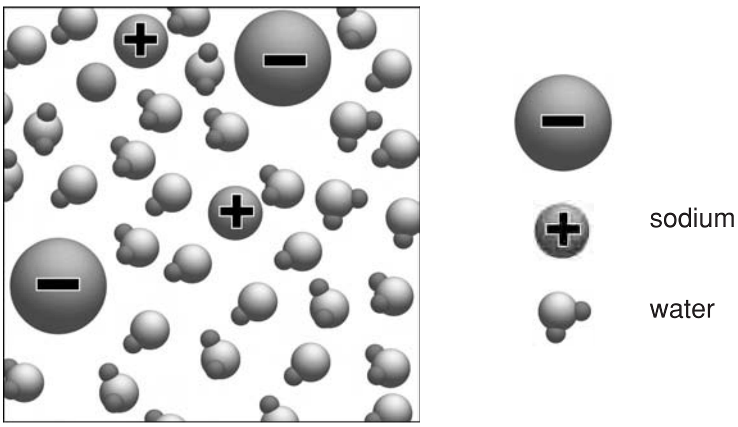
Mixtures

A mixture can consist of:

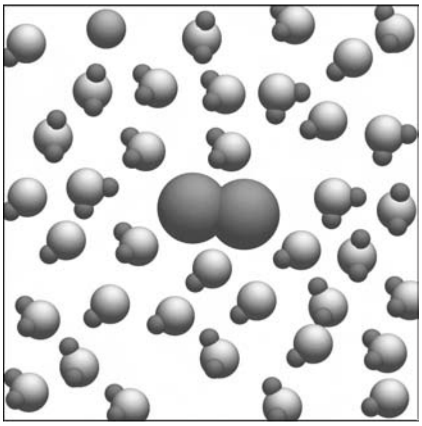
- elements mixed together eg. dry air is a mixture of about 20% oxygen and 80% nitrogen



- compounds mixed together eg. sea water is a mixture of about 3% sodium chloride salt and 97% water (the sodium chloride salt consists of positively charged sodium particles and negatively charged chloride particles that separate in water)



- element(s) and compound(s) mixed together eg. iodine water, made by dissolving the element iodine in the compound water, is a mixture of about 0.1% iodine and 99.9% water.



Where do atoms of elements come from?

The two most common elements in the universe, hydrogen and helium, were formed in the intense heat of the Big Bang about 11 to 15 billion years ago. Most other elements were formed in stars. Heavy elements, such as uranium, are believed to be produced in shock waves of **supernova** explosions.

Look at the chemistry website page for information on discoveries made using NASA's Chandra X-ray Space Telescope.

http://www.lmpc.edu.au/science

All the 92 elements present when the earth formed over 4 billion years ago are still on Earth. Most of the atoms that were present 4 billion years ago are still on earth. However many of the very light hydrogen and helium gas atoms have escaped from the earth's gravity into space.

The atoms of these 92 elements circulate in nature. The additional 23 elements synthesised since 1937 have only been made in small quantities and are normally only found in laboratories.

All matter on Earth, including matter that makes up your body, has come from star dust ejected into space from exploding stars! Atoms from this dust collected together to form the sun and planets of the solar system.

Atoms move from the living world to the non-living world when a living thing dies. Decomposition of its dead body releases atoms making them available for other living things.

This natural recycling can result in your body containing atoms that were once part of the body of any famous person that you can think of!

As a living thing grows more atoms enter its body than leave its body. This is movement of atoms from the non-living world to the living world.

Compare your present body weight with your weight at birth. Where did all the extra weight come from? Can you understand the saying ‘what you eat today, walks and talks tomorrow’?

How many compounds are there?

Just as the 26 letters of the English alphabet can be joined in different ways to form about half a million words, for example elf, element, elementary, so the 115 different atoms of the chemical elements can be joined in different ways to form millions of different **compounds**, for example, CH_4, CH_3COOH, $CH_3COOC_6H_4COOH$.

By 1997 the Chemical Abstracts Service of the American Chemical Society had published information on over seventeen million different compounds!

To learn more about the huge amount of chemical information available through the internet see the chemistry website page.

http://www.lmpc.edu.au/science

Just as there will be new words made and used in the English language next year so there will be new compounds made and used by chemists next year.

The Chemical Abstracts Service reports on over 10 000 new compounds each week!

There are so many compounds known that we need to classify them into groups. They are classified into groups using either characteristics (properties) or the type of atom present in the compound.

Grouping compounds

Just as a group of people can be classified into different groups based on characteristics such as age, sex, and height, so there are different ways of classifying compounds.

Compounds

Organic

- contain a 'backbone' of carbon atoms
- usually found in living things (organisms)
- or fossil fuels (coal, petroleum and natural gas) formed from the remains of living things.

Inorganic

- no 'backbone' of carbon atoms
- usually found in non-living things such as rocks.

What information do you need to decide if a compound is **organic** or **inorganic**?

Check your answer.

Approximately 90% of the compounds reported by the Chemical Abstracts Service are organic compounds.

Another way of classifying compounds is:

Compounds

Covalent

- nonconductors of electricity when liquid or dissolved in water
- usually gas, solid or low melting point solid.

Ionic

- conductors of electricity when liquid or dissolved in water
- usually high melting point solid.

How could you determine whether a compound is ionic or covalent?

Check your answer.

Covalent compounds can be further divided into groups such as hydrocarbons, carbohydrates and fats. Ionic substances can be further divided into groups such as salts and hydroxides.

Some compound group names give you information about the elements they contain.

1 Hydrocarbons are made up of two elements only. Can you name the two elements in a hydrocarbon?

____

2 When heated, most carbohydrates form a black solid element and release water. The ending -ate in a compounds name usually indicates the presence of oxygen. Can you name the three elements in a carbohydrate?

____

Check your answers.

Pure substances

Elements and compounds can be classified as pure substances.

Pure substances have fixed properties. You can look up information about the properties of elements and compounds in data books because the properties of a pure element or a pure compound do not change. For example, when pure, water has a melting point of $0^{o}C$ (a **physical property**) and reacts with magnesium at $80^{o}C$ releasing hydrogen gas (a **chemical property**).

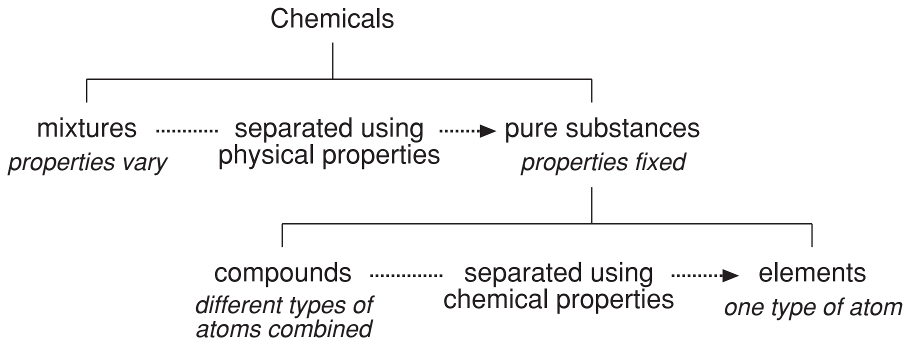
Knowing that the properties of pure substances are fixed makes it much easier to predict what will happen if elements and compounds are mixed to make a product.

Mixtures

Mixtures do not have fixed properties. There is an almost infinite number of mixtures so it is difficult to find information on the properties of mixtures. Two examples of mixtures are described below.

- Sand. River sand is different from beach sand. Every beach has different minerals in its sand.
- Food. Different brands of the same food can have different properties.

It is difficult to predict what will happen when mixtures are mixed together. Concrete suppliers have to be careful with the type of sand they use in producing concrete. Chefs learn by experience which mixtures are best for their cooking.



Here are three ‘numbers’: 115, >17 000 000, almost infinity

1 Which number indicates the number of mixtures on earth?

____

2 Which number indicates the number of elements?

____

3 Which number indicates the number of compounds?

____

4 Can you use the numbers given to calculate the number of pure substances?

____

Check your answers.

Mixtures in the non-living and living Earth

If you collected five samples of soil from five different locations each sample would almost certainly be different. The samples would contain different percentages of water, air, sand, clay, organic matter and so on. There are almost an infinite number of mixtures on earth.

When you look at rock samples you can often see different crystals or grains. It is difficult to find rock samples from different places which have exactly the same mixture of crystals or grains.

If you were given the two elements iron (Fe) and sulfur (S) in powdered form (that is, as very small pieces of solid) you could make many different mixtures such as:

1% Fe + 99% S, 2% Fe + 98% S, 3% Fe + 97% S

If you could weigh the iron and sulfur accurately with a laboratory balance you could make even more mixtures such as:

99.9% Fe + 0.1% S, 99.8% Fe + 0.2% S, 99.7% Fe + 0.3% S,

A mixture of 10% Fe + 90% S will have very different properties from a mixture of 90% Fe + 10% S. The properties of a mixture vary according to the composition of the mixture.

The bodies of living things are mixtures:

- an apple is about 85% water, 12% carbohydrate and 3% fibre
- a nut could be 65% fat, 15% protein, 15% carbohydrate and 5% water
- the human body is about 65% water, 15% protein, 15% fat and 5% carbohydrate
- wood could be about 50% water, 40% cellulose and 10% lignin.

Non-living things such as rocks, dried apple and construction timber made by drying living wood are also mixtures. For example:

- dried apple is about 75% carbohydrate, 15% water and 10% fibre
- construction timber could be about 80% cellulose, 10% lignins and 10% water.

Most of the mixtures that humans use are non-living. Here are some other examples of mixtures from the earth.

Layer	**Description**	**Mixture**	**Elements**	**Compounds**
biosphere	parts of the earth where life is found	soil	iron Fe, oxygen O_2, nitrogen N_2,	water H_2O, silicon dioxide SiO_2
lithosphere	rigid outer rock layer of the earth including all of the earth's crust	rock	gold Au, platinum Pt, silver Ag	iron oxides such as Fe_2O_3, silicon dioxide SiO_2
hydrosphere	water layers such as the oceans	seawater	oxygen O_2, nitrogen N_2	water H_2O, sodium chloride NaCl
atmosphere	layer of gases around the earth	air	nitrogen N_2, oxygen O_2, argon Ar	water H_2O, carbon dioxide CO_2

Do you agree that the compositions of soil, rock, sea water and air vary from place to place? If you do it is easier to understand why there are almost an infinite number of mixtures on earth.

Turn to Exercise 1.1 at the end of this part.

Properties and the particle theory

A property is a characteristic or feature of something. Can you suggest a property of a chemical? Some properties of a chemical are: state of matter (solid, liquid or gas), colour, density, melting point, reaction with oxygen, reaction with acid and so on.

The properties of a chemical depend on:

- the particles that make up that chemical
- how the particles are arranged
- the forces (interactions) between the particles.

There are two main types of properties of chemicals – physical properties and chemical properties. A knowledge of these properties is important in identifying a chemical.

Physical properties

A physical property is a property of the substance by itself. Examples of physical properties are:

- state of matter
- colour
- **density** (usually measured in grams per cubic centimetre)
- melting point MP (temperature at which the pure substance changes from solid to liquid)
- **boiling point**, **BP** (temperature at which the pure substance changes from liquid to gas).

How do you measure melting point or boiling point? What type of measuring instrument would you use?

Check your answer.

Chemical properties

A chemical property is a property of the substance reacting with another chemical.

Examples of chemical properties are what we observe when the substance reacts with:

- oxygen (O_2) gas
- hydrochloric acid (HCl) solution
- sodium hydroxide (NaOH) solution.

For example the compound water has a melting point of 0°C (a physical property) and reacts with magnesium at 80°C releasing hydrogen gas (a chemical property).

The properties we can observe or measure can often be explained by the particle theory.

Observable or measurable property	**Particle theory explanation**
An element cannot be changed into simpler substances.	An element is made up of only one type of atom.
A compound can be changed into simpler substances eg. water can be changed into hydrogen and oxygen by electrical energy; the volume of hydrogen gas is always twice the volume of oxygen gas produced.	A compound is made up of more than one type of atom joined together in fixed ratios eg. H_2O; the atoms are in a fixed ratio of two H to one O in the compound.
The properties of a mixture vary as the components (parts) vary.	The proportions of the different particles making up the mixture vary.
Mixtures are usually easy to separate using differences in physical properties of the parts.	The parts of a mixture are just mixed together and not chemically joined.

Complete the questions on the next page to help you apply the particle theory and test your understanding of elements, compounds and mixtures.

After you have attempted these exercises look at the suggested answers towards the end of this Part. If an answer you give is different spend time trying to understand why the suggested answer was given.

1 Label each of the following diagrams with the appropriate letter. Give reasons for your choice.

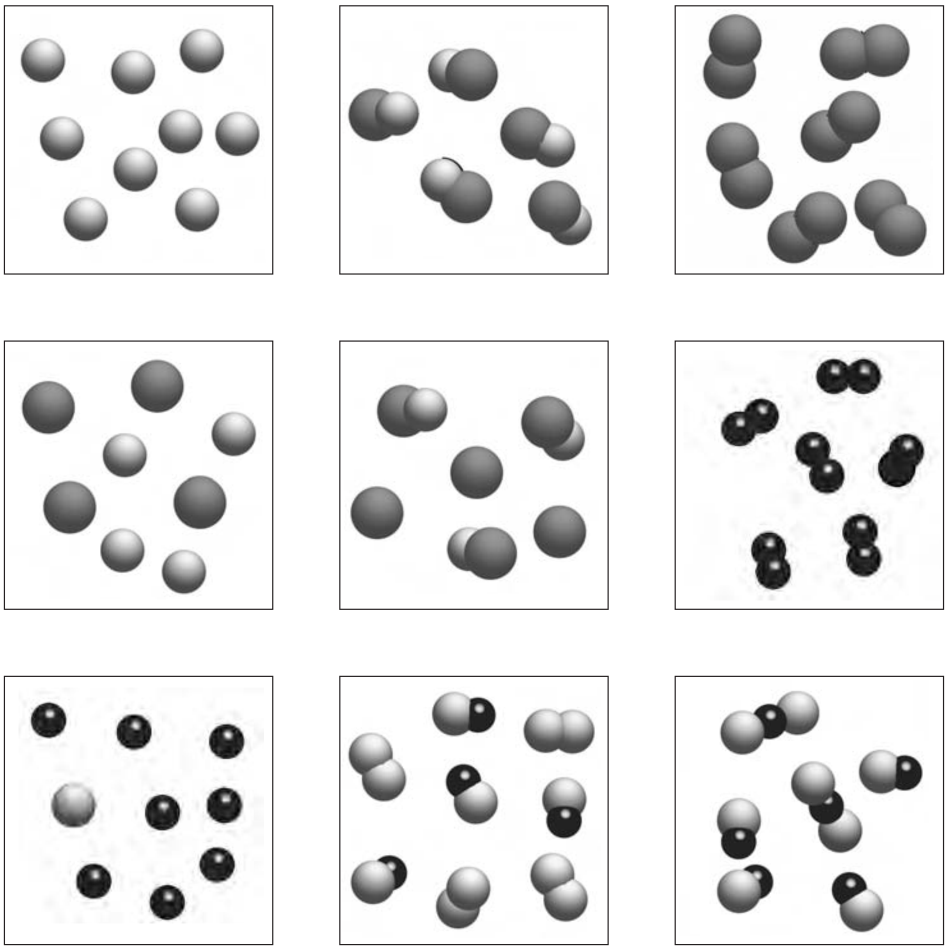
A element

B compound

C mixture of two elements

D mixture of two compounds

E mixture of an element and a compound



2 The Analytical Laboratory for State Forests of NSW analyses foliage (parts of plants) for the following components: aluminium, ash, boron, calcium, iron, magnesium, manganese, moisture content, nitrogen, phosphorus, potassium, sodium and zinc.

a) Which one of the components listed is a compound?

____

b) Which one of the components listed is a mixture?

____

c) If you paid for a sample of foliage to be analysed you could get information on how many elements?

Check your answers.

You can find out more about laboratories that analyse, that is find out the chemical parts of something, through the chemistry website.
http://www.lmpc.edu.au/science

Mixtures from the environment

Mixtures are an important part of your life. Answer the following questions about them.

1 What is a mixture that you are using right now from the atmosphere?

2 What part of your body traps and separates most of the solid particles suspended in this mixture before the solid particles get too far inside your body?

3 What element does your blood remove from this mixture?

4 What compound does your blood release into this mixture?

Check your answers.

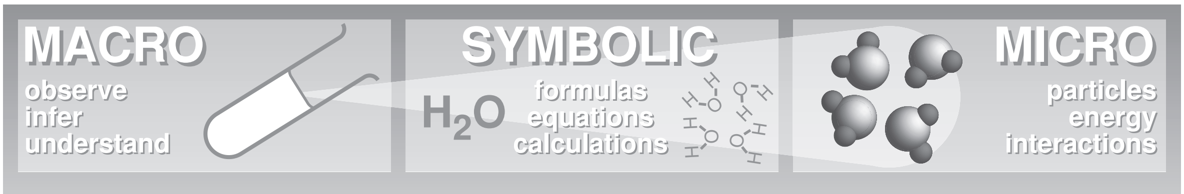
Most mixtures have to be purified before they can be used. Sand for example may have to be sorted according to grain size and washed before use in building materials such as concrete. Separation of unwanted material takes energy and effort in order to make the mixture more valuable.

Most minerals are found as part of a mixture. The mineral could be an element such as gold (Au) or a compound such as gypsum (calcium sulfate combined with water $CaSO_4.2H_2O$; in the crystals of gypsum there are two water molecules to every $CaSO_4$).

Separating grams of the mineral gold from tonnes of unwanted rock material is expensive and this explains the high cost of gold.

Sometimes mixtures need to be separated to remove harmful substances. The 2000 Sydney Olympic Games were held near Homebush Bay. From 1925 until 1997 Homebush Bay was a major production site for organic compounds. In late 1999 about 400 tonnes of contaminated soil was treated to remove organic contaminants so that the soil could be used for landfill.

More information about decontamination can be found on the chemistry web page: http://www.lmpc.edu.au/science



Measurement in chemistry

Measurement of mass/weight

In chemistry mass and weight usually mean the same thing. When chemists measure the mass of a chemical they are weighing the chemical or finding the weight. A chemist working in a laboratory usually measures mass in grams (g). The mass of a small lolly such as a Smartie® M & M®, or Lifesaver®, is about 1 g.

Next time you get a packet of small lollies count them, look at the total mass and then try to calculate the mass of one lolly in grams. Practice estimating the mass of small objects when you see them and hold them. This will help you when you are estimating amounts of chemicals.

Most chemical laboratories can measure mass to one thousandth of a gram or one milligram (1 mg). A grain of sand has a mass of about 1 mg.

Chemistry laboratories measuring very small amounts of chemicals may measure in millionths of a gram or micrograms (1µg). A dust particle that you see floating in sunlight could have a mass of about one microgram.

A chemical supplier might measure some chemicals in thousands of grams. One thousand grams is called one kilogram (1 kg). What foods (mixtures of chemicals) do you buy in kg? A large supplier of chemicals might sell chemicals in tonnes (t). One tonne is 1 000 kilograms.

Complete this information by adding appropriate units.

1 t = 1 000 ___

1 g = 1 000 ___

1 kg = 1 000 ___

1 g = 1 000 000 ___

Check your answers.

Measuring equipment

1 List any equipment you use to measure weight such as bathroom scales or kitchen scales.

2 For each piece of equipment record the largest weight and the smallest weight that can be measured.

3 Also record whether the equipment is analog – using a scale that a pointer moves over – or digital – providing digits (numbers). (Watches with hands are analog, watches giving the time in digits are digital.)

Equipment	Largest weight	Smallest weight	Analog/digital

(Did you include units like g or kg in the middle two columns?)

You will need access to equipment for measuring weight in some of your chemistry activities.

Measurement of volume

Chemists usually prefer to handle chemicals in the liquid form because:

- it is quicker to measure out a volume of liquid chemical than to weigh a chemical
- the particles in a liquid move freely over one another and so if two liquids are mixed the different particles quickly come in contact with one another; particles in a liquid state react much more quickly than particles in the solid state.

Large liquid volumes are measured in litres (L). Smaller liquid volumes are measured in millilitres (mL). Sometimes liquid volumes are given in cubic decimetres (dm^3) or cubic centimetres (cm^3).

$1\ dm^3 = 1\ L$ $\quad\quad$ $1\ cm^3 = 1\ mL$

A decimetre is one tenth of a metre or 10 cm. Imagine a cube with sides 1 dm long. That cube has a volume of $1\ dm^3$ or 1 L.

In the space below, draw a cube with sides 1 cm. This cube has a volume of 1 cm^3 or 1 mL.

Measuring volume

List any equipment you use for measuring volume such as measuring cups or measuring spoons in the kitchen or medicine cabinet. For each piece of equipment record the largest volume and the smallest volume that can be measured.

Equipment	Largest volume (mL)	Smallest volume (mL)

Estimating activity

In chemistry you should develop your ability to estimate. Sometimes you can estimate by comparing the quantity with a known quantity by eye. Estimate the volume of your kitchen sink by imagining how many 1 L cartons of milk would be needed to fill the kitchen sink:

Estimated volume of my kitchen sink is ___ L.

On other occasions you may need to count drops while transferring liquid to measuring equipment and then do a simple calculation.

If you have a dropper bottle count how many drops are needed to occupy a measured volume then calculate the volume of a single drop.

For example if 20 drops are needed to reach the 1 mL mark in a measuring spoon then a single drop has a volume of 1/20 = 0.05 mL

How do you estimate the volume of a small object? Try measuring the total volume of a number of identical objects then divide this total volume by the number of objects.

Calculating density

Density is a very useful physical property for identifying chemicals. For example, the density of fool's gold is a quarter of the density of the element gold.

To calculate density you need to

i) measure or estimate the mass and the volume

ii) do a calculation using the formula

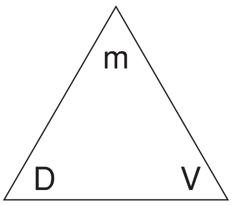
$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad D = \frac{m}{V}$$

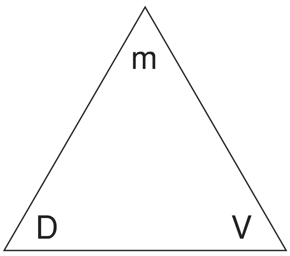
Density is normally expressed in grams per cubic centimetre (g cm^{-3})

Density will be in g cm^{-3} if mass and volume are measured in the following units:

g and cm^3	g and mL	t and m^3
kg and dm^3	kg and L	t and kL

You will need a calculator or ability at doing arithmetic for density calculations. This triangle is a useful way of rearranging the equation so the quantity you wish to calculate is on one side and the quantities you know are on the other side of the equation.





$D = \frac{m}{V}$ In the triangle D is on one side and m is over the V.

$\frac{m}{D} = V$ In the triangle V is on one side and m is over the D.

$m = DV$ In the triangle m is on the top by itself and DV is on the bottom.

In the triangle D on one side equals m over V on the other side.

In the triangle V on one side equals m over D on the other side.

In the triangle m on top by itself equals D times V on the bottom.

Here are some questions about calculating density.

1 If you know the value of m and V use D = m/V to calculate D.

If you know the value of m and D use m/D =V to calculate ___.

If you know the value of D and V use m = DV to calculate ___.

2 Some density calculations for you to try.

a) Calculate the density of a sample of gold coloured rock that has a mass of 28 g and a volume of 5.5 cm^3.

____

____

____

Gold has a density = 19.3 g cm^{-3}. Is the sample gold? _______

b) Calculate the volume of 1 kg of water if the density of water is 1.0 g cm^{-3}. Give the answer in

i cm^3 ____

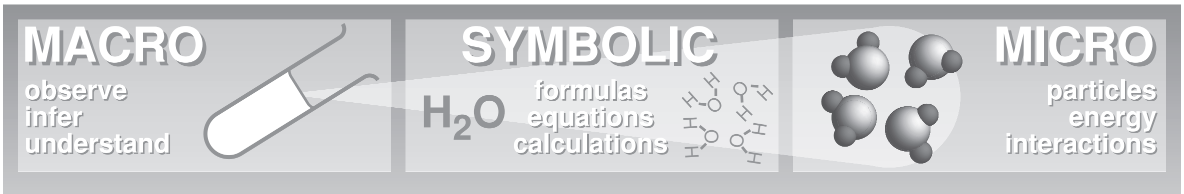
ii mL ____

iii L ____

Check your answers.

Like to find out more about density by using the internet? Have a look at sites on the chemistry webpage. If you look towards the end of the **URL** you can get an idea of what information you will find at a website.

http://www.lmpc.edu.au/science



Separating mixtures

Separation techniques

In this section you are going to look at different procedures that can be used to separate naturally occurring mixtures. Each procedure uses a different physical property to separate the parts of the mixture.

Chemicals

mixtures ·········· separated using physical properties ·······► pure substances

properties vary *properties fixed*

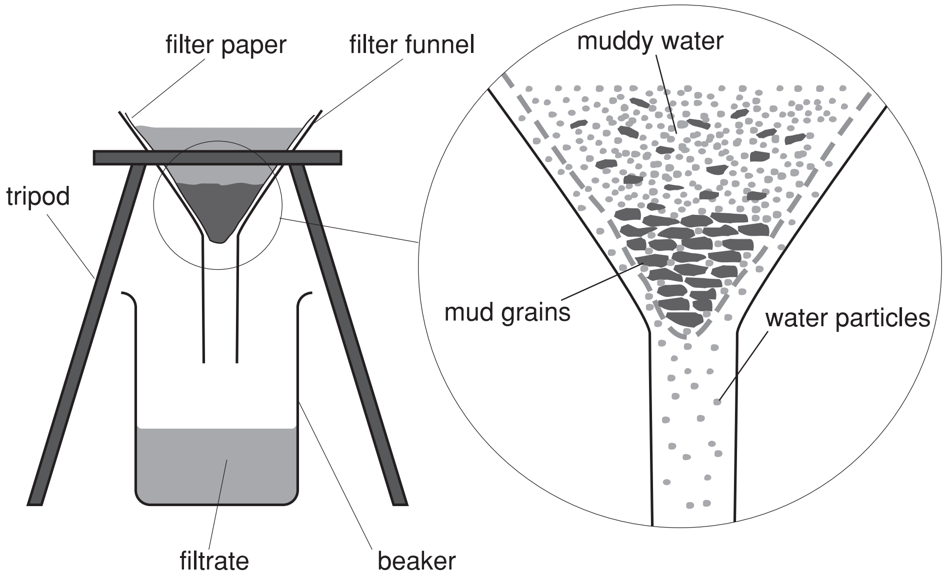
You will be given a written description and a scientific drawing of equipment. The equipment shown to carry out the separation procedure could be from a school laboratory or from an industry.

Sieving and filtration

A sieve is a piece of equipment that has a series of holes in it. It is used to separate particles of different sizes. The holes let small objects pass through but not others. Look in your kitchen for an example such as a tea strainer, coffee filter, kitchen colander or flour sifter.

A filter paper is a sieve with very small holes in it. When filter paper is used to filter mud from muddy water the water particles are small enough to pass through holes while the mud grains are too large. The liquid which passes through holes is called **filtrate**. The mud trapped by the filter paper is called the **residue**. This is shown in the diagram on the next page.

In the space below, can you draw a labelled diagram below to show how a tea strainer, coffee filter, kitchen colander or flour sifter is used for filtration?



Equipment used to separate an insoluble substance from a solution.

Sedimentation followed by decanting

Have you ever tried panning for gold in the sediments of a river? Panning uses the high density of gold for sedimentation to separate gold grains and decanting to wash unwanted sediment away from the gold.

Sedimentation allows insoluble solid to separate from liquid. The higher density solid settles to the bottom of the container of liquid. The liquid is then poured off in a process called decanting leaving the solid and part of the liquid behind. Can you think of a situation in a kitchen where you have carried out decanting?

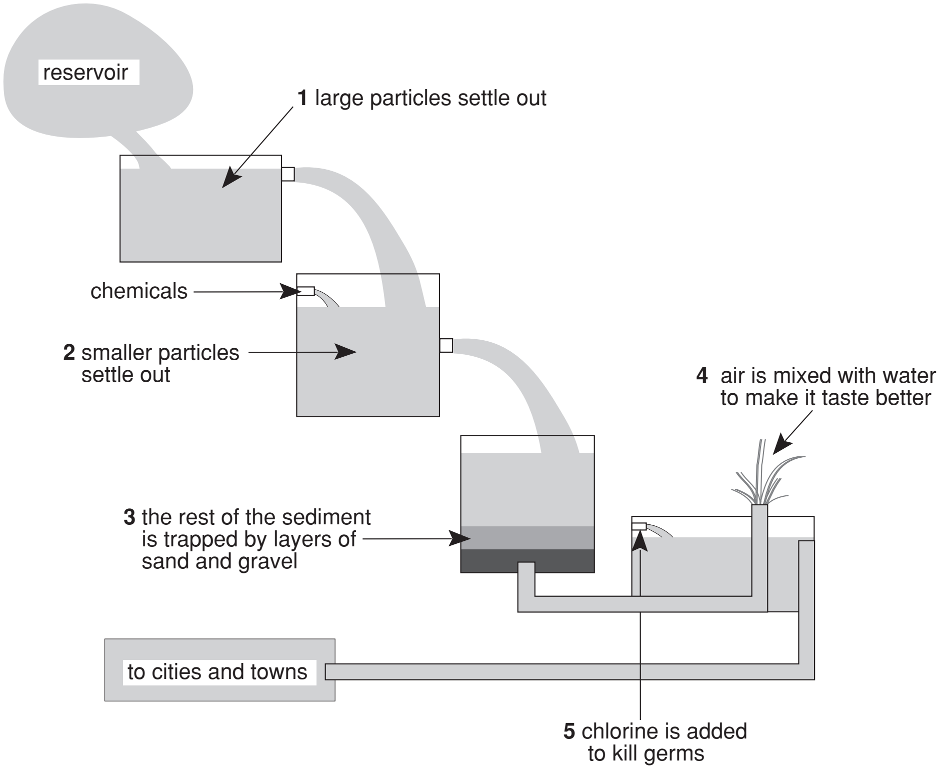
The diagram on the next page shows what happens to water between a reservoir (dam) and homes.

1 Give the numbers of the two steps where sedimentation occurs.______

2 Give the number of the step where filtration occurs. ____________

3 Give the number of the step where chemicals are added to increase sedimentation. ____

Check your answers.



Insoluble substances are removed from drinking water by sedimentation.

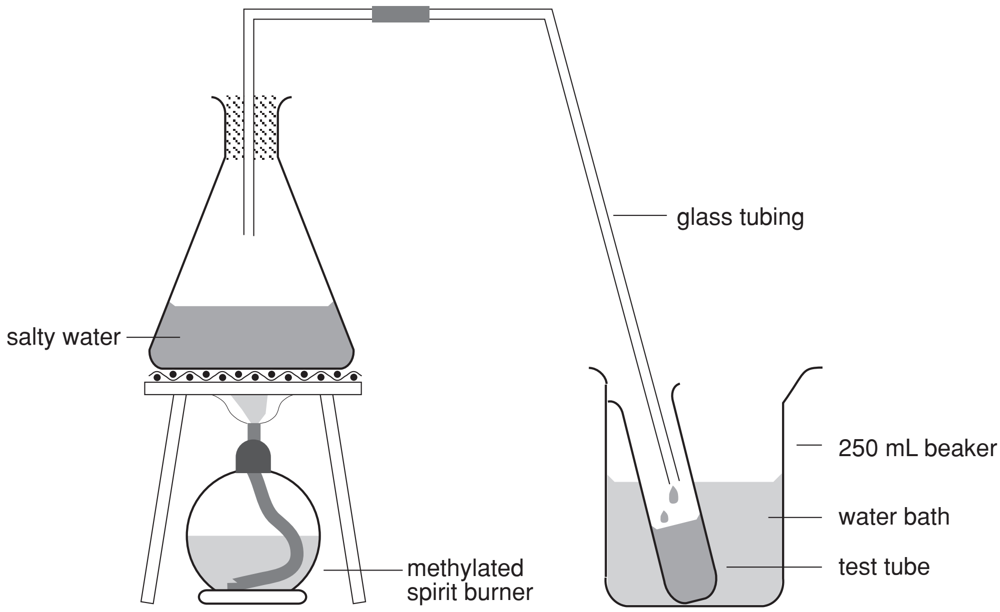
Distillation and condensation

Distillation separates a liquid mixture into its parts by using differences in boiling point (BP). Alcoholic drinks with a high alcohol content are usually made by distillation eg brandy is distilled from wine.

Simple distillation equipment can be used to separate a liquid (low BP) from dissolved solid (high BP). This equipment could be used in a school laboratory to separate salt from water in a salt solution. This set up is shown in the diagram on the next page.

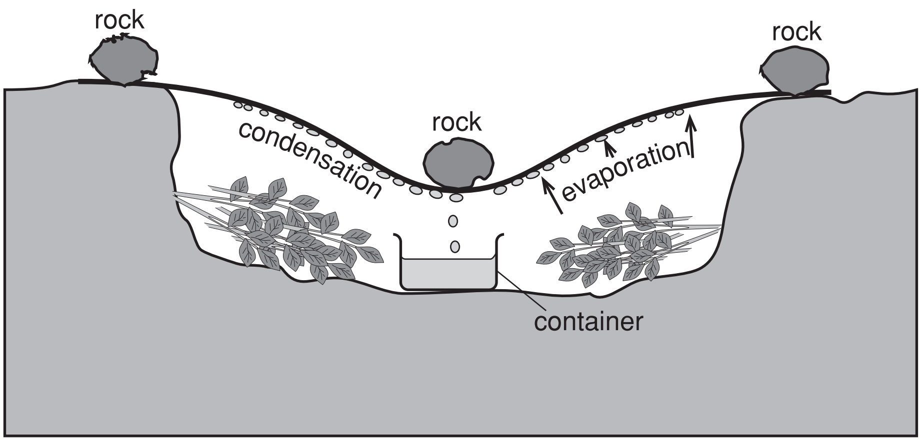
In this equipment the glass tubing, cooled by surrounding air, acts as a **condenser**. The condenser changes any liquid which has boiled off as gas back to the liquid in a purer form.

In parts of the world where there is little water but frequent fogs, vertically hanging strings can be used to collect water. A fog forms when air containing water vapour cools so much that the water vapour condenses into little drops of water. These little drops of water are so small that they float in the air. The drops of water stick to the vertically hanging strings, collect into bigger drops which then run down the string to a water storage area.



Simple distillation equipment set up to separate salt from seawater.

1 People who are short of water in desert regions have used the plastic sheet method shown below to obtain enough drinking water to survive. Label the plastic sheet in the diagram.



A set up used to obtain drinking water in the desert.

2 Describe how this makeshift equipment obtains water that could save your life.

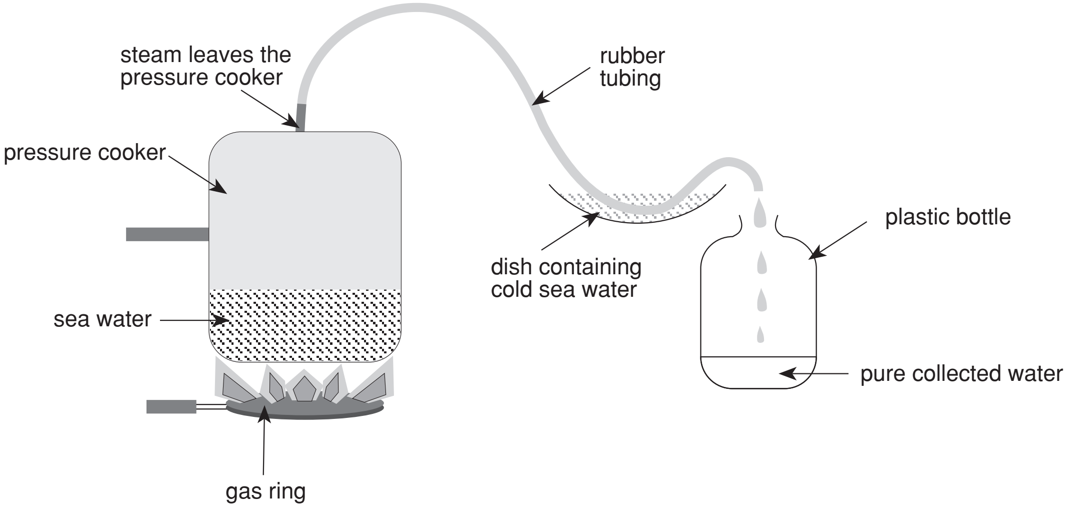
___

___

___

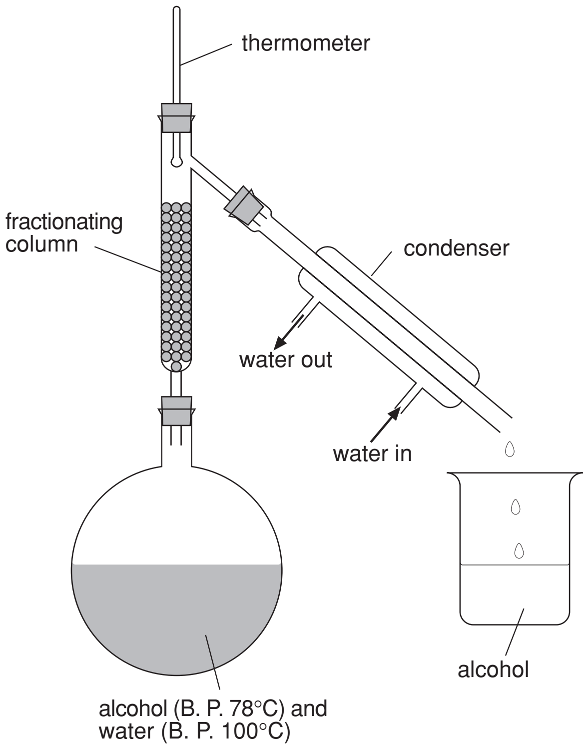
Check your answers.

Most large ships use waste heat from their engine rooms to distil sea water to obtain fresh water for washing or drinking. In the 1973 Round the World Yacht Race, one yacht lost its drinking water from a leaking tank. The crew of the yacht rigged up apparatus to separate fresh water.



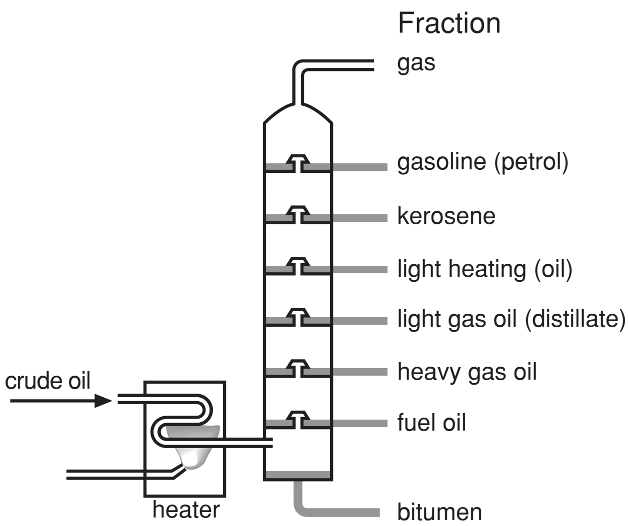
A device used to obtain drinking water from seawater.

If a mixture of liquids which have boiling points close together needs to be separated a fractionating column is used.



Draw in suitable heating equipment for this diagram. Any equipment involving a flame must be kept well away from the flammable alcohol.

The liquid with the lowest boiling point evaporates and reaches the top of the fractionating column first. This liquid will make up the first fraction to be collected from the condenser. The liquid with the highest boiling point will be the last liquid to evaporate and will make up the last fraction to be collected.



Petroleum refineries have tall distillation columns to separate the components of petroleum.

Petroleum refineries have tall fractional distillation columns used to separate petroleum into petrol, kerosene, diesel fuel, lubricating oil and other fractions. In the diagram above note how the flame does not come in contact with the petroleum or its products.

Crude oil is a mixture of hydrocarbons. Some of these hydrocarbon particles are large and heavy, requiring a lot of energy to move. Other hydrocarbon particles are small and light in weight, requiring little energy to move.

Answer the following questions about fractional distillation of hydrocarbons

1 Which particles would you expect to collect at the top of the fractionating column? ___________________________________

2 Which particles would remain at the bottom? _________________

3 Another important application of fractional distillation is the separation of liquid air into nitrogen, __________ and argon gases.

4 Can you list four mixtures that can be separated by distillation?

____

____

Check your answers.

Answer Exercise 1.2 now.

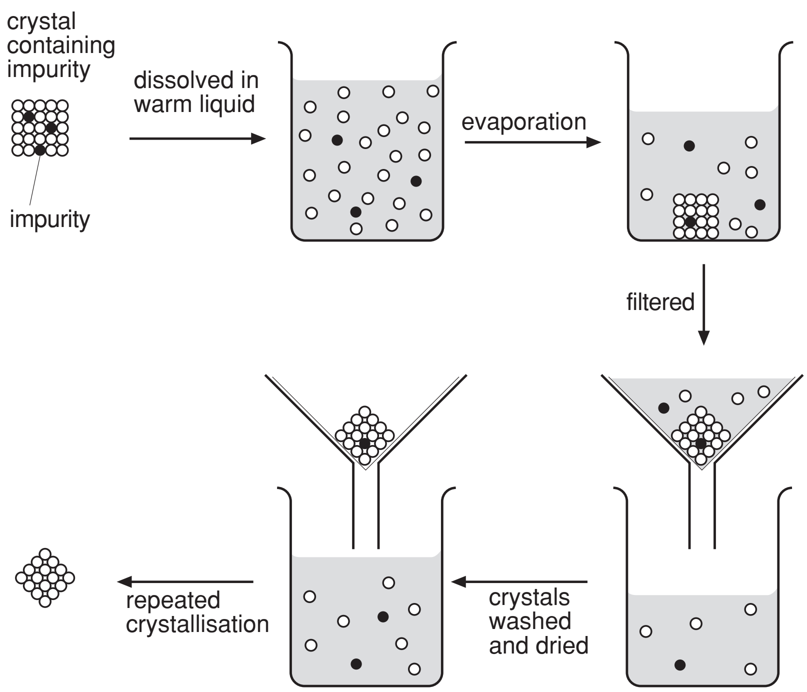
Evaporation and crystallisation

Evaporation is a way of separating a mixture (the **solution**) of dissolved solid (the **solute**) and liquid (the **solvent**). In evaporation the liquid is usually lost into the air as it evaporates leaving the solid behind.

Solar evaporation using heat energy from the sun is used to separate salt from sea water in Queensland and North West Australia. You can carry out an evaporation by dissolving some table salt in water and leaving a shallow layer of this mixture to evaporate into the air.

Crystallisation is an important way of separating solid crystals from impurities.

If a chemical is contaminated with impurities it can often be dissolved in a suitable warm liquid (the solvent). When the warm liquid is cooled or evaporated some pure crystals of the chemical will form. Most of the impurities stay dissolved in the liquid which can be decanted or filtered off and discarded. The crystals can be washed with clean solvent to remove any impurities from the outside and the pure crystals dried. Repeated crystallisations can produce very pure crystals.

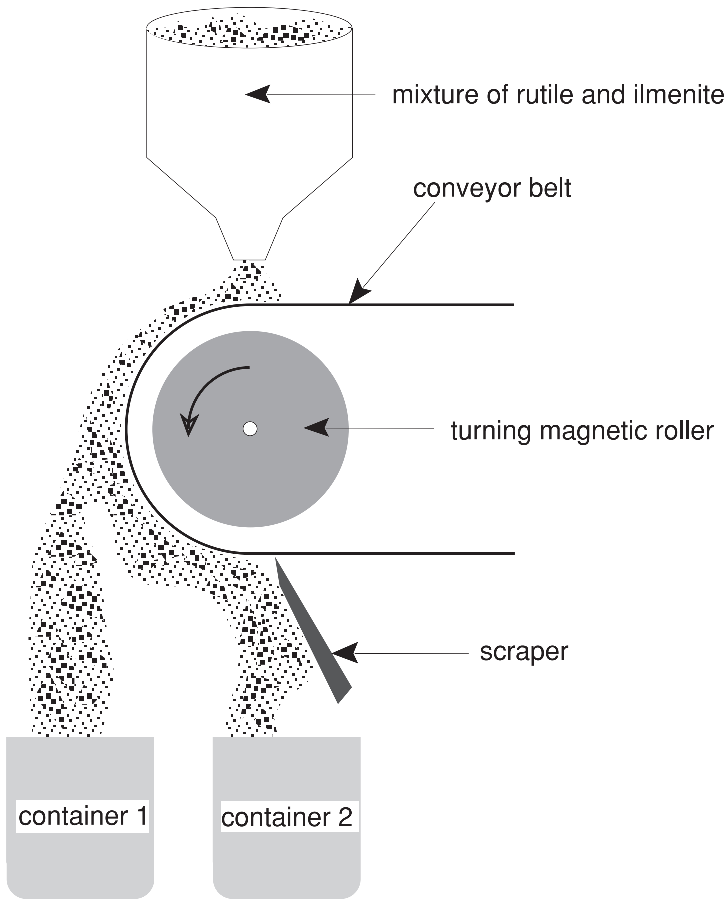


Some substances can be purified by evaporation and crystallisation.

Magnetic attraction

Magnetic attraction is a well known technique for separating iron (ferrous metal) from other metals (non-ferrous metals) eg. steel cans from aluminium cans.

Separation of valuable minerals from beach sand produces a mixture containing rutile and ilmenite. Ilmenite is magnetic, but rutile is not. Here is a diagram of equipment used to separate the mixture.



______________   ______________

Ferrous metals can be separated from non-ferrous metals by magnetism.

1 One container has rutile in it and the other has ilmenite. Describe how this occurred.

____

____

2 Write the contents under each container in the diagram above.

Check your answers.

Next time you get a chance to walk through sand barefooted have a look at you feet immediately after the walk. Can you see particles from the sand on your feet? Do some types of particles in the sand stick to your feet more than other types? Your feet are not magnetic; the attractive forces between the skin of your feet and different mineral particles vary.

Chromatography

Your turn to do some lolly chemistry at home! Chromatography separates a mixture of substances by using differences in ability to move through a medium. We will use filter paper as our medium and water to carry the mixture through the medium.

Using chromatography to separate food dyes

What you need:

- a packet of coloured lollies such as Smarties®, M & Ms®, or jellybeans
- two pieces of filter paper each cut into a rectangle about 9 cm by 6 cm
- a small clean paint brush (like in a young child's paint set) or cotton wool buds
- a glass or transparent plastic container.

What you do:

1 Using a graphite ('lead') pencil draw a line 2 cm from and parallel to the short end of the rectangular filter paper. Do this for both pieces of filter paper. This is shown in the diagram below.

2 Take a lolly of a dark colour. Wet the hairs of the brush with water then shake once to remove excess water. Run the hairs of the brush over the surface of the lolly to dissolve the food colour. Spot the colour on the pencil line about 1 cm from the edge of the paper.

3 Wash the brush well with water and repeat step 2 with a different colour lolly but this time put the colour spot 1 cm away from the previous spot but still on the pencil line.

4 Repeat step 2 until you have 4 different colours on the paper. Write the colour in pencil near the spot. Use the second piece of rectangular filter paper if you have more than four strong colours.

5 Place no more than 0.5 cm depth of water in a glass or transparent plastic container.

6 Put the paper in the container being very careful not to have the colour spots covered by water. Bend the top of the paper over the top of the container.

7 Leave until the water soaking up through the paper reaches the top of the container. Remove the paper and dry in air.

8 Draw what you can see has happened on the rectangular paper outline below. Coloured pencils could be useful to do this.

Questions for you to answer for this chromatography activity.

1 Which lolly colours have separated into two or more colourings?

2 Which of the colourings travelled the furthest?

This colouring has a much stronger attraction for the water than for the paper.

3 Which colouring has the strongest attraction for the paper?

Explain why you chose this colouring.

4 Suppose that a maker of coloured lollies starts with five different food dyes. How could they make more than five different lolly colourings?

Check your answers.

Chromatography means colour writing. Can you understand why?

Using chromatography to identify food additives

Additives are chemicals added to food but not normally consumed as foods by themselves. Food additives can be used to improve taste, appearance, keeping quality or stability and to preserve food.

The Food Standards Code requires food labels to list all ingredients in descending order of proportion by weight, except for water which can be listed last.

This code, supplied by the Australia New Zealand Food Authority (ANZFA) is influenced by internationally agreed food standards from the United Nations Food and Agriculture and World Health Organisations. Numbers used are based on an international system for identifying food additives. Look at the label on the packet of lollies that you used in the last activity. Use the food additive numbers and colours below to name colourings that you separated from the lollies.

Additive number	Additive name	Colour	✓ if this was separated
102	tartrazine	yellow	
110	sunset yellow FCF	orange yellow	
120	carmines or cochineal	pinkish red	
122	azorubine	red	
123	amaranth	purplish red	
124	ponceau 4R	orange red	
127	erythrosine	cherry pink	
132	indigotine	deep blue	
133	brilliant blue FCF	greenish blue	
142	food green S	bluish green	
151	brilliant black BN	bluish black	

1 Some food additives used as colourings can be extracted from plants. Can you guess what plants these food colourings can be extracted from?

160 carotenes ____

162 beet red. ____

2 Titanium dioxide (171), although called a colouring, is white. It is found in Smarties®, M & Ms®, but not jellybeans. What part of Smarties®, and M & Ms®, do you think contains 171? __________

If you can't think of an answer try sucking a Smartie® or M & M®, for about 20 seconds then have a look at it.

Check your answers.

Reviewing separation techniques

Complete the *Example* column by placing air, gravel, petroleum, seawater and swimming pool water in the appropriate space.

Separation procedures according to the states of matter present		**Example**
solids of different sizes	sieving, sedimentation	
solids and liquids	filtration for insoluble solids	
dissolved solids in liquids	distillation, evaporation and crystallisation	
liquids	fractional distillation	
gases	**liquefaction** followed by fractional distillation	

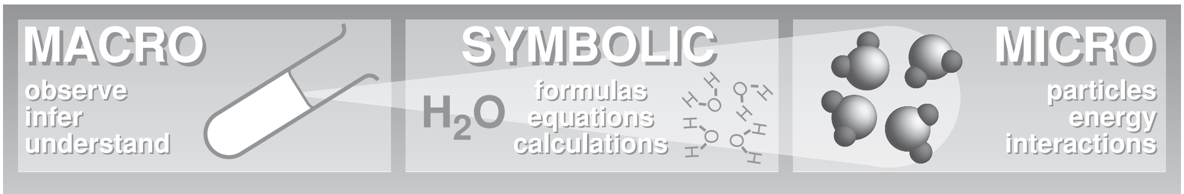
Check your answers.

1 Use this list of separation methods to complete the first column of the table on the next page.
   - sieving
   - filtering
   - sedimentation and decanting
   - distillation
   - evaporation and crystallisation.

2 Then use this list of physical properties to complete the second column. (Hint: one of these physical properties will need to be used twice.)
   - boiling point
   - density
   - particle size
   - solubility.

Check your answers.

Separation method	Physical property	Solids of different sizes	Insoluble solid and liquid	Dissolved solid and liquid	Liquids
			solid tea leaves and liquid tea		
			clear water and mud		
		gold panned from sediment			
				fresh water from sea water	brandy from wine
				sea salt from seawater	



Quantitative analysis

Analysis is the process of identifying the components of something.

Qualitative analysis finds out what is in the mixture. Identifying the components of a mixture to be sand, salt and water is qualitative analysis. **Quantitative analysis** is carried out after qualitative analysis. Quantitative analysis finds out how much of each component is in the mixture. Identifying that a mixture is 5% sand, 20% salt and 75% water or 5 g sand, 20 g salt and 75 g water is quantitative analysis.

Quantitative analysis carried out by weighing is called **gravimetric analysis**. Identifying that a mixture is 5 g sand, 20 g salt and 75 g water is gravimetric analysis.

Another type of quantitative analysis is called **volumetric analysis**. Identifying that a mixture is 5 mL sand, 20 mL salt and 75 mL water is volumetric analysis.

If the results of a quantitative analysis are given as percentage composition such as 5% sand, 20% salt and 75% water you should also indicate if the percentages are by weight or volume.

Quantitative analysis of dry air

Component	**% by weight**	**% by volume**
Nitrogen N_2	75.5	78.1
Oxygen O_2	23.1	20.9
Argon Ar	1.3	0.9
Carbon dioxide CO_2	0.05	0.03

Use the previous table to answer the following questions.

1 Which chemical has been removed from air to make dry air

____

2 Explain why the analysis above was quantitative and not just qualitative.

____

____

3 The weight figure for nitrogen is less than the volume figure for nitrogen but the weight figure for oxygen is more than the weight figure for oxygen. This is because the nitrogen particles (N_2) weigh less than the oxygen particles (O_2).

Can you use the figures to **justify** that carbon dioxide particles (CO_2) are heavier than oxygen particles (O_2)?

____

____

Check your answers.

Gravimetric analysis

In this activity you will be analysing a mixture of unknown proportions. You will separate the components of a mixture of sand, salt and water and carry out gravimetric analysis.

What you will need:

- dry sand
- dry table salt
- weighing scales such as kitchen scales
- a container to hold water
- a funnel to hold filter paper (a funnel can be made by cutting off the top part of an empty plastic drink bottle)
- filter paper
- heat source for evaporating salty water, eg a stove and saucepan
- two spoons.

What you will do:

1 Have someone you know (eg teacher, parent, another student, friend) make up a mixture of sand, salt and water using one of these proportions by weight:

sand:salt:water = 1:1:18 OR 2:1:17 OR 1:2:17 OR 3:1:16 OR 1:3:16

Get this person to write down the weights they used on a piece of paper. Have them seal the information so that you do not know the proportions in the mixture.

2 Using the knowledge that sand is insoluble (does not dissolve) in water and salt is soluble (does dissolve) in water plan a way to separate your mixture into sand, salt and water. Include a way of separating the salt and water.

3 Discuss your method with a responsible person before trying to use your method. Ask that person to point out any difficulties or possible hazards. Use this advice to minimise risks.

There is information about folding a filter paper in the Appendix. If you have a funnel follow the cone filter instructions. If you do not have a funnel fold the self supporting filter.

4 Carry out your method with care. Aim to get dry sand and dry salt. Be very careful if you heat a mixture of salt and water; when most of the water has evaporated the remaining salt crystals can 'spit out' of the heating container.

How did you dry the sand? ______________________________

How did you dry the salt? ______________________________

5 Use your weighing scales to measure and record:

weight of dry sand ______________________________

weight of dry salt ______________________________

6 Use your results to decide if the mixture of sand: salt: water was

1:1:18 OR 2:1:17 OR 1:2:17 OR 3:1:16 OR 1:3:16.

____

7 Write a conclusion about the proportions of sand: salt: water in the mixture.

____

____

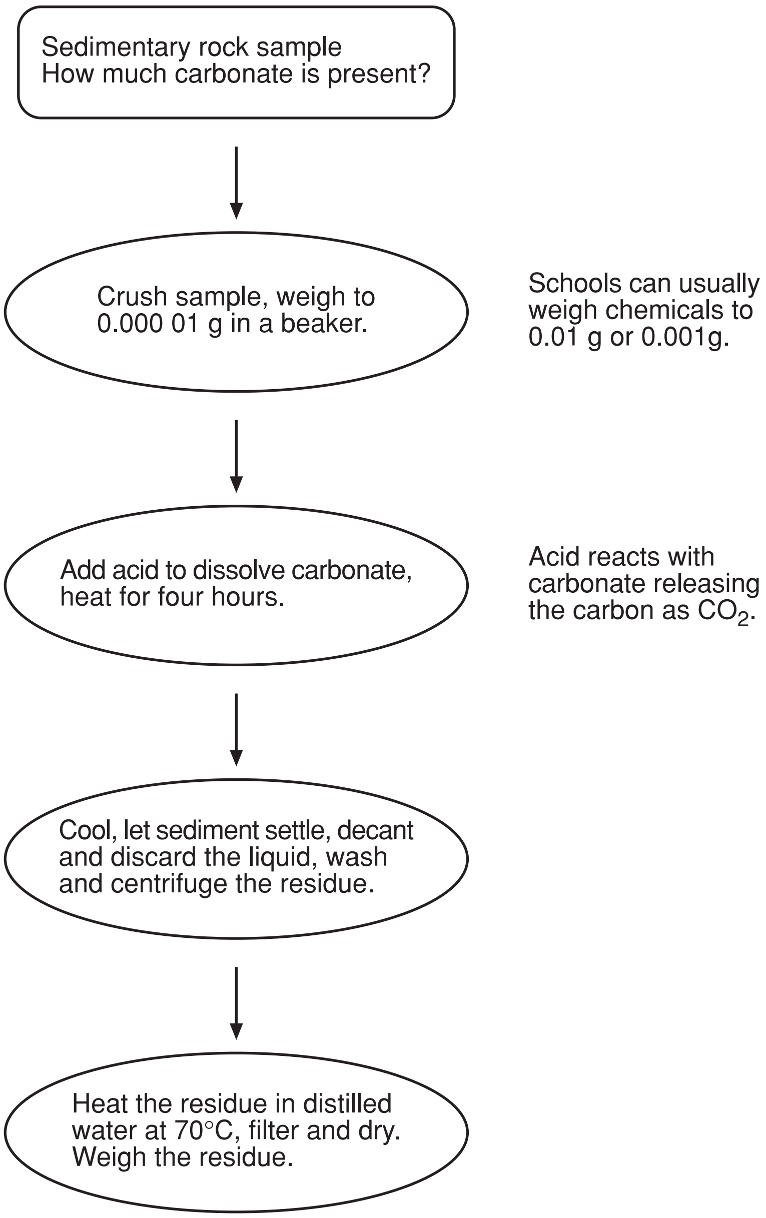
____

8 Show your written conclusion to the person who made up the mixture. Get that person to show you what they had written about the weights used. Do you both agree?

____

Carbon content of rocks

A scientist interested in measuring the total amount of carbon in sedimentary rock heated the rock to 800°C to remove and measure all the carbon in the rock as CO_2. Later, she wanted to find out how much of the carbon in the rock was organic carbon (not inorganic carbonate compounds) and so carried out the following gravimetric procedure.



From the lower weight of the residue, compared to the original sample, the scientist was able to calculate the amount of inorganic carbon present as carbonate.

total carbon = inorganic carbon + organic carbon

organic carbon = total carbon – inorganic carbon

If rock samples contain high levels of organic carbon this could indicate high levels of hydrocarbons such as in petroleum rich rocks.

Measuring fibre content

Another scientist was interested in the amount of fibre in fruits and vegetables. The method involved:

- grinding weighed dry samples in water
- keeping the mixture at a constant temperature (incubating) of 37^{o}C for 90 minutes
- adding four times the volume of 95% alcohol to the mixture to separate the fibre (if he had 200 mL of dry sample in water he added 4 x 200 = 800 mL of 95% alcohol to separate the fibre)
- the fibre that sedimented out was filtered off, dried and weighed.

  Proportion of fibre = weight of dry fibre/weight of dry sample

  % of fibre = proportion of fibre x 100.

When you look at supermarket food mixtures such as cereals you will often see information about fibre content. This information is less common on packets of fruit and vegetables.

Would you like to try measuring the fibre content of a dried fruit or vegetable? The optional activity outlined below works best for fruit and vegetables with a low starch content such as dried apple, apricot, cabbage, carrot, onion and soybeans.

Here's how you could measure fibre content at home if you have sensitive weighing scales that weigh at least to the nearest gram.

You will need:

- scales to weigh the dried sample and the dried fibre. The amount of dried sample you take should be about 100 times what the scales weigh to eg if scales weigh to nearest g take 100 g of dried sample (if you don't have a dried sample try cutting the fruit or vegetable into thin strips and dry them in the sun).

- a blender or food processor that grinds food to very small pieces
- a small container and a container at least 5 times the small container volume
- a filter such as a flour sifter or muslin or old pantihose or old handkerchief
- methylated spirits (this is close to 95% alcohol). Always keep this away from heat, flame and sparks. You will need at least 1.6 L of methylated spirits if you can weigh to the nearest gram.

Here is how you could determine the fibre content of your sample

1 Weigh the dried sample and record its weight.

2 Measure out four times the sample weight of water, for example, 400 g (=400 mL) of water for a 100g sample.

3 Blend the dried sample to very small pieces; wash the blended sample into your small container with the water.

4 Stir and leave the blended sample in the water somewhere warm for an hour.

5 Transfer all of the mixture to the larger container; you may have to add a small amount of extra water to wash out the smaller container.

6 Estimate the volume of water mixture you have; add about 4 times this volume of methylated spirits, stir the new mixture well then let it stand somewhere undisturbed for half an hour.

7 Filter the mixture trapping the fibre on your filter.

8 Dry the fibre on the filter in the sun.

9 When the fibre feels dry and brittle remove and weigh the dry fibre.

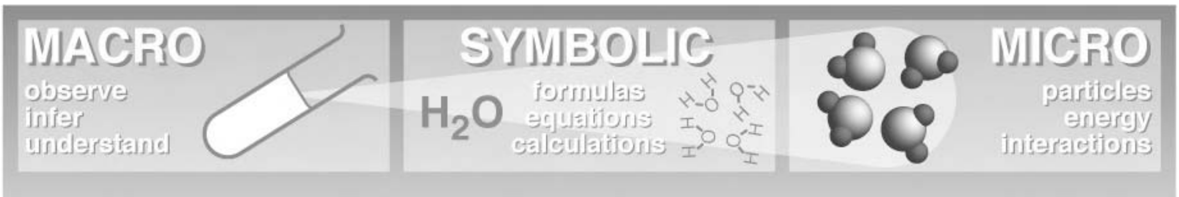
10 Calculate % fibre in the original sample.

11 See if you can find out the amount of fibre in the fruit or vegetable you used from a label, the internet or a book. How do your answer and the label/internet/book answer compare?

By now you should realise that gravimetric analysis involves:

- weighing
- separating a component from a mixture (usually by sedimentation)
- filtering
- drying
- weighing again

Answer Exercise 1.3 now.



Suggested answers

Particle theory

In a *solid* the particles are close together and have fixed positions. The particles are lined up in rows and columns like eggs in an egg carton or the oranges in a fruit box.

In a *gas* the particles have 'empty space' between one another and move randomly at high speed. The particles bounce off the walls of the sealed container.

In a *liquid* the particles are close together but can move freely over one another.

Using the particle theory

Matter as a gas is the easiest state of matter to compress.

Explaining changes of state

1 $\text{solid} \underset{\text{solidification}}{\overset{\text{melting}}{\rightleftharpoons}} \text{liquid} \underset{\text{condensation}}{\overset{\text{evaporation and boiling}}{\rightleftharpoons}} \text{gas}$

2 Ice melts to form liquid *water* which boils to form *steam.*

Steam condenses to liquid water which solidifies to form *ice*.

Elements

1	2	3	4	5	6	7	8	9	10
mon or mono	di	tri	tetra	penta	hexa	hepta	octa	nona	deca

How many elements are there?

Symbol	Element
H	hydrogen
B	boron
C	carbon
N	nitrogen
O	oxygen
F	fluorine
P	phosphorus
S	sulfur
K	potassium
V	vanadium
Y	yttrium
I	iodine
W	tungsten
U	uranium

2 *Six* elements in the periodic table have three letter symbols.

3 The number of elements which are represented by two letter symbols is 115 – 14 – 6 = *95*.

Compounds

Name of compound	Formula of compound
nitrogen monoxide	NO
dinitrogen trioxide	N_2O_3
dinitrogen pentoxide	N_2O_5
carbon disulfide	CS_2
diphosphorus pentoxide	P_2O_5

Grouping compounds

Does the compound contain carbon? Does the compound come from living things or their remains? If so the compound is organic.

Measure the conductivity of the liquid compound or its solution in water. If it conducts it is ionic.

1 The two elements in a hydrocarbon are *hydrogen* and *carbon*.

2 The three elements in a carbohydrate are *carbon* and *hydrogen* and *oxygen*.

Mixtures

1 almost infinity

2 115

3 > 17 000 000

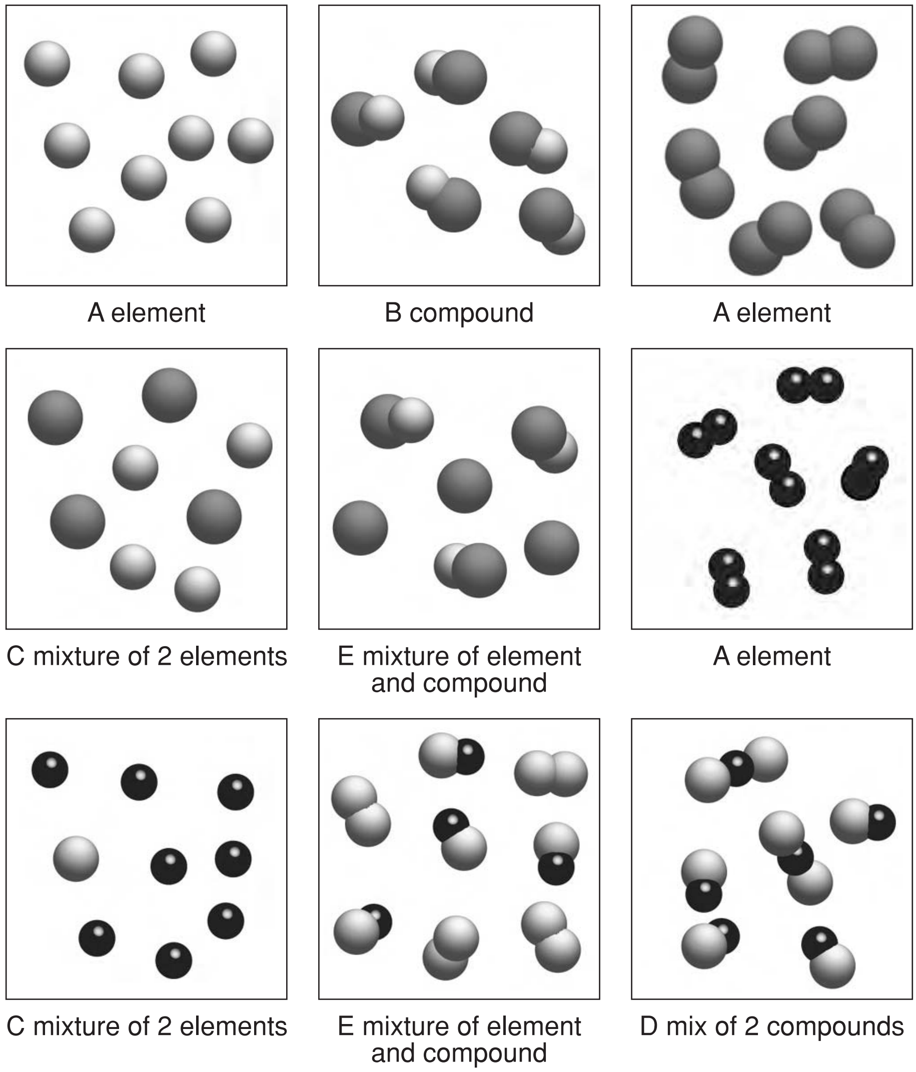
4 115 + > 17 000 000, that is > 17 000 115

Physical properties

Use a thermometer immersed in liquid. For MP the thermometer bulb should be in contact with melting solid and the melted liquid. For BP liquid should be boiling and the thermometer bulb in the middle of the boiling liquid.

Chemical properties

1



2 a) moisture content = water

b) ash

c) 11

Mixtures from the environment

1 *Air* is a mixture that you are using right now from the atmosphere.

2 *Hair and mucus* inside your nose trap and separate most of the solid particles suspended in the air before the solid particles get too far inside your body.

3 Your blood removes the element *oxygen* from this mixture.

4 Your blood releases the compound *carbon dioxide* into this mixture.

Measurement of mass/weight

1 t	=	1 000 kg
1 g	=	1 000 mg
1 kg	=	1 000 g
1 g	=	1 000 000 μg

Calculating density

1 If you know the value of m and V use the first equation to calculate *D*.

If you know the value of m and D use the second equation to calculate *V*.

If you know the value of D and V use the third equation to calculate *m*.

2 a) $D = m/V = 28$ g/5.5 $cm^3 = 5.1$ g cm^{-3} therefore the sample is not gold.

b) i $V = m/D = 1000$ g/1.0 g cm^{-3} = 1 000 cm^3

ii V = 1 000 mL

iii V = 1 L

Sedimentation followed by decanting

1 Steps 1 and 2.

2 Step 3.

3 Step 2.

Distillation and condensation

Here is a description of how this makeshift equipment obtains water that could save a life.

- Collect vegetation in the cool temperatures of early morning at dawn.
- Place vegetation in the hole, position the container in the centre of the hole.
- Cover the hole with plastic sheet placing a rock over the container and rocks around the edge of the hole.

- During the day heat from the sun will evaporate water from the vegetation (and possibly from the ground).
- This water will condense in the cool of the evening on the underside of the plastic and run down to collect in the container.

1 Particles at the top are small and light in weight.

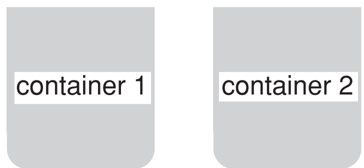
2 Particles which would remain at the bottom are large and heavy.

3 Another important application of fractional distillation is the separation of liquid air into nitrogen, *oxygen* and argon gases.

4 Wine, sea water, crude oil/petroleum and liquid air.

Magnetic attraction

1 The magnetic ilmenite remained on the conveyor belt, attracted by the magnetic roller until scraped off into container 2. The rutile falls into container 1 because it is not magnetic.



2 *rutile* *ilmenite*

Chromatography

3 The colouring that travels the shortest distance has the strongest attraction for the paper.

4 By mixing colours for example, red and yellow to give orange, yellow and blue to give green, all five colours to give brown

1 Carotenes (160) can be extracted from *carrots* and other orange-yellow vegetables such as *pumpkin*.

Beet red (162) can be extracted from *beetroot*.

2 The part which contains 171 separates colouring from the lolly and chocolate centre.

Reviewing separation techniques

Separation procedures according to the states of matter present		Example
solids of different sizes	sieving, sedimentation	*gravel*
solids and liquids	filtration for insoluble solids	*swimming pool water*
dissolved solids in liquids	distillation, evaporation and crystallisation	*sea water*
liquids	fractional distillation	*petroleum*
gases	liquefaction followed by fractional distillation	*air*

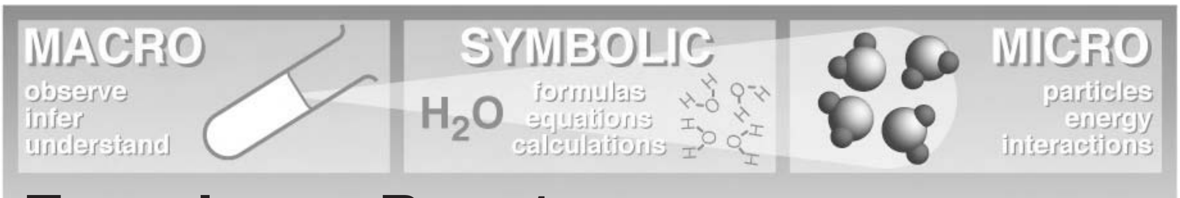
Separation method	Physical property	Solids of different sizes	Insoluble solid and liquid	Dissolved solid and liquid	Liquids
sieving	*particle size*		solid tea leaves and liquid tea		
filtering	*particle size*		clear water and mud		
sedimentation and decanting	*density*	gold panned from sediment			
distillation	*boiling point*			fresh water from sea water	brandy from wine
evaporation and crystallisation	*solubility*			sea salt from sea water	

Quantitative analysis of dry air

1 water

2 amounts were measured

3 the weight figure for CO_2 is 0.05/0.03 times, that is 5/3 times, the volume figure. The weight figure for oxygen is only slightly larger, 23.1/20.9, times the volume figure.



Exercises - Part 1

Exercises 1.1 to 1.3 Name: ________________________________

Exercise 1.1: Chemicals in your home

A small number of pure elements, a larger number of pure compounds and a huge number of mixtures are found in the average home. Mixtures do not have fixed properties because the proportions in the mixture vary.

When you buy a packaged food is it more likely to be an element, compound or mixture?

Most of the chemicals in your home, such as packets or tins of processed food, are parts of mixtures. The label on the mixture packaging will list the elements (rarely found) and the compounds (most common) that are in the mixture. Any mixtures which have been used in making the larger mixture product are often labelled extract, gum or essence.

Sometimes three or four digit numbers are used to represent the compounds in processed food mixtures:

- 100 to 199 represent colourings added to the food
- 200 to 299 represent preservatives such as sulfur dioxide SO_2 (220)
- 600s include flavour enhancers such as monosodium glutamate MSG (621)
- powerful sweeteners such as cyclamates and saccharin are found in the 900s
- **enzymes** (biological **catalysts**) such as proteases and lipases are found in the 1100s.

Look in your kitchen, bathroom, laundry, garage or workshop or garden shed for labels listing chemicals. Read any hazardous properties or safety warnings on the label.

List the names of eight different products containing an element or a compound in the first column of the table. Write the name of one of the chemicals listed on the label in the second column. If the chemical is in the periodic table it is an element. If it is not an element then write compound. If you aren't sure put a question mark after your answer.

The *Product name* is the name of the product containing the chemical.

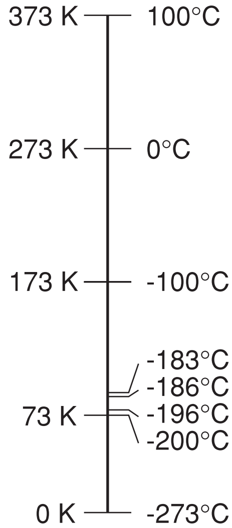
Product name	**Name of chemical**	**Element or compound?**
table salt	sodium chloride	compound
Nutri-grain®	iron	element

Next time you visit a supermarket, hardware store, craft shop, pharmacy, etc. look closely at label information about contents. Look for the names of chemicals in the products.

In your chemistry course we will try to use chemicals that are readily available as much as possible. Many of these will be chemicals used in food.

Exercise 1.2: Separating air by fractional distillation

The boiling points of the three main gases in air are nitrogen –196°C, oxygen –183°C and argon –186°C.



Remembering that –200°C is a lower temperature than –180°C arrange these three gases in order of increasing boiling point temperature:

_________________ ____________________ __________________

Suppose that you had some liquid air at –200°C containing just these three gases. If you warmed the mixture which gas would boil off at –196°C? ____

After this gas boiled off you would have a mixture of liquid ___________ and liquid ___________.

Heating this mixture further to –186°C causes the __________ to boil off as gas leaving behind liquid __________.

Can you calculate the boiling points of the three gases in kelvin? Hint: If you find this difficult to do try using this formula: K = °C + 273.

____

____

____

Exercise 1.3: Industrial separation of a mixture

Your chemistry course requires you to:

- identify data sources, gather, process and analyse information from secondary sources to identify the industrial separation processes used on a mixture obtained from the biosphere, lithosphere, hydrosphere or atmosphere and use the evidence available to:
  - identify the properties of the mixture used in its separation
  - identify the products of separation and their uses
  - discuss issues associated with wastes from the processes used.

Note: In this context:

- analyse means to identify components and the relationship between them
- secondary sources include books, magazines, newspapers, library resources, internet websites or knowledgeable people
- identify means to recognise and name.

Below are some examples of an industrial separation process used on a mixture. Add one of the words biosphere, lithosphere, hydrosphere or atmosphere to complete each sentence.

a) distillation of petroleum from the ___________________________

b) distillation of sea water from the ___________________________

c) separation of cream in milk from the ________________________

Can you write another example? ______________________________

Use the table on page 66 to complete this information gathering task. You need to identify a mixture, outline the separation process and complete the third column of the table. An example in the second column will guide you on what is required.

Here are some ideas to help you get started:

- Are there any local mines or quarries or chemical plants or processors of agricultural products (such as milk, wool, cotton, sugar cane) or minerals (sand minerals, ores)?

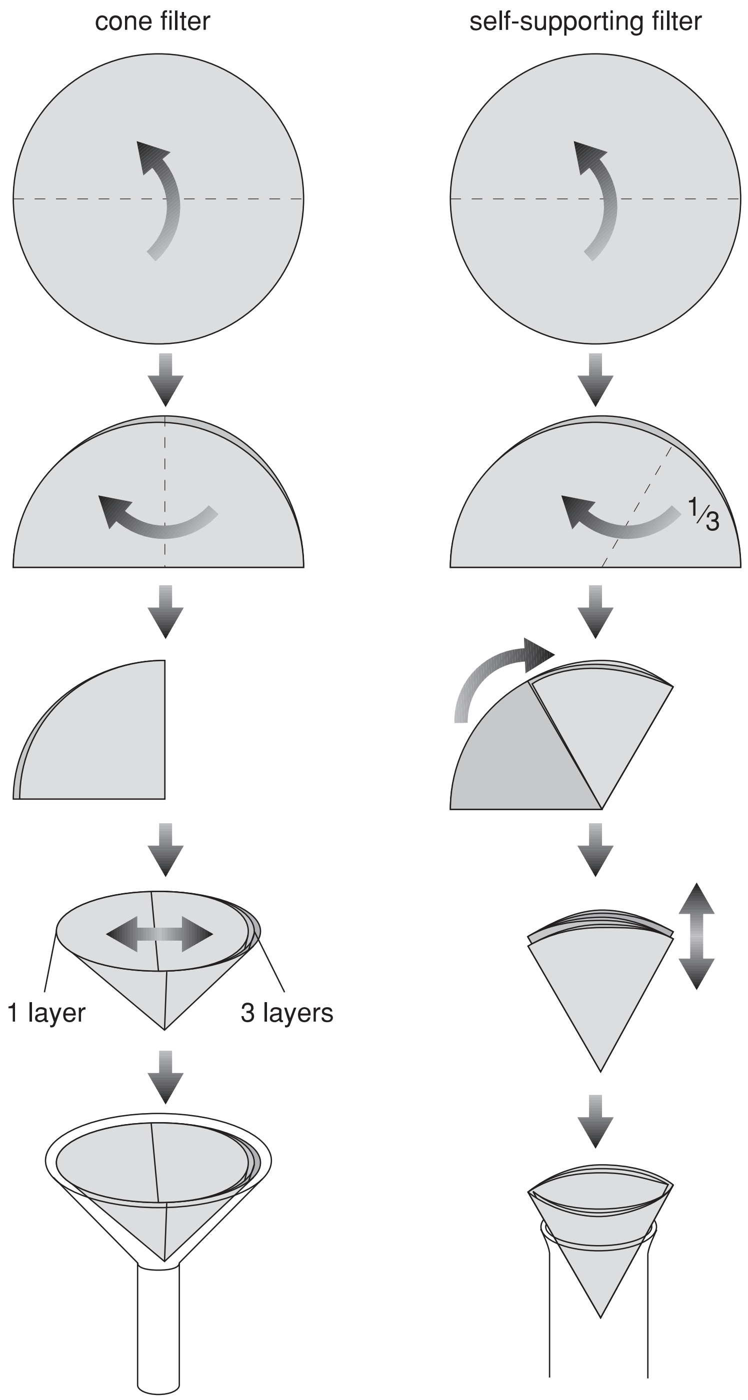
- Does the local historical society or museum have information? Does someone know a retired person who may have worked in a separation industry and would like to share their knowledge?
- Australian Aboriginals and early European settlers separated mixtures to survive.

Look at the chemistry website page for sites that could be useful in starting. http://www.lmpc.edu.au/science

In the bottom half of this page write down brief notes (possibilities, ideas, possible contacts or sources, important words, simple diagrams, etc.) that could help you do this exercise. Develop these into rough notes before you start to fill in the table. You may prefer to put notes into the table in pencil just in case you decide to change anything later.

Mixture	air	
Biosphere/lithosphere/ hydrosphere/atmosphere	atmosphere	
Separation processes [could be a labelled diagram]	liquefaction of air using low temperature equipment followed by distillation to separate the nitrogen, oxygen and argon	
Property used by separation processes	different boiling points	
Products of separation and uses	liquid nitrogen for cooling, oxygen gas for oxy-acetylene flame, argon gas for filling light globes	
Issues associated with wastes	air must be filtered so liquid oxygen can be kept away from combustible materials	
Where did you get your information from? (give details of information sources so that another person could check your information)	Encyclopedia Britannica CD-ROM distillation of air	

Appendix



Chemistry
Preliminary Course
Stage 6

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING
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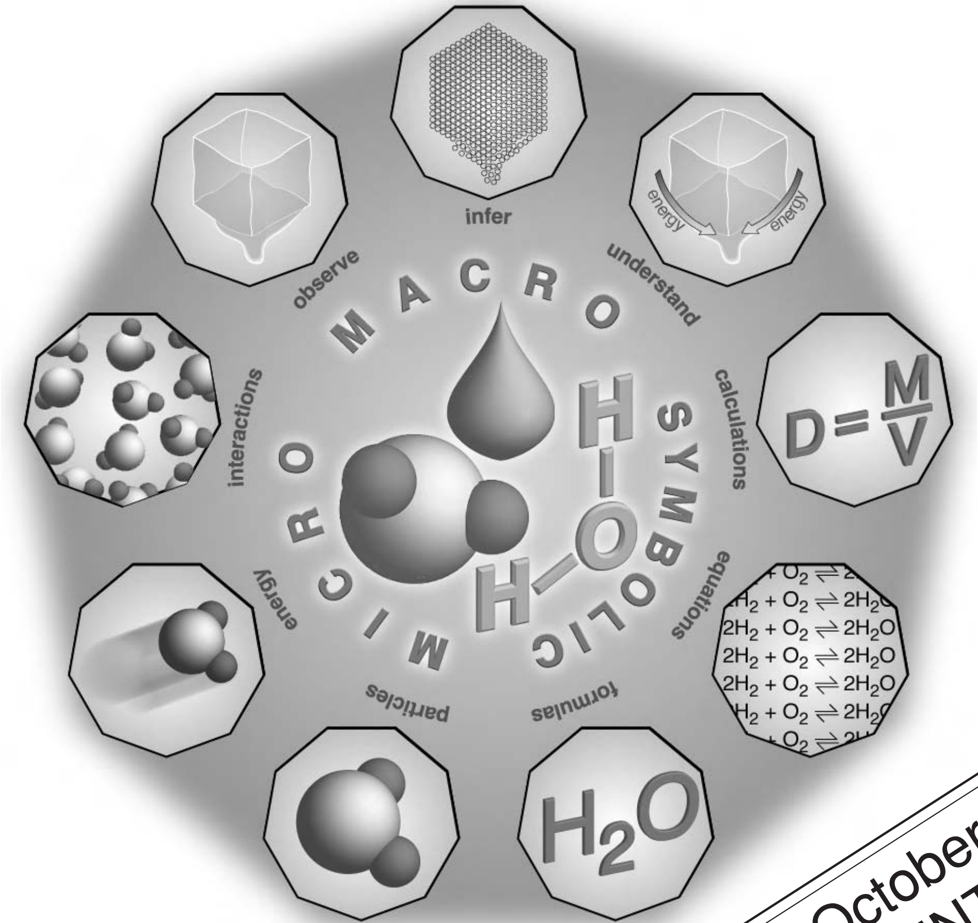
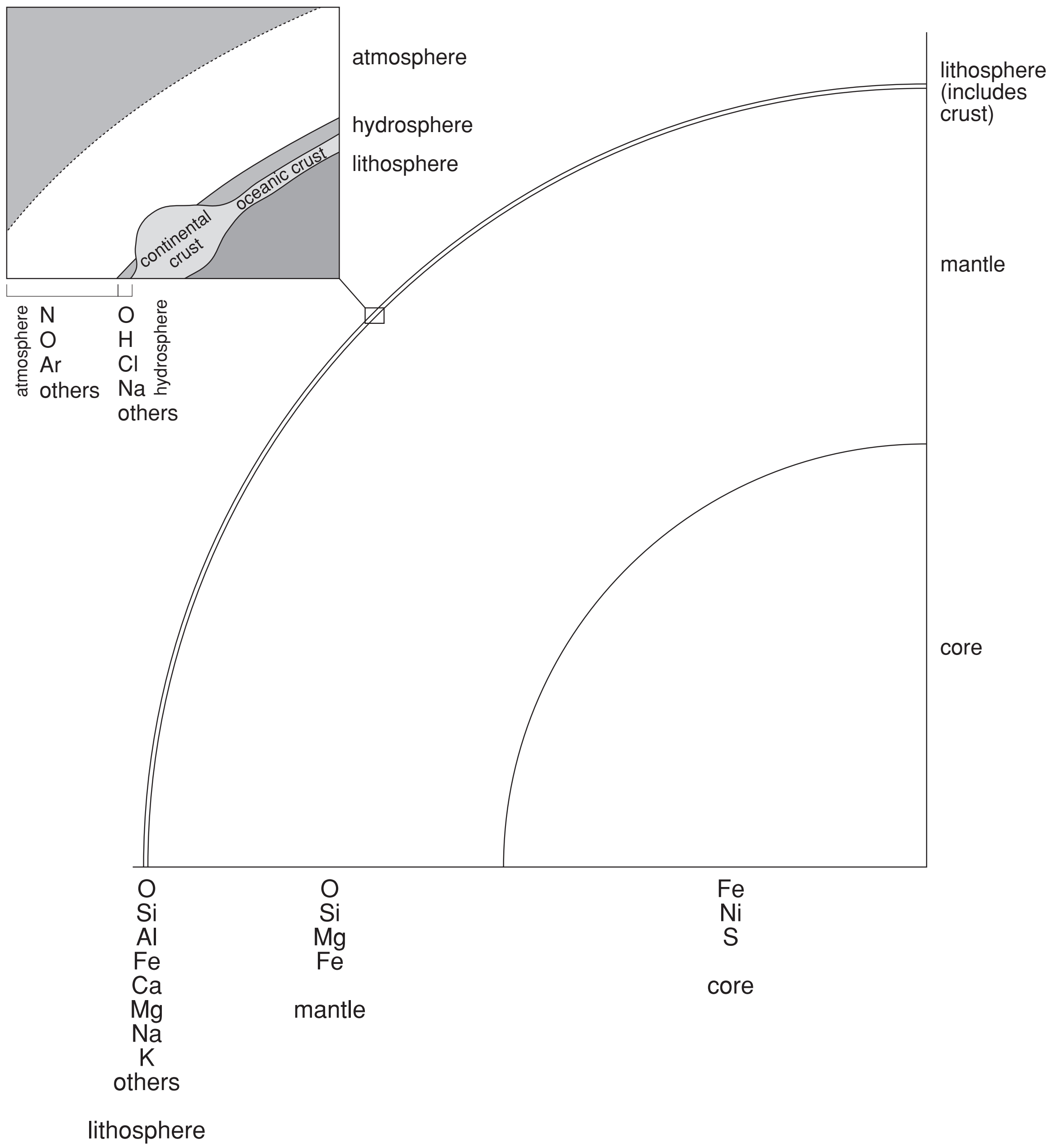
The chemical earth

Part 2: Elements



Incorporating October 2002 AMENDMENTS



atmosphere
hydrosphere
lithosphere
continental crust
oceanic crust
atmosphere
N
O
Ar
others
hydrosphere
O
H
Cl
Na
others
lithosphere (includes crust)
mantle
core
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mantle
Fe
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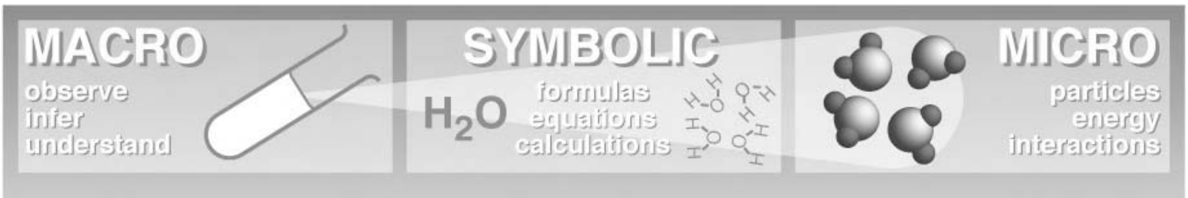
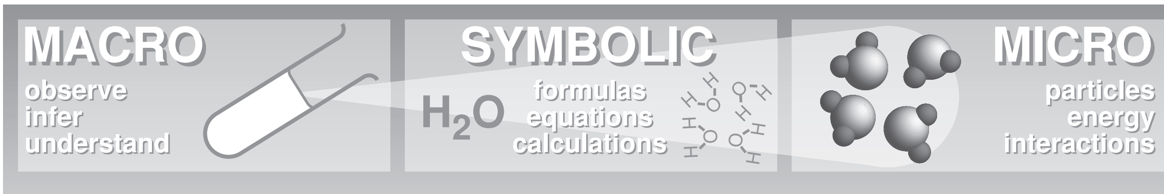
S
core


MACRO
observe
infer
understand
SYMBOLIC
H_2O
formulas
equations
calculations
MICRO
particles
energy
interactions

Contents



Introduction

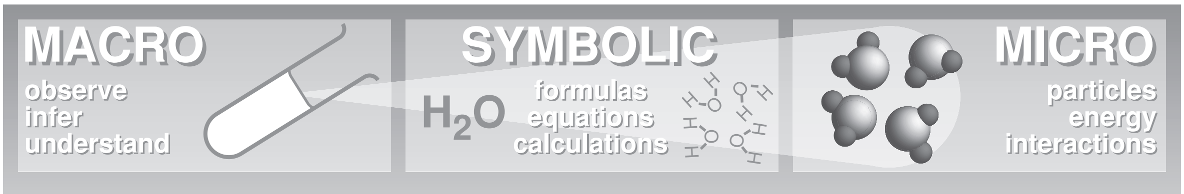
Although most elements are found in combinations on Earth, some elements are found uncombined.

In Part 2 you will be given opportunities to learn to:

- explain the relationship between the reactivity of an element and the likelihood of its existing as an uncombined element
- classify elements as metals, non-metals and semi-metals according to their physical properties
- account for the uses of metals and non-metals in terms of their physical properties.

In Part 2 you will be given opportunities to:

- plan and perform an investigation to examine some physical properties, including malleability, hardness and electrical conductivity, and some uses of a range of common elements to present information about the classification of elements as metals, non-metals or semi-metals
- analyse information from secondary sources to distinguish the physical properties of metals and non-metals
- process information from secondary sources and use a Periodic Table to present information about the classification of elements as:
  - metals, non-metals and semi-metals
  - solids, liquids and gases at 25˚C and normal atmospheric pressure.



Reactivity of elements

Elements that react readily with other elements are said to be **reactive** or show high activity. These elements are never found in nature as the pure element because they readily react with their surroundings to form compounds.

Examples of reactive elements are found in:

- the first column of the Periodic Table below hydrogen H.

  This group is known as the alkali metals and consists of lithium Li, sodium Na, potassium K and so on.

- the second last column of the Periodic Table.

  This group is known as the halogens (meaning salt-producers because they are found in many salts) and consists of fluorine F, chlorine Cl, bromine Br and so on.

Other elements are of such low reactivity that they are mostly found in nature as the pure element. The elements of lowest reactivity are found in the last column of the Periodic Table. This group is known as the noble gases and consists of helium He, neon Ne, argon Ar, krypton Kr, xenon Xe and radon Rn. Elements like these that do not react are called **inert**.

Another part of the Periodic Table where you can see elements that are found uncombined is in the middle part containing the precious metals gold Au, platinum Pt, palladium Pd, iridium Ir, rhodium Rh, osmium Os and ruthenium Ru.

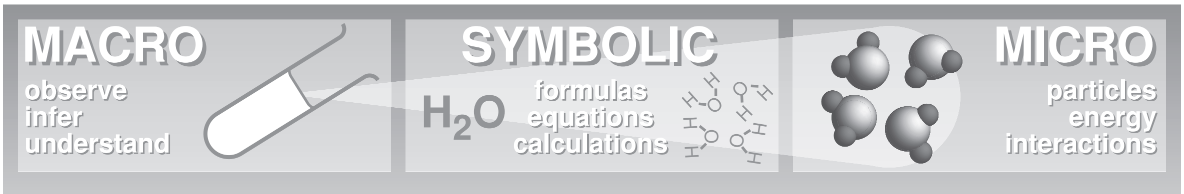
The Periodic Table can be divided into eighteen columns, called **groups**, and a number of rows, called **periods**. The elements in a group have similar chemical properties.

Note that the 18 groups are numbered from the left hand side.

Using coloured pencils colour and label the groups listed below on the Periodic Table shown on the next page. You might like to use so-called hot or active colours (red, orange) for reactive elements and so-called cool or inactive colours (blue, violet) for the less active:

- the reactive alkali metal group (group 1)
- the reactive halogen group (group 17)
- the inert noble gas group (group 18)
- the inert precious metal part.

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		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra																



Investigating physical properties

In the previous activity you saw periodic table patterns of reactivity, a chemical property of elements.

In this section you are going to learn about physical properties of solid elements:

- **malleability** – the ability to be shaped without breaking. Some solids, like soft metals, can be extended by hammering or rolling.

  A solid is malleable if it can be found in many different shapes. If you want to investigate how easily a solid can be shaped make sure you wear safety glasses, hammer gently and carefully.

- **ductility** – the ability to be drawn into a wire without breaking, is used by scientists who wish to make accurate quantitative measurements.

  Although the degree of malleability can be measured by the thinness of the foil or leaf produced malleability or malleable is usually used as a qualitative description rather than a quantitative measurement.

  Brittle is the term used to describe materials that crack or break easily when deformed.

- **hardness** – the ability to resist applied pressure.

  This property can be estimated on a ten-point scale ranging from 1 for talc (a soft mineral used in talcum powder) to 10 for diamond (the hardest natural substance).

  The table on the next page can help you decide on the hardness of the solids.

- Electrical **conductivity** – the ability to allow passage of an electric current. If you have access to an electrical multimeter you can get a measure of conductivity by using the conductivity/continuity setting or the **resistance** (marked **ohms**) setting. If a solid is a good conductor then the conductivity/continuity setting will make a sound or give a reading when the solid is between the probes.

Resistance is the **reciprocal** of conductivity. If you test a good conductor the resistance reading will be zero or very low. If you test a poor conductor the resistance reading will be very high. A **semiconductor** will give an intermediate conductivity reading.

Hardness scale	Standard mineral	Use of common article
1	talc	easily scratched by fingernail
2	gypsum	just scratched by fingernail
3	calcite	just scratched by copper coin
4	fluorite	scratched by iron nail
5	apatite	scratched by ordinary knife
6	orthoclase	scratched by hardened steel knife
7	quartz	hard to estimate hardness using common materials
8	topaz	
9	sapphire	
10	diamond	

The hardness scale for minerals.

Elements which show three or four of these physical properties (malleability, ductility, hardness, electrical conductivity) could be called metals.

Elements which show none or only one of these physical properties could be called non-metals.

Elements intermediate in properties between metals and non-metals are called **semi-metals** and are important in the electronic industry as semi-conductors.

Now you will collect some samples of common elements and examine them.

After you have collected some samples of solid elements plan how you will safely investigate malleability, hardness and electrical conductivity. Only then should you go ahead with this activity.

You will need to find some samples of solid elements. Some possibilities are listed in the table that follows.

Element	**Symbol**	**Uses**
aluminium	Al	Foil in kitchen, window frames, ladders, some saucepans
carbon	C	charcoal or graphite in so-called ‘lead’ pencils
copper	Cu	copper water pipes, inside of electrical wires
iron	Fe	iron nails, roofing material
lead	Pb	lead shot, lead sinkers, lead foil for roof flashing
magnesium	Mg	some metal pencil sharpeners, ‘mag’ alloy wheels
sulfur	S	added to soil to reduce alkalinity; from plant nurseries
silicon	Si	electronic components such as diodes or silicon chips (cut the diode in half at right angles to connecting wires)

Note the different forms of silicon and silicon containing substances:

Silicon is the element (Si).

- Silica is the compound (SiO_2) silicon dioxide, commonly found as sand grains.
- Silicones are **synthetic** compounds used in water-repellent greases, sealants and rubbers.
- Silicates are natural minerals containing metals, silicon and oxygen.

Which of the elements that you examined would you call:

i) metals ____

ii) non-metals ____

iii) semi-metals? ____

Classifying elements

The Periodic Table below shows some shading. The shaded elements have properties between those of metals and non-metals. These elements are called semi-metals.

Divide the metals and non-metals by drawing a thick line between B and Al, then Al and Si. Continue the thick line diagonally in step fashion to separate metals and non-metals.

Below are some contrasts in physical properties. Select the descriptions below that apply to metals. Write these under the side of the periodic table where you find the metals.

high electrical conductivity	OR	low electrical conductivity
hard and malleable	OR	soft and brittle
shiny surface	OR	dull surface
high heat conductivity	OR	low heat conductivity
higher density	OR	lower density

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		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra																

Two other elements (both in the second bottom row) are sometimes considered semi-metals. Predict these two other semi-metals, check your answers, then shade them in the periodic table above.

Standards and science

Physical properties are usually measured at a fixed temperature and a standard pressure so that scientists can confirm the measurements of other scientists.

The fixed temperature most commonly used is 25°C (= 298K) because this is a comfortable and easily controlled temperature for humans doing laboratory work.

The pressure most used is normal atmospheric pressure at sea level.

This is equal to:

1.00×10^5 pascal = 1.00×10^5 Pa = 100 kilopascal = 100 kPa

You may have noticed that air pressure in weather maps and on radio and TV broadcasts is measured in hectopascals (hPa). Atmospheric pressure is usually about 1000 hPa which is the same as 100 kPa.

25°C (= 298K) and 1 atmosphere (100 kPa) pressure are most commonly used for measurement of physical properties in laboratories.

The word standard is used in scientific work in another way.

The standards of science establish practices that help ensure that scientific work is **valid** (leading to effective results and worthwhile conclusions) and **reliable** (trustworthy with results able to be repeated).

A very important part of your chemistry course is developing the ability to judge the validity and reliability of data (information). This applies to data you have gathered from first-hand investigations and data you have been given from secondary sources such as these notes. If you find something in these notes that you think is not valid or reliable please contact your teacher for discussion. This can help your learning, your teacher to help you and also help future students of this course.

There is a widespread perception that science has certain moral and social standards. These standards have been summarised using the acronym CUDOS by John Ziman, an English physicist and ethicist. [Australasian Science magazine March 1999]

- Communality. Scientific knowledge is public knowledge because, in part, it is conducted collaboratively as a social enterprise by the scientific community.
- Universality. Scientific reports should be objective and impersonal. The race, nationality, class or personal characteristics of an individual scientist are irrelevant to the science he or she does

- Disinterestedness. Scientists should be motivated by the search for truth and not be biased by thoughts of personal and financial advancement
- Originality. Science makes progress because researchers enjoy the academic freedom to choose for themselves their research studies and techniques
- Scepticism. Scientific claims must be subjected to open scrutiny by a process of public verification.

Examine the Periodic Table below that shows:

- melting points in °C
- boiling points in °C at normal atmospheric pressure.

-259					**Key:**	**MP**											-272
-253						**BP**											-269
180	1278											2300	3974	-210	-219	-220	-249
1342	2471											3660	3930	-196	-183	-188	-246
98	650											660	1410	44	113	-101	-189
883	1110											2467	3267	280	445	-34	-186
63	842	1538	1660	1910	1857	1244	1535	1495	1455	1085	420	30	937		217	-7	-157
760	1484	2730	3287	3407	2672	2095	2750	2870	2730	2572	907	2403	2830	s613	685	59	-152
39	769	1522	1852	2468	2610	2157	2310	1964	1554	962	321	157	232	631	450	114	-112
686	1384	3338	4377	4758	5560	4880	4150	3695	2970	2212	767	2080	2602	1635	990	184	-108
28	725		2233	3000	3410	3180	3045	2450	1772	1064	-39	303	327	271	254	302	-71
669	1640		4450	5534	5660	5630	5000	4500	3825	2808	357	1457	1740	1560	962	335	-62
27	700																
680	1737																

920	795	935	1024	1042	1072	826	1313	1360	1410	1472	1529	1545	824	1663
3470	3433	3510	3074	2730	1791	1596	3273	3230	2567	2694	2900	1950	1194	3402

1050	1750	1572	1135	637	640									
3200	4788	4000	3818	3900	3230									

Now answer these questions.

1 Can you name the only two elements that are liquids at 25°C and 100 kPa? (Hint: one is a metal used in some thermometers; the other is a non-metal.)

____

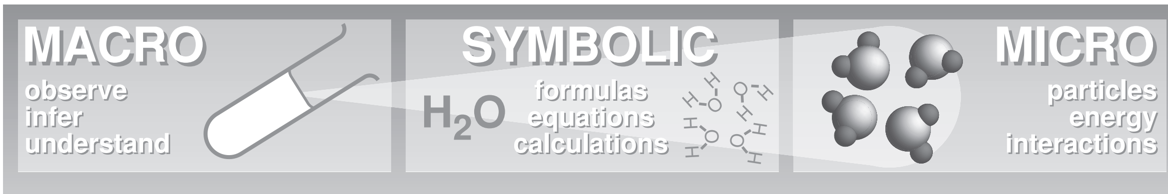
2 Which group (vertical column) consists of gases only? __________

3 Which group consists of metals with low MPs? ________________

4 One of the elements does not have a melting point listed because this element sublimes, that is, changes directly from solid to gas without going through a liquid phase. Can you name this element? _______

5 Another element in the second row sublimes. Its MP is higher than its BP. Name the element. ________________________________

Check your answers.



Atoms and molecules

The symbol that we use for an element can also be used to represent a single atom of that element. For example O is often used as ‘shorthand’ for the element oxygen, but really represents a single atom of oxygen.

Most elements consist of single atoms and can be represented by just their symbol. However some elements consist of atoms joined together as molecules.

Oxygen at ground level in the atmosphere is always represented as O_2 because its atoms are always paired together in a diatomic molecule.

Elements which should be written as diatomic molecules are:

H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2 and At_2.

1 Where can these elements be found in the Periodic Table? Are they metals or non-metals?____

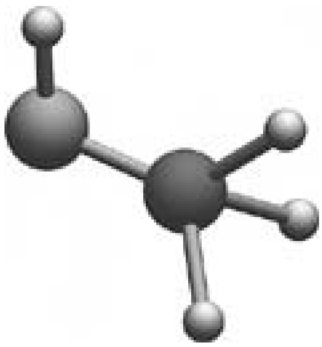
2 How many of these elements can you name without looking at a periodic table? ____

3 Can you name them all after looking at a periodic table? ________

Molecules can be made up of the same type of atom (such as O_3, an element) or different types of atom (such as H_2O, a compound).

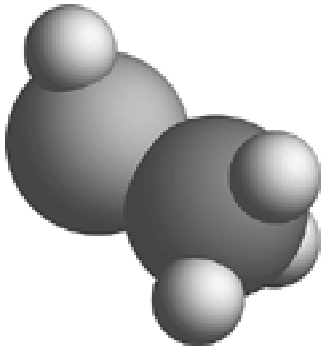
In diagrams we can represent single atoms as circles 2-dimensionally (2D) or as spheres using 3-dimensional (3D) effects.

When drawing molecules atoms can be shown joined by a ‘stick’ in a ball and stick model.



Ball and stick model of a molecule.

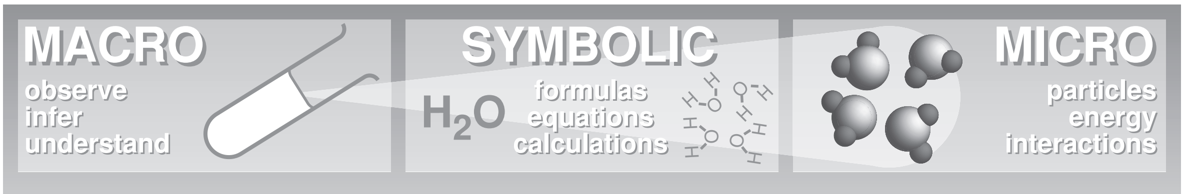
Atoms can also be shown joined together by partly merging in a space-filled model.



A space-filled model of a molecule.

Both these types of diagrams will be used throughout this course.

Now do all the exercises on the next pages and return them to your teacher unless you have been told to do otherwise.



Suggested answers

Classifying elements

Po, polonium, and At, astatine, are sometimes considered to be semi-metals. These two elements are available in such small amounts that few chemists have seen them or carried out experimental work with them.

Standards and science

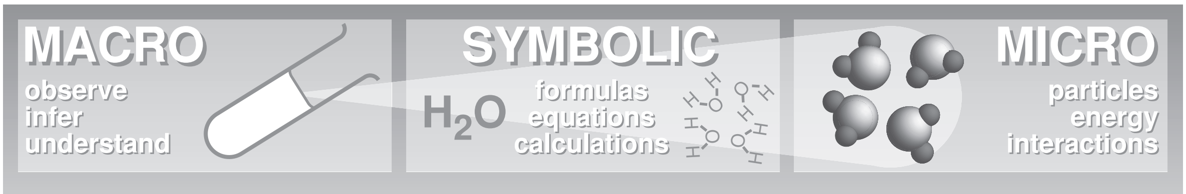
1 mercury and bromine

2 the last group (far right hand column) – the noble gases

3 the first group (far left hand column) below hydrogen – the alkali metals

4 arsenic

5 carbon



Exercises - Part 2

Exercises 2.1 to 2.5 Name: ________________________________

Exercise 2.1: Using a spreadsheet to visualise data

In this exercise you will:

- recall some relationships between elements using the Periodic Table
- have hand-on use of computer simulations for modelling or manipulating data
- extract and reorganise information in the form of diagrams
- work individually and in teams.

Do you have access to a computer with a spreadsheet program? If you don't, try to find someone who does and is willing to let you use the computer and **spreadsheet** program. Hopefully that person will help you use their computer and give you experience working with them as part of a team.

This exercise will not give you detailed directions. You will be provided with a general plan and it is left up to you to see what can be accomplished.

1. Access the spreadsheet program
2. Using the layout of the periodic table showing melting points and boiling points, enter melting point values into cells for:
   - the first column (H and the alkali metals)
   - the second column (known as the alkaline earth metals)
   - the second row (from Li to Ne)
   - the second last column (the halogens)
   - the last column (the noble gases).
3. Make sure you have used the layout of the periodic table supplied by leaving some cells empty.

3 Make sure you have used the layout of the periodic table supplied by leaving some cells empty.

4 Save the spreadsheet you have made so far.

5 Highlight (darken on the screen) a rectangular shape that includes all the information you have entered into the spreadsheet.

6 Go to the chart producing icon (called ChartWizard in Excel spreadsheet).

6 Choose a 3-D column chart with cylindrical shape eg Chart Type cylinder, Chart sub-type 3-D column.

7 Try to label your chart using the spreadsheet program.

8 Print out a copy of your spreadsheet.

9 If you are happy with your spreadsheet save the chart then print out a copy to send-in to your teacher.

Exercise 2.2: Common element symbols and names

The Periodic Table below has the symbols for the elements that you will study most in your chemistry course. You can save yourself considerable time in the future by learning the names of the elements that go with the symbols.

H																	He
Li													C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca			V	Cr	Mn	Fe			Cu	Zn					Br	
	Sr									Ag			Sn			I	
	Ba										Hg		Pb				

La														
Ac			U											

Write the name of each element shown under its symbol.

Exercise 2.3: Uses and properties of elements

Here is a list of some of the physical properties you have studied so far:

- density
- melting point
- boiling point
- colour
- malleability
- hardness
- electrical conductivity.

Which property would you consider to be the most important in making:

a) jewellery

____

b) electrical wiring

____

c) electrical insulators

____

d) a sculpture

____

e) a light weight structure

____

f) a kiln

____

g) a hammer?

____

Don’t forget to explain your choices.

Exercise 2.4: Physical states

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

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

Ac	Th	Pa	U	Np	Pu									

Physical states of elements at room temperature and pressure
liquid state = *l*, gaseous state = *g*, all other elements are solids

a) Using coloured pencils colour in the gaseous elements in one colour and the liquid elements in a different colour. Leave the solid elements uncoloured.

   i How many gaseous elements are there? ___________________

   ii Name the only liquid metal. ____________________________

   iii Name the only liquid non-metal _________________________

   iv If new elements with atomic numbers 113, 115 and 117 were made would you expect them to be solid, liquid or gas? Explain how you reached your conclusions.

   ____

   ____

Exercise 2.5: Classification of forms of elements

Using ten different coloured pencils colour the key and elements to show ten different forms in which elements are separated from the Earth.

Key: ❑ free = uncombined element, ❑ Carb = carbonate, ❑ Chl = chloride,
❑ Hyd = hydride, ❑ Ox = oxide, ❑ Phos = phosphate,
❑ sea = seawater, ❑ Sil = silicate, ❑ Side = sulfide, ❑ Sate = sulfate

H Ox																	He free
Li Carb Sil	Be Sil											B Ox	C Hyd Ox	N free	O free	F as CaF_2	Ne free
Na Chl	Mg Carb											Al Ox	Si Ox	P Ox	S Side	Cl sea	Ar free
K Chl	Ca Carb Sate	Sc Sil	Ti Ox	V Ox	Cr Ox	Mn Ox	Fe Ox	Co Side	Ni Side Sil	Cu Side Carb	Zn Side Carb	Ga Side	Ge Side	As Side	Se Side	Br sea	Kr free
Rb Sil	Sr Carb Sate	Y Phos	Zr Sil Ox	Nb Ox	Mo Side	Tc -	Ru free	Rh free	Pd free	Ag Side	Cd Side	In Side	Sn Ox	Sb Side	Te Ox	I sea	Xe free
Cs Sil	Ba Sate		Hf Sil	Ta Ox	W Ox	Re Side	Os free	Ir free	Pt free	Au free	Hg Side	Tl Side	Pb Side	Bi Side	Po -	At -	Rn free
Fr -	Ra -																

Does your colouring show any trends or patterns in the Periodic Table?

____

In your own words describe three trends or patterns.

____

____

____

Chemistry
Preliminary Course
Stage 6

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING
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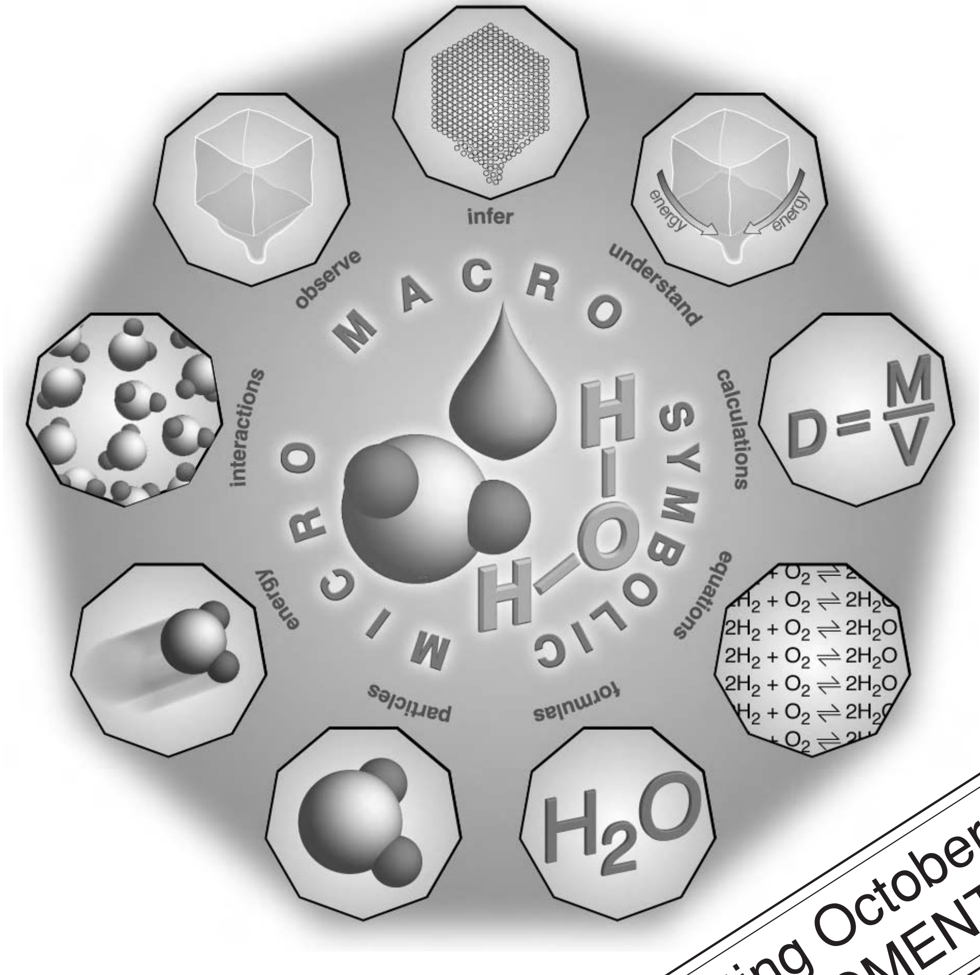
The chemical earth

Part 3: Compounds



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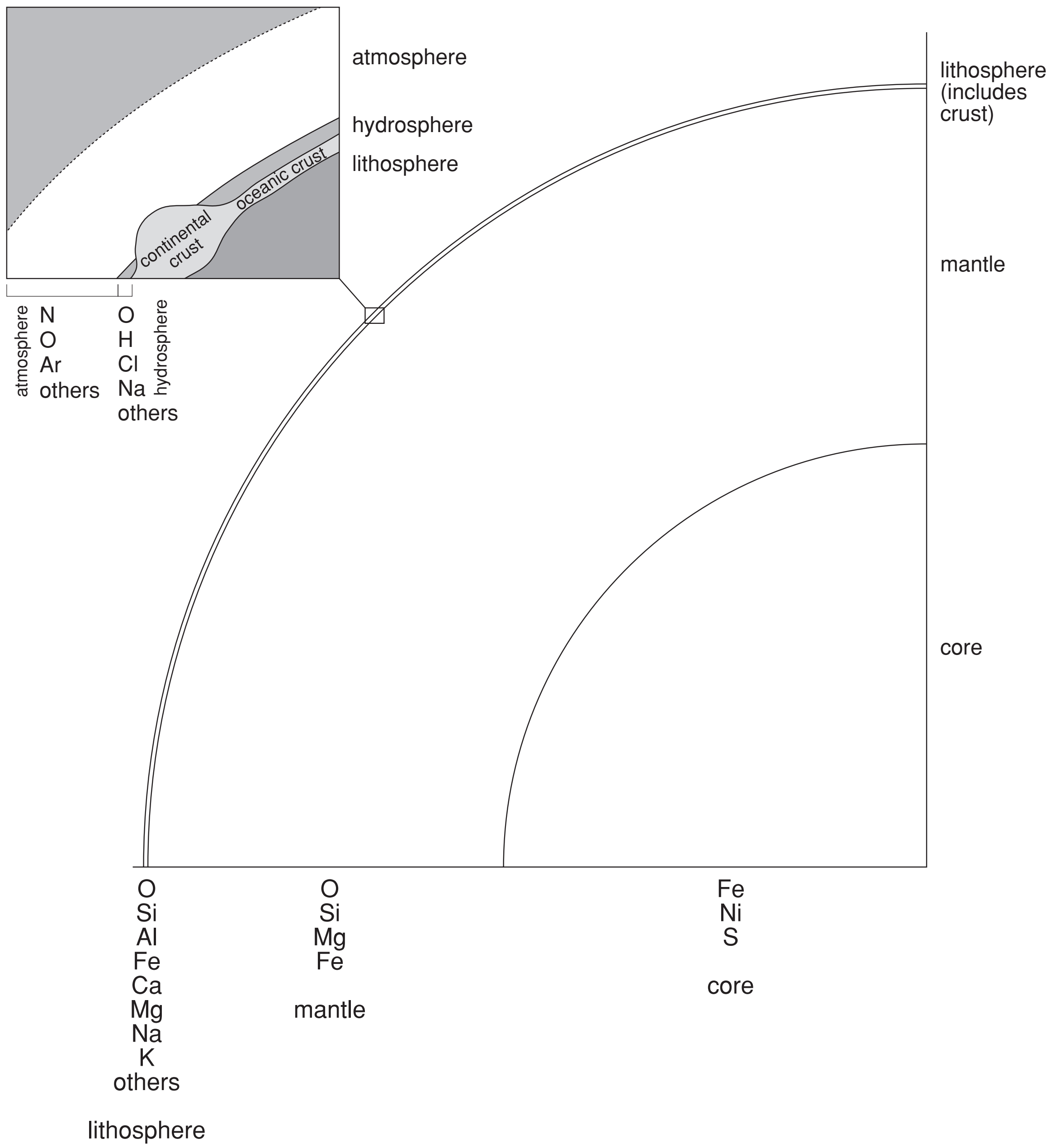
AMENDMENTS


atmosphere
hydrosphere
lithosphere
oceanic crust
continental crust
atmosphere
N
O
Ar
others
O
H
Cl
Na
others
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mantle
core
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Fe
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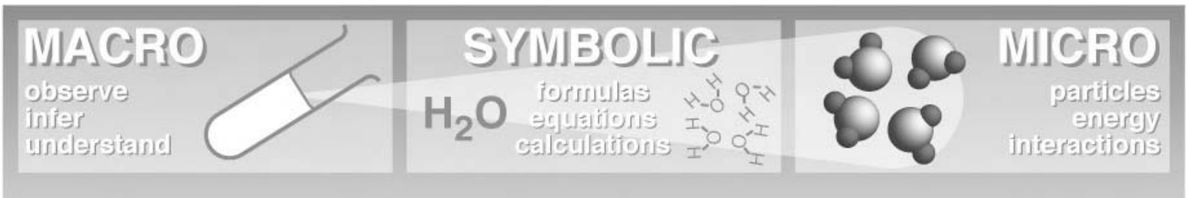
core


MACRO
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SYMBOLIC
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MICRO
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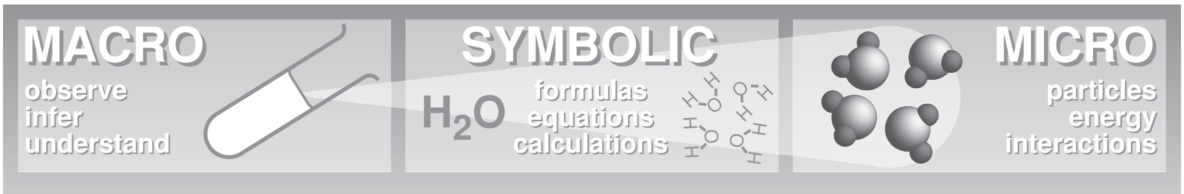
energy
interactions

Contents



Introduction

In the first part of this module *The chemical earth* you learnt that matter is made up of particles. To picture, that is, visualise matter you used the particle theory model. This model uses things you are familiar with such as balls to represent things that are too small, too big or too difficult to see. Tick the features of the particle theory model that you remember:

In the solid state particles vibrate about fixed positions. ❑

In the liquid state particles move over one another freely. ❑

In the gaseous state particles move at high speed. ❑

In the second part of the module you learnt about atoms and molecules and the interactions or forces between them. Tick what you remember:

Atoms were the smallest particles studied. ❑

Molecules are made up of atoms joined together eg. H_2, H_2O. ❑

Atoms and molecules which significantly interact are found as solids. ❑

Weak interactions between particles produce gas or liquid at room temperature. ❑

In this third part you are going to learn about the subatomic structure of atoms, that is, what makes up atoms. This will help you understand how atoms interact strongly through their outer electrons to join together. You will also be able to use these strong interactions at the atomic level called bonds to explain why elements on Earth are usually present as compounds rather than free elements.

In Part 3 you will be given opportunities to learn to:

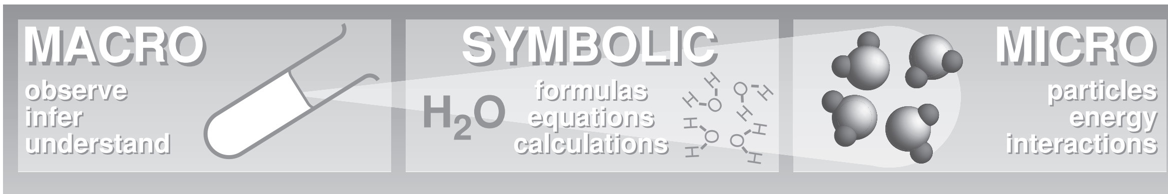
- identify that matter is made of particles that are continuously moving and interacting
- describe qualitatively the energy levels of electrons in atoms

- describe atoms in terms of mass number and atomic number
- describe the formation of ions in terms of atoms gaining or losing electrons
- apply the Periodic Table to predict the ions formed by atoms of metals and non-metals
- apply Lewis electron dot structures to:
  - the formation of ions
  - the electron sharing in some simple molecules
- describe the formation of ionic compounds in terms of the attraction of ions of opposite charge
- explain why the formula for an ionic compound is empirical
- describe molecules as particles which can move independently of each other
- distinguish between molecules containing one atom (the noble gases) and molecules with more than one atom
- describe the formation of covalent molecules in terms of sharing of electrons

  construct formulae for compounds formed from
  - ions
  - atoms sharing electrons.

In Part 3 you will be given opportunities to:

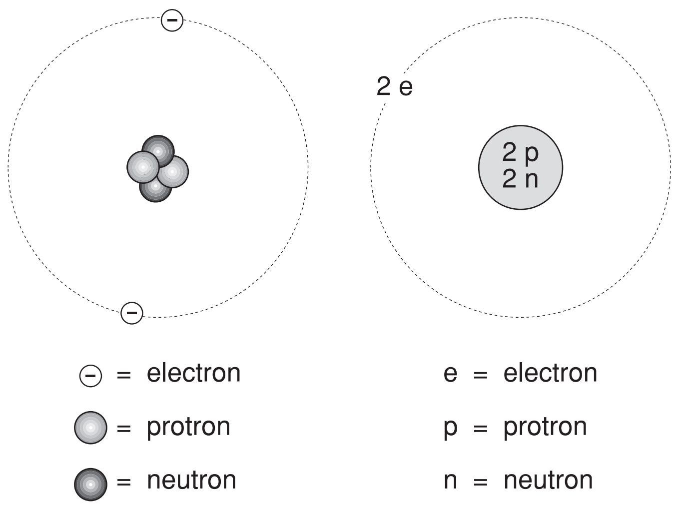
- analyse information by constructing or using models showing the structure of metals, ionic compounds and covalent compounds
- construct ionic equations showing metal and non-metal atoms forming ions.



Atomic structure

In chemistry three subatomic particles – the **electron**, the **proton** and the **neutron** – are used to represent (ie model) atomic structure. The distribution of electrons in the outer layer or shell of atoms is used to explain how atoms join together. The table below presents information about subatomic particles.

Subatomic particle	Abbreviation	Charge	Mass (kg)	Comparative mass
electron	e	-1	9.1×10^{-31}	0.0005
proton	p	+1	1.7×10^{-27}	1
neutron	n	0	1.7×10^{-27}	1



Two different ways of representing the same atom.

Atomic number and mass number

The diagrams on the previous page show that the core of an atom, called the **nucleus**, contains neutrons and protons.

Examine the periodic table outline below which shows atomic numbers. Can you see a pattern in the numbers? The **atomic number** of an atom is equal to the number of protons in the nucleus.

1																	2
3	4											5	6	7	8	9	10
11	12											13	14	15	16	17	18
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
55	56		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
87	88																

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71

89	90	91	92	93	94									

Try filling in the remaining atomic numbers from 95 to 118. Compare your effort with the comprehensive Periodic Table provided in Part 1 of this module.

Another term that can be used to describe an atom is the **mass number**. The mass number of an atom is equal to the total number of protons and neutrons in the nucleus. The element chlorine is a mixture of atoms with mass numbers 35 and 37. A chlorine-37 atom has two more neutrons than a chlorine-35 atom.

What is the atomic number and mass number for the atom shown in the diagrams on the previous page?

Energy levels of electrons in atoms

The atomic number is equal to the total number of electrons outside the nucleus in a neutral atom. That is, the total number of negative electrons in shells equals the total number of positive protons in the nucleus so that the whole atom is electrically neutral.

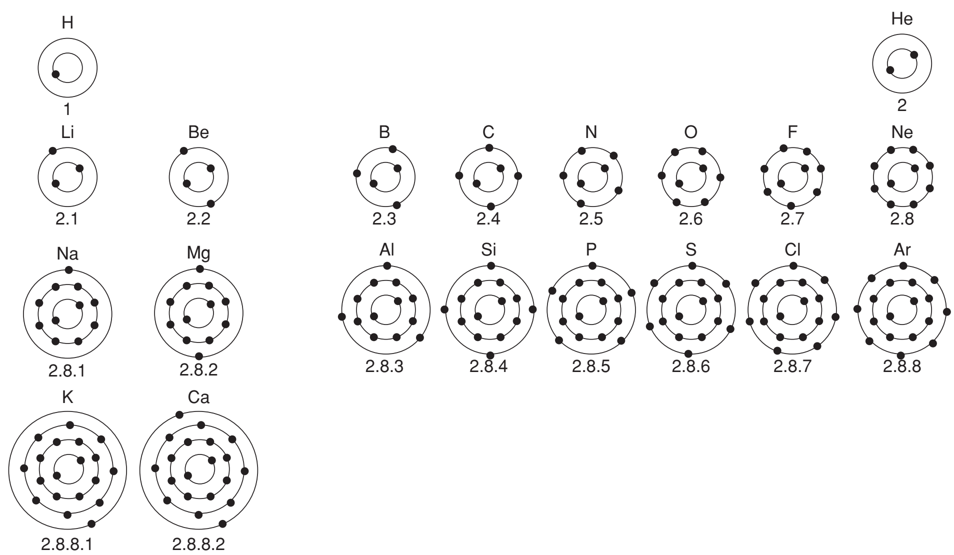
The negative electrons are outside the nucleus in layers called shells. The atom shown in the diagram on page 5 has only one shell containing two electrons.

Electrons fill the shells closest to the nucleus first. The closer to the nucleus a shell is, the lower its energy level. The shell closest to the nucleus can hold a maximum of two electrons. The second shell out from the nucleus can hold a maximum of eight electrons.

Can you see a connection between the number of electrons in a shell and the number of elements in the top two horizontal rows (periods) of the periodic table?

The arrangement of the elements into a periodic table like the one that you use was worked out in the 1870s by a Russian scientist Dmitri Mendeleev. Mendeleev used the patterns he found in the chemical properties of elements to arrange the elements in the format that we use.

In 1913 the work of the Danish scientist Neils Bohr helped scientists understand the arrangement of electrons in shells. The arrangement of electrons in the outer layers of an atom determines the chemical properties of its element. Thus the periodic table arrangement of elements is determined by the arrangement of electrons in atoms.

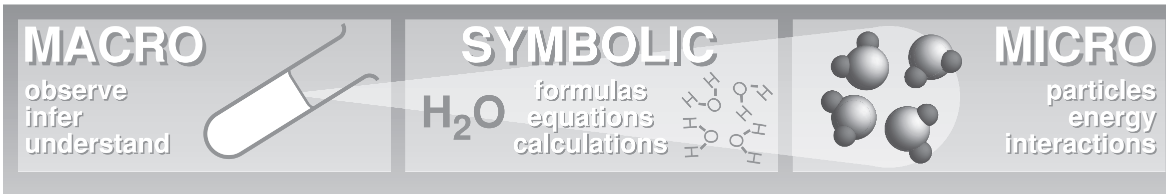


Arrangement of electrons in the first twenty elements

The 2.8.8.1 **electron configuration** of a potassium atom shows:

- 2 electrons in the first shell (the shell closest to the nucleus)
- 8 electrons in the second shell
- 8 electrons in the third shell
- 1 electron in the fourth shell.

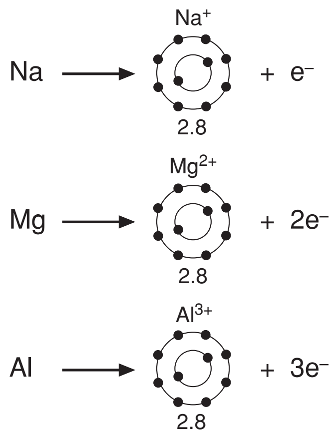
Later you will see how the number of electrons in the outermost, highest energy shell – known as the **valence shell** (also spelt as **valency shell**) – determines interactions between atoms at the atomic level.



Formation of ions

An atom is electrically neutral. If an atom loses one or more negative electrons there will be more protons than electrons and a positively charged ion is formed. Ions are electrically charged particles.

These diagrams show changes in the electron shells when sodium, magnesium and aluminium metal atoms react with oxygen gas in air. These metal atoms lose electrons and form positive ions.



Periodic table trends

If the reactions of these metals with oxygen are carried out in a laboratory:

- sodium reacts with oxygen in a matter of seconds,
- a piece of magnesium needs to be heated by a flame first,
- while aluminium to react needs to be finely divided particles strongly heated by a flame.

Note that as you move across a period from sodium to magnesium to aluminium the reactivity of the metals decreases.

This is known as a periodic table trend. The periodic table is very useful for summarising trends in chemical properties.

This trend in chemical properties can be related to the amount of energy required to remove:

- one electron from a sodium atom
- two electrons from a magnesium atom
- three electrons from an aluminium atom.

But why does sodium form an ion with a charge of +1, magnesium an ion with a charge of +2 and aluminium an ion with a charge of +3?

1 Write down the number of electrons in the outer shell of each of these ions.

   a) sodium____

   b) magnesium _______________________________________

   c) aluminium____

2 This number of electrons in the outer shell of an atom or an ion is a very stable, that is low energy, arrangement.

   Which group (vertical column) of elements in the periodic table consists of atoms that are unreactive, not even joining with identical atoms to form molecules? (Hint: they are all gases.)____________

3 Apart from the top member of this group, helium, how many electrons are in the outer shell of each of these elements? ________

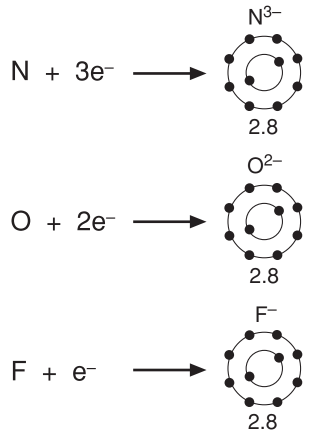
4 Eight electrons in the outer shell is a very stable arrangement of electrons. This is sometimes called the noble gas or inert gas electron configuration. The idea that eight electrons is a very stable arrangement is called the octet rule. What number does octet remind you of?____

Check your answers.

By losing electrons(s) metal atoms change into ions with eight electrons in their outer shell.

Note: For the first four elements of the periodic table – hydrogen, helium, lithium and beryllium – the most stable arrangement of electrons is two in the outer shell. This is because the first electron shell can only hold two electrons.

The diagrams following show changes in electrons shells when nitrogen, oxygen and fluorine atoms change into negative ions during reaction with magnesium metal.

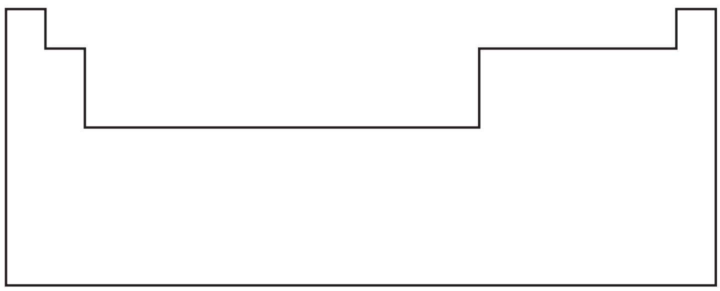


Consider the reactions of these three gases with magnesium.

- Magnesium requires a very high temperature before it will react with nitrogen.
- Magnesium can react with oxygen in the air when heated with a match flame.
- Magnesium reacts quickly with fluorine at room temperature.

Can you see a trend in chemical reactivity of these non-metals across the period? Moving across a period from left to right the metals become less reactive but the non-metals become more reactive!

1 Can you summarise these trends by using arrows and simple labels on this outline of the main part of the periodic table?



2 Why does nitrogen form an ion with a charge of -3, oxygen an ion with a charge of -2 and fluorine an ion with a charge of -1? Use the phrase ‘gaining electrons’ in your answer.

____

____

____

Check your answers.

Predicting ions formed by atoms

Look at the ions formed from the metals sodium, magnesium and aluminium. What do they have in common? Did you notice they are all positive ions?

Metal atoms have a small number of electrons in their outer shell. The easiest way for metal atoms to achieve an outer shell of eight electrons (or two in the case of lithium metal and beryllium metal) is to lose the small number of electrons in their outer shell. In doing this the metal atoms change to positive ions.

metal atom	$\rightarrow$	positive ion	+ electron(s)
Na	$\rightarrow$	Na^+	+ e^-
Mg	$\rightarrow$	Mg^{2+}	+ $2e^-$
Al	$\rightarrow$	Al^{3+}	+ $3e^-$

Look at the ions formed from the non-metals nitrogen, oxygen and fluorine – they are all negative ions.

Non-metal atoms have a number of electrons in their outer shell less than but close to eight. The easiest way for non-metal atoms to achieve an outer shell of eight electrons is to gain the number of electrons needed.

Thus when non-metal atoms form ions they form negative ions. (The only exception to this is the smallest atom, hydrogen, which has the ability to form positive hydrogen ions H^+ as well as negative hydride ions H^-).

non-metal atom	+ electron(s)	$\rightarrow$	negative ion
N	+ $3e^-$	$\rightarrow$	N^{3-}
O	+ $2e^-$	$\rightarrow$	O^{2-}
F	+ e^-	$\rightarrow$	F^-

Negative ions are called **anions** (**a n**egative **ion**). Positive ions are called **cations**.

Lewis electron dot diagrams for ions

The electron shell diagrams we have used to represent atoms and ions can be simplified using ideas developed by the American chemist Gilbert Lewis.

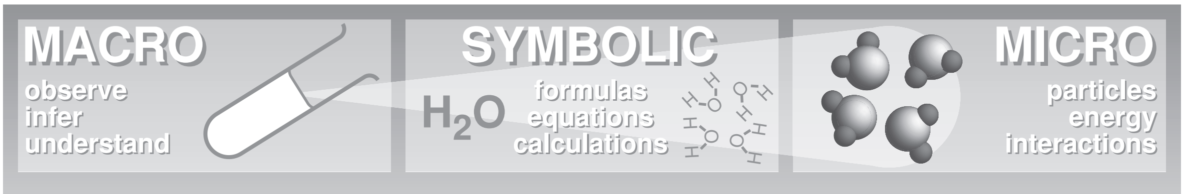
An atom of an element is represented by its symbol and the number of electrons in the outer shell is shown as dots. Instead of dots we will use small circles for electrons in metal atoms and small crosses for electrons in non-metal atoms in our diagrams below.

Use the examples at the beginning of this table to complete all missing parts in the table below.

Atom/ion	**Symbol**	**Electron configuration**	**Lewis electron dot structure**
Sodium atom	Na	2.8.1	Na o
Sodium ion	Na^{+}	2.8	Na^{+}
Magnesium atom	Mg	2.8.2	o Mg o
Magnesium ion	Mg^{2+}	2.8	Mg^{2+}
Aluminium atom	Al	2.8.3	o o Al o
Aluminium ion	Al^{3+}	2.8	Al^{3+}
	N	2.5	$\overset{\times\times}{{}^{\times}_{\times}N^{\times}}$
Nitrogen ion	N^{3-}	2.8	N^{3-}
Oxygen atom		2.6	$\overset{\times\times}{{}^{\times}_{\times}O^{\times}_{\times}}$
Oxide ion	O^{2-}		O^{2-}
Fluorine atom	F		$\underset{\times}{\overset{\times\times}{{}^{\times}_{\times}F^{\times}_{\times}}}$
		2.8	F^{-}

Check your answers.

Note: In chemistry when you are talking about a single ion, that is, an ion, then pause between 'an' and 'ion' as you say 'an ion'. When you are talking about negative ions and using the word anion do not pause between the two parts (syllables) of the word. Say 'anion' as one word.



Formation of compounds

Ionic compounds

Oppositely charged particles attract. When metal atoms react with non-metal atoms the loss of electrons by the metal atoms create positive ions while the gain of electrons by the non-metal atoms create negative ions. A positive metal ion and a negative non-metal ion attract one another strongly.

This strong attraction between oppositely charged ions is called an **ionic bond** and the compound is called an ionic compound.

$$Na + F \longrightarrow Na^{+} + F^{-}$$

Sodium fluoride, NaF, is ionic. MP 993°C

$$Mg + O \longrightarrow Mg^{2+} + O^{2-}$$

Magnesium oxide, MgO, is ionic. MP 2852°

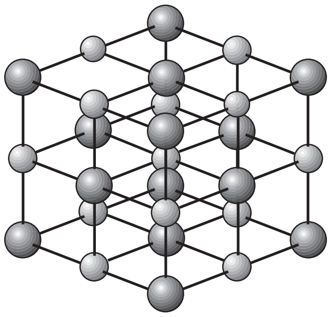
Ionic compounds are solids with high melting points. The MPs are high because a lot of energy is required to overcome the attraction between the oppositely charged ions.

When an atom loses electron(s) to form a positive ion there is a significant decrease in its size. Conversely when an atom gains electron(s) to form a negative ion there is a significant increase in size. These sizes are usually measured in picometres (pm): 1 pm = 10^{-12} m.

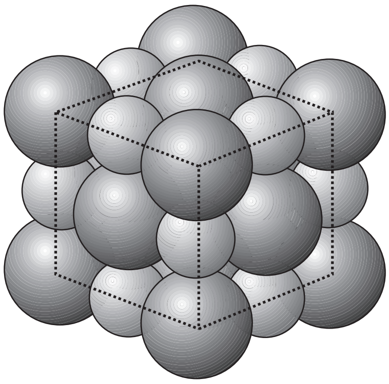
A sodium atom has a radius of 186 pm while a sodium ion radius is 102 pm. A fluorine atom has a radius of 71 pm while a fluoride ion radius is 133 pm.

Label a sodium ion and a chloride ion in each of the diagrams for sodium chloride shown below.

Models for the ionic compound sodium chloride made up of ions with ionic radiuses of 102 pm and 181 pm. (Hint: use the previous information about sodium and fluorine to decide which is the smaller ion with a radius of 102 pm).



Ball and stick model.



Space filled model.

Note that each sodium ion is surrounded by six oppositely charged chloride ions and similarly each chloride ion is surrounded by six oppositely charged sodium ions.

Why an ionic formula is empirical

How do you find out the formula of a compound?

1 Prepare as pure a sample as possible eg. a sample of sodium fluoride.

2 Carry out qualitative analysis of the compound to find out what elements are present in the compound. eg sodium and fluorine.

3 Carry out quantitative analysis to find out how much by weight of each element is present in the compound. eg. 5.5 g of sodium and 4.5 g of fluorine OR 55% sodium and 45% fluorine.

4 Calculate the simplest whole number ratio of particles in the compound.

This requires a knowledge of **atomic weights** of the elements.

Sodium has an atomic weight of 23 while fluorine is lighter with an atomic weight of 19.

Divide the measured weight of each element by its atomic weight to get the ratio of particles.

	sodium	:	fluorine
Weight ratio	55	:	45
Particle ratio	55/23	:	45/19
	= 2.4	:	= 2.4
that is	1	:	1

Because there is one sodium particle to one fluorine particle the formula is NaF.

A formula found this way is known as the empirical formula. Empirical means based on experiment rather than theory.

The formula we write for an ionic compound is always an empirical formula. An empirical formula gives the simplest whole number ratio of particles in the compound.

Look at the models for sodium chloride on the previous page.

1 What is the simplest ratio of sodium:chlorine in these models? ______

2 If the model contained ten times as many particles what would be the simplest ratio?

3 If the model was halved in size what would be the simplest ratio of sodium:chlorine? ______________________________

It doesn't matter how big or small a lump of sodium chloride is the particle ratio of sodium:chlorine = 1:1 and the formula is always NaCl.

Compound formulas

Sprinkle some sodium chloride (table salt) crystals onto your hand.

Did you receive an electric shock? _______

The observation made that you don't get an electric shock is evidence that the salt crystals overall are electrically neutral.

Your observations can be explained by the model that sodium chloride is made up of equal numbers of Na^+ and Cl^- ions. The positive charges balance the negative charges so that each salt crystal is electrically neutral.

Each time chemists want to construct a formula for a compound formed from ions they could carry out steps for determining empirical formula outlined on the previous page.

Constructing chemical formulas

However, rather than carrying out this lengthy macro level procedure chemists developed a shortcut method of constructing formulas.
The chemist's shortcut method uses:

- the micro level interpretation that matter is made up of particles
- the symbolic level representation of ions.

Here is how the chemists' shortcut method works.

Magnesium and fluorine

Suppose an ionic compound is found to contain only magnesium and fluorine elements.

The micro level interpretation of this compound would picture it made up of magnesium ions and fluoride ions. The symbolic representation of these ions is as Mg^{2+} and F^-.

Now if handling magnesium fluoride does not give you an electric shock then the total charge on all the magnesium ions must equal the total charge on all the fluoride ions. Because the charge on Mg^{2+} is twice the charge on F^- twice as many fluoride ions as magnesium ions are needed.

The formula for magnesium fluoride is therefore MgF_2.

Aluminium and oxygen

How would you work out the formula for an ionic compound made up of aluminium and oxygen only?

The Al^{3+} and O^{2-} ions must be in a simple whole number ratio so that the total charge on all the Al^{3+} = total charge on all the O^{2-}. This requires two Al^{3+} (ie six positive charges): three O^{2-} (ie six negative charges).

The formula for aluminium oxide is therefore Al_2O_3.

Trends in ionic charge

Examine the periodic table below which shows the ionic charge for selected elements under the symbol for that element. What is the charge on ions of:

a) Group 1 elements (alkali metals)? ___________________________

b) Group 2 elements (alkaline earth metals)? ____________________

c) non-metal ions in Group 15 (N, P etc)? ______________________

d) non-metal ions in Group 16 (O, S etc)? ______________________

e) non-metal ions of Group 17 (the halogens)?___________________

H +																	He
Li +	Be 2+											B	C	N 3–	O 2–	F –	Ne
Na +	Mg 2+											Al 3+	Si	P 3–	S 2–	Cl –	Ar
K +	Ca 2+	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br –	Kr
Rb +	Sr 2+	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I –	Xe
Cs +	Ba 2+		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At –	Rn
Fr +	Ra 2+																

Check your answer.

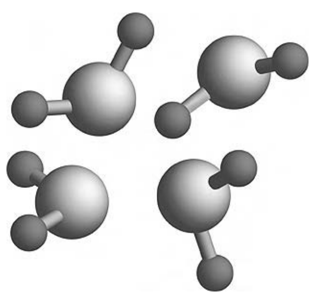
Using your knowledge of ion charges to work out the formulas of ionic compounds, fill in the table below.

Compound name	Ions present	Ion ratio to give neutral charge	Formula
calcium bromide	Ca^{2+} Br^{-}	1: 2	$CaBr_2$
barium oxide	Ba^{2+} O^{2-}		BaO
sodium sulfide		2: 1	Na_2S
magnesium nitride	Mg^{2+} N^{3-}		Mg_3N_2

Molecules

Practically all **molecules** are made up of atoms joined together. The group of atoms making up a molecule moves independently of the identical groups of atoms in nearby molecules.

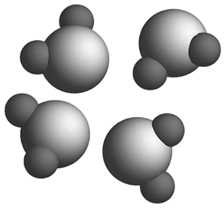
The diagram below shows ball and stick models of water H_2O molecules. The large ball is the oxygen atom, the small balls are hydrogen atoms. The sticks represent the bonds that join the atoms together in a molecule. The bonds are called **covalent bonds**.



Ball and stick model of water molecules.

Molecules made up of atoms joined together by covalent bonds are sometimes called covalent molecules. Covalent reminds us of the type of **bonding** (strong forces of attraction) keeping the atoms together in a molecule.

The idea that outer valence electrons are shared in covalent bonds can be seen in space-filled models which show the outer valence shell layers of joined atoms merging.



Space-filled model of water molecules.

The only molecules to consist of a single atom are the molecules of the noble gases. These molecules are called monatomic. They cannot be called covalent molecules because they do not contain covalent bonds.

The noble gas atoms have eight electrons in their outer shell (or, in the case of helium, two electrons because this number is all that its single shell can hold). As a result of the stability of these electron configurations, noble gas atoms do not join together, and rarely combine with other atoms.

molecules
particles that move
independently of each other

covalent
atoms covalently
bonded together

monatomic
He Ne Ar Kr Xe Rn

Molecules can be covalent or monatomic.

Lewis electron dot diagrams for molecules

In 1916 Gilbert Lewis suggested that atoms react with one another in order to achieve very stable electron configurations like those in noble gas atoms.

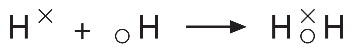
Remember that in ionic compounds:

- metal atoms can lose electrons to form metal ions with noble gas configurations
- non-metal atoms can gain electrons to form ions with noble gas configurations.

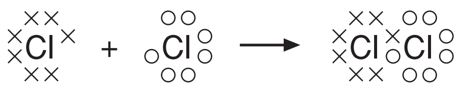
The attraction between these oppositely charged ions is called an ionic bond.

Atoms in covalent molecules are joined by covalent bonds formed by sharing electrons. Sharing of electrons enables the joined atoms to have noble gas electronic configurations.

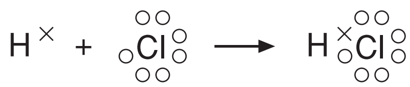
Consider hydrogen gas H_2. Each of the hydrogen atoms has a single electron. By sharing their electrons each hydrogen atom will have two electrons in their first electron shell. This is the stable electron configuration found in the noble gas helium:

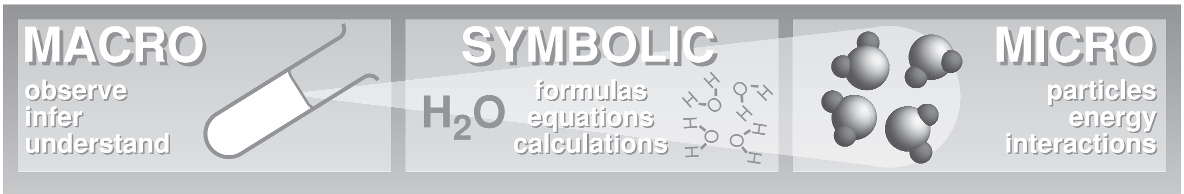


Consider chlorine gas Cl_2. Each chlorine atom has seven electrons in its outer shell. Electrons arrange themselves in pairs. If the unpaired electrons in each chlorine atom are brought together and shared, each chlorine atom now has eight electrons in their outer shell. This is a stable noble gas electron configuration.



Similarly a hydrogen atom and a chlorine atom can both achieve noble gas electron configurations by sharing electrons. This joining by sharing forms a molecule of the compound hydrogen chloride HCl.





Chemical equations

Writing word equations

Answer these examples.

1 When sodium metal is placed in a gas jar containing greenish-yellow chlorine gas immediate reaction occurs filling the inside of the gas jar with a white solid.

What compound would you expect to be formed by reaction between sodium and chlorine? ______________________________

Here is the word equation for this reaction.

sodium + chlorine → sodium chloride

2 If a test tube of hydrogen gas is ignited near where the hydrogen has mixed with oxygen gas from the air a small explosion occurs. The inside of the test tube now has a coating of colourless liquid.

Can you think of a colourless liquid formed from hydrogen and oxygen? ____

Complete the word equation for this reaction.

hydrogen + oxygen → ______________

3 When red mercury oxide is heated the solid decomposes to a silvery liquid and colourless gas. The colourless gas relights a glowing splinter of wood.

Complete the word equation for this reaction.

mercury oxide → __________ + _____________

4 Magnesium metal burns in air releasing bright light and forming a white powdered solid compound.

magnesium + ____________ → ___________

5 When carbon in the form of charcoal is burnt in a limited supply of air some heat is released and a poisonous gas carbon monoxide produced.

_______________ + _____________ → ______________

When the carbon is burnt in a plentiful supply of air more heat is released and carbon dioxide gas is released. Where does solid charcoal go to when it is burnt in a fire?

____________________ + __________________ → ____________________

6 A mixture of hydrogen and chlorine gas reacts rapidly when exposed to sunlight.

____________________ + __________________ → ____________________

Check your answers.

Constructing ionic equations

There are four main steps in constructing an ionic equation:

1 Write the names of reactants on the left hand side and the names of products on the right hand side

An → from the reactants to the products has the same meaning as the word gives. Thus

sodium	+	chlorine	→	sodium chloride
sodium	plus	chlorine	gives	sodium chloride

2 Write the formulas for each reactant and product below each name:

$Na + Cl_2 \rightarrow NaCl$

Metals are always written as the element symbol.

Non-metals are written in molecular form if the molecule consists of two or three atoms. Non-metals made up of larger molecules such as tetra-atomic phosphorus, octa-atomic sulfur and polyatomic (many atoms) carbon are written as single atoms eg. P, S, C.

The formula used for an ionic compound is the empirical formula showing the simplest whole number ratio of particles in the compound.

3 Balance the equation so that you have the same number of each type of atom on both sides. This must be done because in a chemical reaction no atoms are created or destroyed. The atoms are simply rearranged.

$Na + Cl_2 \rightarrow NaCl$

There is not yet balance as there are two chlorines on the left hand side (LHS) and only one chlorine on the right hand side (RHS).

Balance the equation by putting whole numbers, called coefficients, in front of formulas. If two chlorine atoms react one would expect two units of sodium chloride to form as each unit of NaCl contains only one chlorine.

$$Na \quad + \quad Cl_2 \quad \rightarrow \quad 2NaCl$$

Each unit of sodium chloride contains one sodium. With two units of NaCl there are two sodiums on the RHS. Two sodiums are needed on the LHS.

$$2Na \quad + \quad Cl_2 \quad \rightarrow \quad 2NaCl$$

Note: In balancing equations you cannot change formulas. The formula for a reactant or product is fixed. You can only change the number of units of a formula by putting coefficients in front of the formula.

4 In an ionic equation particles present as ions are shown as ions.

Metals such as sodium are regarded as made up of atoms.

Non-metals such as chlorine are made up of covalent molecules.

Compounds of metals and non-metals such as sodium chloride are usually ionic.

$$2Na \quad + \quad Cl_2 \quad \rightarrow \quad 2Na^+Cl^-$$

Now it's your turn to write an ionic equation for the reaction between calcium and oxygen.

Set your working out in the four steps demonstrated for the reaction between sodium and chlorine:

1 words

2 correct formulas

3 balance

4 show ions.

As you develop your skills in writing balanced ionic equations you will often be able to reduce the number of steps. Knowledgeable chemists can often leave out the first step. Skilful and experienced chemists can go straight to step 4 but they then check their answer to make sure they have the same number of each type of atom on LHS and RHS.

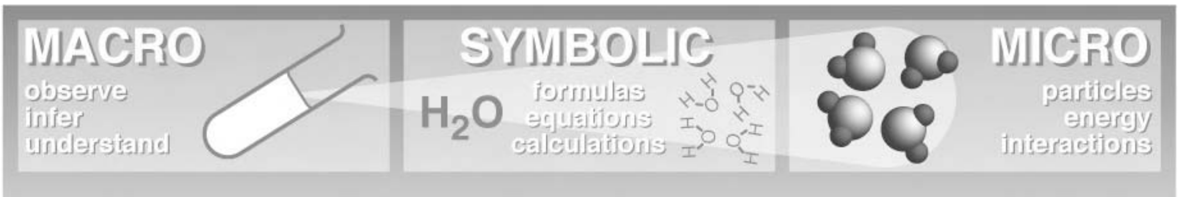
Some more practice for you. Write balanced ionic equations for the reactions between:

a) magnesium and chlorine

b) sodium and sulfur

c) magnesium and nitrogen

Now it's time to do the return exercises.



Suggested answers

Atomic number and mass number

The atomic number is 2 as the nucleus contains 2 protons. The mass number is 4 as the nucleus contains a total of 4 protons and neutrons.

Periodic table trends

1 The number of electrons in the outer shell of a:

a) sodium ion is 8

b) magnesium ion is 8

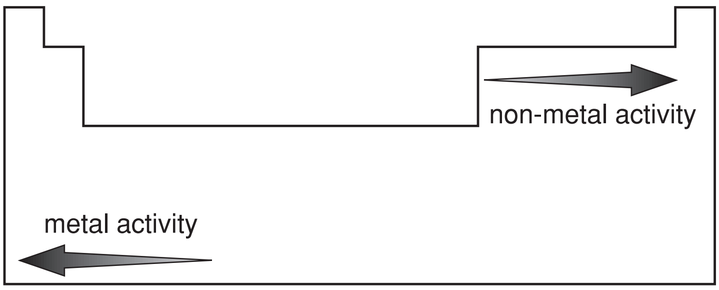
c) aluminium ion is 8

2 The group (vertical column) of elements in the periodic table which consists of atoms that are unreactive, not even joining with identical atoms to form molecule is the noble gases of group 18.

3 The number of electrons in the outer shell of each of these elements is 8.

4 Octet reminds me of 8.

1 Here is the summary of these trends.



2 Each atom is gaining electrons so that there are eight electrons in the outer shell of each ion.

Lewis electron dot diagrams for ions

Atom/ion	**Symbol**	**Electron configuration**	**Lewis electron dot structure**
Sodium atom	Na	2.8.1	Na o
Sodium ion	Na^+	2.8	Na^+
Magnesium atom	Mg	2.8.2	o Mg o
Magnesium ion	Mg^{2+}	2.8	Mg^{2+}
Aluminium atom	Al	2.8.3	o o Al o
Aluminium ion	Al^{3+}	2.8	Al^{3+}
Nitrogen atom	N	2.5	×× ×N× ×
Nitrogen ion	N^{3-}	2.8	N^{3-}
Oxygen atom	O	2.6	×× ×O× ××
Oxide ion	O^{2-}	2.8	O^{2-}
Fluorine atom	F	2.7	×× ×F× ×× ×
Fluoride ion	F^-	2.8	F^-

Compound formulas from ion charges

1 + (= 1+)

2 2+

3 3-

4 2-

5 – (= 1–)

Compound name	Ions present	Ion ratio to give neutral charge	Formula
Calcium bromide	Ca^{2+} Br^{-}	1: 2	$CaBr_2$
Barium oxide	Ba^{2+} O^{2-}	1:1	BaO
Sodium sulfide	Na^{+} S^{2-}	2: 1	Na_2S
Magnesium nitride	Mg^{2+} N^{3-}	3:2	Mg_3N_2

Writing word equations

1 sodium chloride

2 water

hydrogen + oxygen → water

3 mercury oxide → mercury + oxygen

4 magnesium + oxygen → magnesium oxide

5 in a limited supply of air

carbon + oxygen → carbon monoxide

in a plentiful supply of air

carbon + oxygen → carbon dioxide

6 hydrogen + chlorine → hydrogen chloride

Constructing ionic equations

1 calcium + oxygen → calcium oxide

2 $Ca + O_2 \rightarrow CaO$

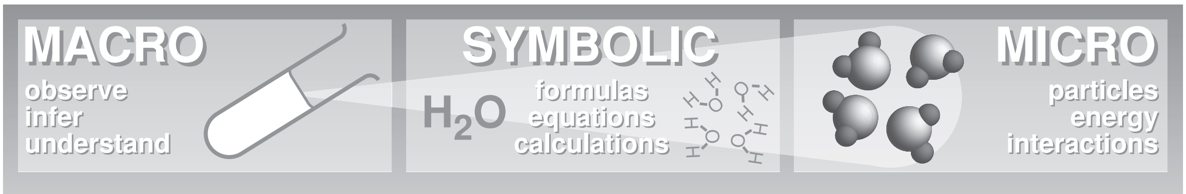
3 $2Ca + O_2 \rightarrow 2CaO$

4 $2Ca + O_2 \rightarrow 2Ca^{2+}O^{2-}$

a) $Mg + Cl_2 \rightarrow Mg^{2+}Cl^{-}{}_2$

b) $2Na + S \rightarrow Na^{+}{}_2S^{2-}$

c) $3Mg + N_2 \rightarrow Mg^{2+}{}_3N^{3-}{}_2$

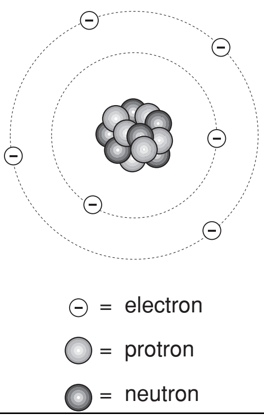
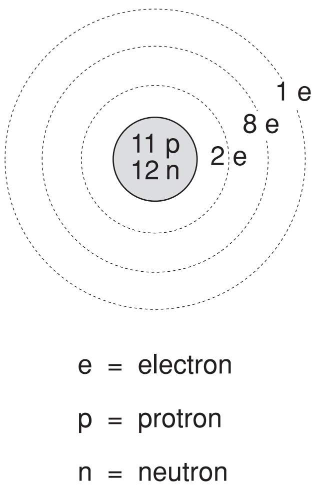


Exercises – Part 3

Exercises 3.1 to 3.4 Name: ___________________________________

Exercise 3.1: Atomic structure

Use information from your periodic tables to complete the table below:

Atomic structure	Atomic no.	Element name	Mass no.
			
			

Exercise 3.2: Calculating an empirical formula

A pure sample of magnesium fluoride was found to be 39% magnesium and 61% fluorine by weight. Taking the atomic weight of magnesium as 24 and fluorine as 19 try to work out the empirical formula of magnesium fluoride.

	magnesium	:	fluorine
Weight ratio	39	:	61
Particle ratio	39/24	:	
	=	:	
that is		:	
empirical formula			

Exercise 3.3: Ionic or covalent?

A metal and a non-metal usually react forming an ionic compound. Compounds formed by two non-metals reacting are always covalent.

Note: Prefixes (mono-, di-, tri-, tetra-, penta-, hexa-, etc.) are used for naming compounds of non-metals with non-metals, but not normally for naming compounds of metals with non-metals.

It is unusual to come across the name of a compound of a metal with a non-metal which includes prefixes. When you do the compound is probably covalent rather than ionic.

For example uranium hexafluoride UF_6 is a gas consisting of covalent molecules. The use of prefixes in this compound of a metal and non-metal is a hint that the compound is covalent rather than ionic.

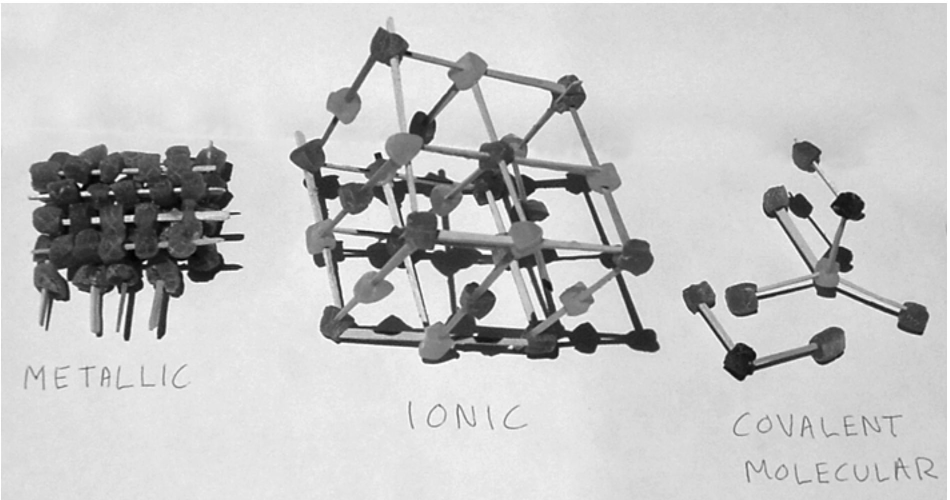
Using these ideas label each of the following compounds as ionic or covalent.

copper oxide	CuO
carbon monoxide	CO
sulfur trioxide	SO_3
carbon tetrachloride	CCl_4

calcium fluoride	CaF_2
aluminium bromide	$AlBr_3$
dinitrogen pentoxide	N_2O_5

Exercise 3.4: Constructing models

The models shown below were made from pieces of jelly snakes and toothpicks.



The student used the following information in making his models:

- Metals are made up of identical particles arranged in rows and columns and layers
- Ionic compounds are made up of oppositely charged particles so he used two different colours. He chose to make up a model of sodium chloride where each positive ion is surrounded by 6 negative ions and vice versa. Next time he makes this model he plans to use the larger jelly snake heads, all of the same colour, to represent the larger negative ions.
- Covalent compounds are made up of atoms (different elements represented by different colours) joined by covalent bonds (represented by half a toothpick). He made a model of water and a model of methanol CH_3OH.

What could you use to make your models?

Here are some possibilities for representing particles and bonds:

Particles	**Bonds**
Plasticine	none needed – plasticine sticks together
Blu-tack®	none needed
Play dough	popsticks
Ping pong balls	a drop of nail polish remover as glue
Polystyrene pieces	metal wire

Some of these models will be of the ball and stick type; others will be space-filled type.

Look around you and see what you can find that could be useful for making models. You may find suitable materials amongst waste that nobody wants.

Construct your models of a metal, an ionic compound and a covalent compound. Then write a report of half a page describing:

- How you made your models (include drawings with labelled keys of the final models)
- Ways of improving what you have done if you had to make the models again.

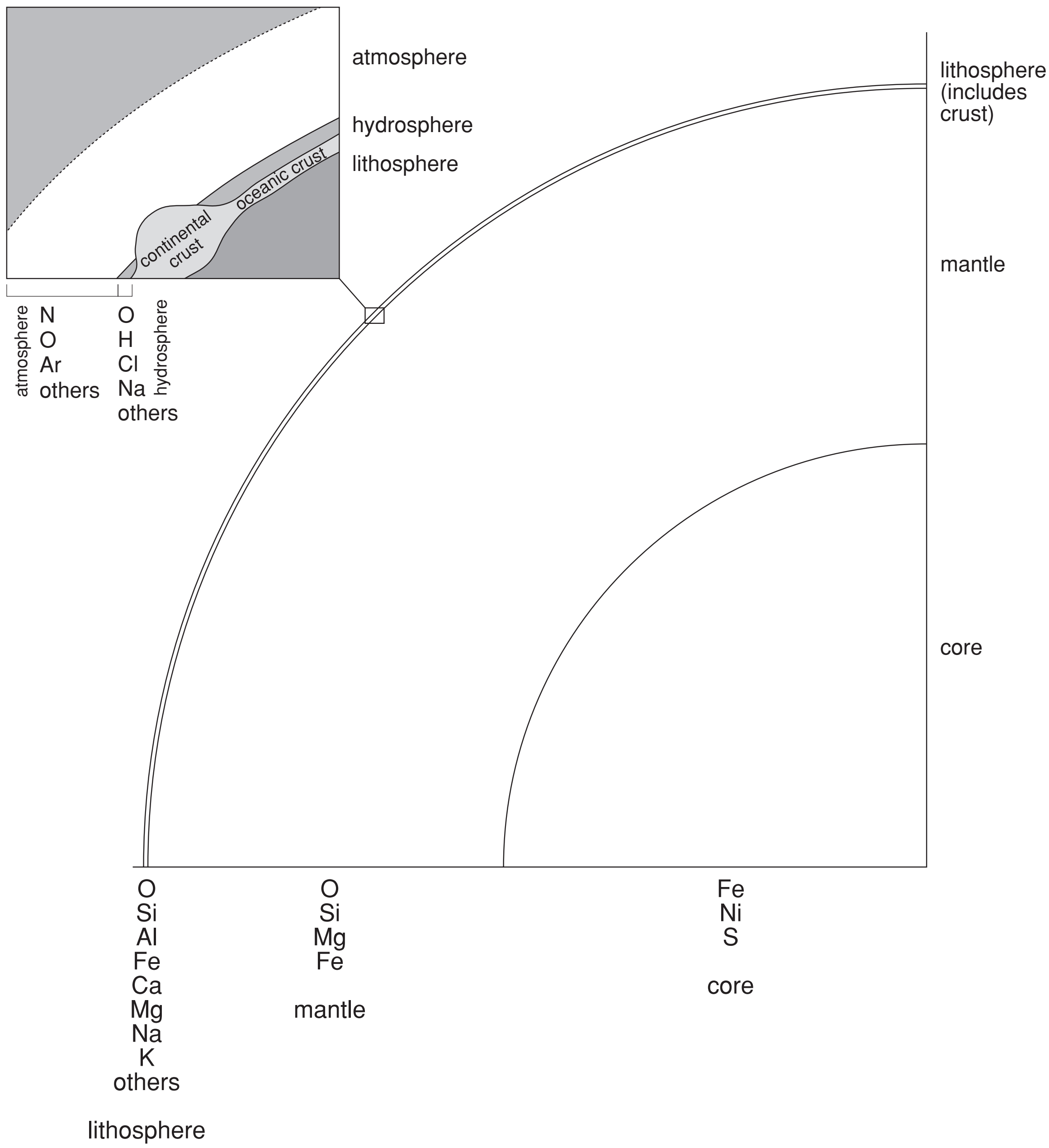
Chemistry
Preliminary Course
Stage 6

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING
TAFE NSW
OPEN TRAINING AND EDUCATION NETWORK - DISTANCE EDUCATION

The chemical earth

Part 4: Extraction requires energy

Incorporating October 2002
AMENDMENTS


atmosphere
hydrosphere
lithosphere
continental crust
oceanic crust
atmosphere
N
O
Ar
others
O
H
Cl
Na
others
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mantle
core
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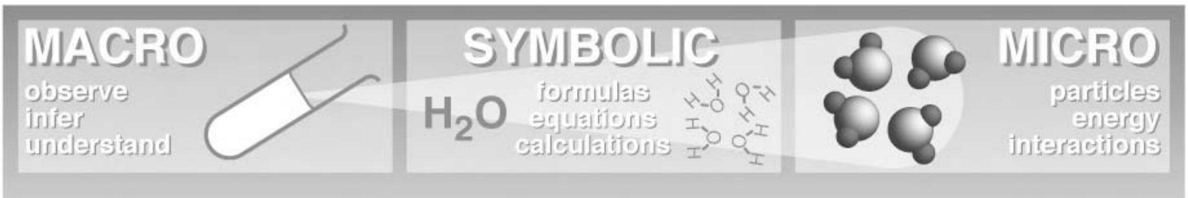
MACRO
observe
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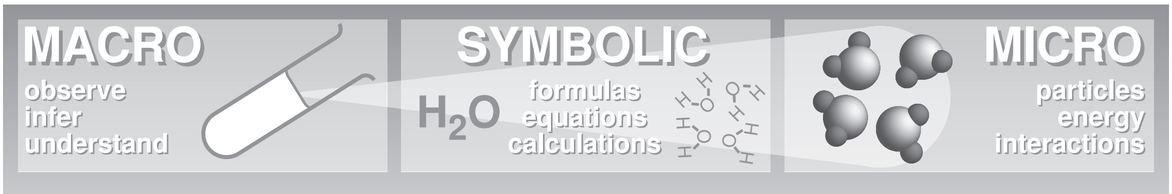
H2O
formulas
equations
calculations
MICRO
particles
energy
interactions

Contents



Introduction

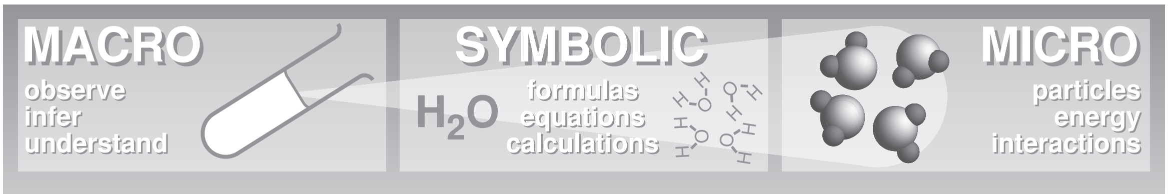
In this part you will be learning about the energy required to extract elements from their naturally occurring sources.

In Part 4 you will be given opportunities to learn to:

- identify the differences between physical and chemical change in terms of rearrangement of particles
- summarise the differences between the boiling and electrolysis of water as an example of the difference between physical and chemical change
- identify light, heat and electricity as the common forms of energy that may be released or absorbed during the decomposition or synthesis of substances and identify examples of these changes occurring in everyday life
- explain that the amount of energy needed to separate atoms in a compound is an indication of the strength of the attraction, or bond, between them

In Part 4 you will be given opportunities to:

- plan and safely perform a first-hand investigation to show the decomposition of a carbonate by heat, using appropriate tests to identify carbon dioxide and the oxide as the products of the reaction
- gather information using first-hand or secondary sources to:
  - observe the effect of light on silver salts and identify an application of the use of this reaction
  - observe the electrolysis of water, analyse the information provided as evidence that water is a compound and identify an application of the use of this reaction
- analyse and present information to model the boiling of water and the electrolysis of water tracing the movements of and changes in arrangements of molecules.



Physical changes

Carry out the activity and check your answers as you go.

You will need: a candle, a box of matches, a piece of cardboard to stand the candle on, a paper towel or paper tissue, a small container half full of water.

1 Light a match and warm the bottom of the candle until the solid wax melts. Hold the bottom of the candle on the cardboard until the wax solidifies.

You have just observed two physical changes:

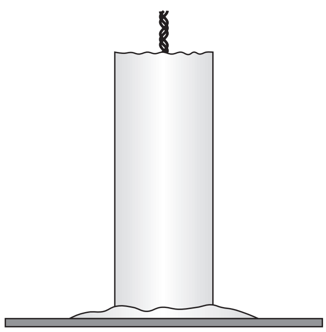
– Solid wax melting to liquid wax.

– Liquid wax solidifying to _______ wax.

In a physical change the identity of the substance does not change. The wax particles (molecules) are identical in the solid and liquid states. Only the way in which the particles move and the amount of heat energy they have are different. Changes of state are the most common type of physical change.

If a small drop of liquid wax falls on your skin does this feel different to a similar sized lump of solid wax falling on your skin? Liquid wax contains (more/less) heat energy than solid wax.

Draw an arrow to the part of this diagram where physical changes have occurred in setting up the equipment:



2 Fold the paper towel or tissue into a thin strip and place one end into the half filled container of water. Can you see the liquid water moving upwards between the paper fibres?

What physical change can this water undergo when it gets to the top of the paper?. The water evaporates changing from _______ to gas

This physical change will enable more liquid water to enter the paper at the bottom as liquid water escapes from the top by changing to ______.

The gaseous water then mixes with the air surrounding the top of the paper.

Draw a small diagram showing how you carried out the activity. Label your diagram with the three labels liquid water in the container, liquid water in the paper, gaseous water in the air.

3 Examine the wick at the top of a candle.

You can probably see that the wick is made up of strands of cotton. When you hold a lit match flame beside the wick then solid wax nearby melts to _________ wax. This liquid wax moves up the spaces between the strands of cotton just as liquid water moved up the spaces between the paper fibres in the previous activity.

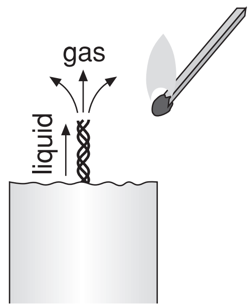
When the liquid wax reaches the top of the wick the wax will change from liquid to ______ and then mixes with the gaseous air surrounding the top of the wick.

The changes that occur are listed.

a) Solid wax melting to liquid wax.

b) Liquid wax changing to _______ wax.

These are both _________ changes. No new substance is produced. Only the way in which the wax particles move and the amount of heat energy they have are different.



4 Hold a lit match flame beside the top of the wick and watch what happens to the solid wax at the top of the candle.

Did you see liquid wax form and move up the wick?____________

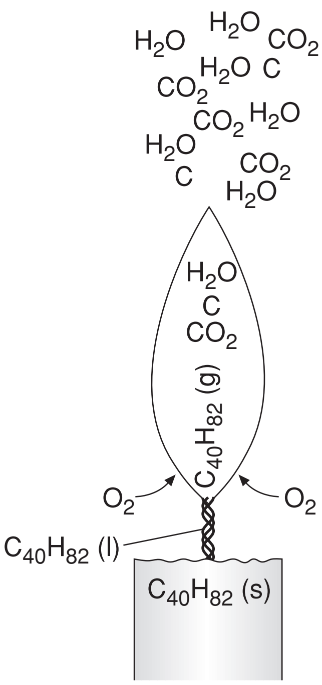
What happened when liquid wax at the top of the wick changed to gas then mixed with air near the lit match? Did a candle flame appear?__________

Blow out the lit match and observe the candle flame. If a candle flame did not appear, light another match and hold the match flame closer to the top of the wick until you get a candle flame.

List five **observations** (things you can see or hear or feel or smell) happening at the flame, wick and top of the candle. Try to include some quantitative observations which involve measurement or estimation of quantities.

____

____



5 When you made observations on the candle flame you were observing a chemical reaction. Inside the flame the wax particles and oxygen particles from the air were undergoing chemical change. A chemical change is a chemical reaction in which at least one new substance is produced.

The atoms in the wax and oxygen atoms from the air rearranged. The rearrangements produced new substances and released heat energy producing a flame made up of fast moving, energetic particles.

Place the steel blade of a knife just above the top of the candle flame for a few seconds. Which black element has collected on the steel blade? If you are not sure the information that candle wax is a mixture of hydrocarbon molecules with formulas like $C_{40}H_{82}$ might help you.

A website link on the chemistry page will show you ball and stick models of hydrocarbon molecules containing up to eight carbon atoms. http://www.lmpc.edu.au/science

To visualise a wax molecule imagine a molecule with five times as many atoms. A new substance you can observe being produced in a candle flame is the black element ____________.

Carbon particles in the flame give it a yellow colour. Some of the carbon atoms from the hydrocarbon molecules have collected on the knife blade as soot (carbon). Other carbon atoms have combined with O_2 to form CO_2 molecules. The hydrogen atoms from the hydrocarbon have combined with oxygen molecules to form water H_2O. The CO_2 and H_2O molecules produced have moved into the surrounding air.

Name three new substances produced by the chemical changes in a candle flame:

a) ____

b) ____

c) ____

Complete the sentences below:

An example of a physical change involving candle wax is ______

____

(In a physical change no new substance is produced.)

An example of a chemical change involving candle wax is ______

____

(In a chemical change at least one new substance is produced).

Another type of physical change

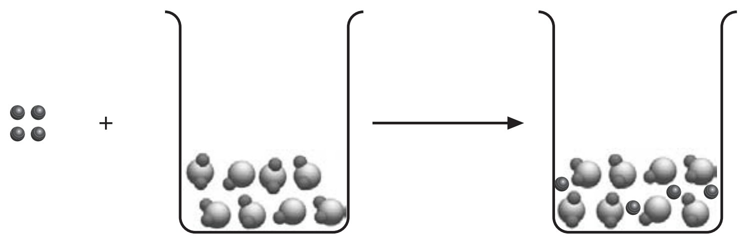
A change of state is a physical change because no new substance has been produced.

Another important type of physical change occurs when a substance dissolves in a liquid to form a solution. If the particles of the substance do not undergo a chemical change but just mix with the liquid particles this is a physical change. It is easy to recover the original substance by evaporating the liquid from the solution.

The substance that dissolved is called the solute. The liquid in which it dissolved is called the solvent. The mixture formed is called the solution.

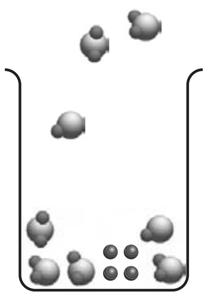
solute + solvent $\longrightarrow$ solution

salt + water $\longrightarrow$ salty water



Salt dissolves in water to form a solution (salty water).

Evaporation of the solution will allow solvent to escape into the air producing new crystals.



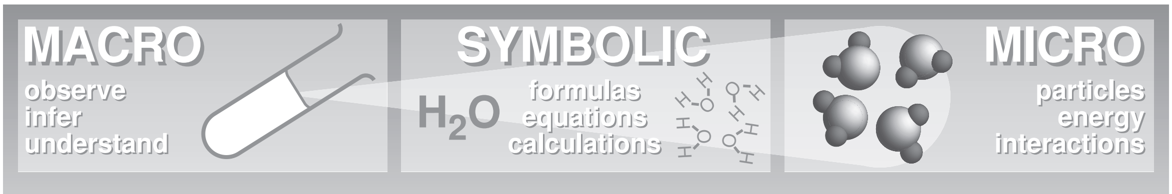
Water evaporates from the mixture leaving salt to crystallise.

Optional activity

You can model formation of a solution using lollies!

- 100's and 1000's (small coloured balls) can represent the solvent molecules if you put them in a glass and shake the glass so the 100's and 1000's move freely over one another.
- You can make a model of a solid solute by taking eight small lollies and wetting them so you can stick them together into a cube shape. Cake decorating silver balls (called cachous) or small lollies would be suitable.
- When the lollies are dry and stuck together add the solute cube to the 100's and 1000's solvent and shake. Stir the mixture with a spoon to simulate dissolving. What happens to the small lollies?

Remember that when you have completed an experiment dispose of the chemicals safely. If you have handled these lollies don't feed them to anyone else.



Chemical changes

When a chemical change occurs atoms are just rearranged. No atoms are created and no atoms are destroyed.

If you look at the right hand side (RHS) or product side of a balanced equation in symbols you will see the same atoms as on the left hand side (LHS) or reactant side. However the atoms will be rearranged and in different combinations. For example:

$2Na + Cl_2 \rightarrow 2\ NaCl$

You can see that the sodium on the RHS is now combined with chlorine.

The new arrangement of atoms shows that a new substance has been produced and so a chemical change has occurred. In rearranging a particle could:

- form a covalent bond with a different particle

- change from atom to ion

- change from ion to atom.

Different types of equations

If magnesium is placed in water at 80°C you can observe the magnesium slowly dissolve forming magnesium hydroxide and releasing hydrogen gas. This is a chemical change because new substances have been produced.

Magnesium + water $\rightarrow$ magnesium hydroxide + hydrogen

This chemical change can be represented by chemical equations in symbols.

$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$

This is a molecular equation.

In the molecular equation the magnesium is shown combined with hydroxide to form the new substance magnesium hydroxide.

$Mg + 2H_2O \rightarrow Mg^{2+} + 2OH^- + H_2$

This is an ionic equation.

In the ionic equation the magnesium is shown to have changed into magnesium ions.

These equations show that new substances are produced by

- particles rearranging into new combinations (molecular equation)
- particles changing into new particles (ionic equation).

On the LHS the magnesium consists of magnesium atoms in the metal.

On the RHS of both equations magnesium has changed to a new substance.

When you are asked to write an equation it is expected that you will write the equation in symbols and make sure the equation is balanced. Chemical equations are balanced when:

1 atoms are conserved (all atoms of each element on the LHS are present on the RHS)

2 electric charge is conserved (the sum of the charges on the LHS equals the sum of the charges on the RHS).

A molecular equation shows no charged particles. To confirm that it is balanced just check that atoms present on LHS = atoms present on RHS.

To confirm that an ionic equation is balanced first check that atoms are conserved then that electric charge is conserved.

Decomposition of a carbonate by heat

For this activity you will need the following materials and equipment

- A suitable carbonate such as copper carbonate. Copper carbonate can sometimes be bought as a green powder at craft or pottery suppliers. The minerals malachite and azurite are both forms of copper carbonate.

- A heat source eg. a candle flame/spirit burner/Bunsen burner and matches
- A container in which to heat the carbonate. This could be a small test tube or a steel spoon or a steel knife blade
- Some limewater.

  This is made by adding a small amount of lime (a chemical obtainable from a hardware store, bricklayer or builder) to a sealable container half filled with water. Do not use lime from a nursery or agricultural supplier – this is usually powdered limestone calcium carbonate.

  Shake the lime with the water then add more water until the container is almost full. Some of the solid lime, $Ca(OH)_2(s)$, will dissolve to form a water solution $Ca(OH)_2(aq)$.

Keep the lime away from eyes and skin. Lime or limewater in eyes must be immediately washed away with lots of water.

  Seal the container and always keep it topped up with water to minimise contact with air.

  When the limewater is needed the top layer is carefully decanted as a colourless, transparent solution and the container resealed. Use clear limewater only. Limewater turns cloudy when exposed to CO_2.

- Information about oxides shown in the table below.

Name	Formula	Ions present	Colour	MP (^oC)
Copper(II) oxide	CuO	Cu^{2+}, O^{2-}	Black	1326
Copper(I) oxide	Cu_2O	Cu^+, Cu^+, O^{2-}	Red	1235

Planning your experiment

1. Prepare the limewater at least one day before you do the experiment because $Ca(OH)_2(s)$ is not very soluble in water and takes a while to form $Ca(OH)_2(aq)$.

2 Organise a suitable source of heat.

3 Find a safe place to heat the carbonate away from flammable solids, liquids and gases.

4 Use eye protection – either safety goggles or glasses to protect your eyes.

5 Work out a way of holding a drop of limewater near the heated carbonate – will you need the assistance of another person?

6 Arrange a safe place to put the hot container until it is cool; keep the solid product of the decomposition somewhere safe until you need it for practical work in the next module on metals.

The experiment

Carry out your experiment and record important observations in the space below.

1 Complete the missing words in this conclusion.

______ carbonate undergoes a chemical ______ when heated forming two new substances:

______ oxide which is a ______ coloured solid

______ dioxide gas which turns colourless ______ cloudy.

2 Can you write an equation in words for this chemical change?

______ → ______ + ______

3 Now can you write a balanced equation (using symbols) for this chemical change? Use $CuCO_3$ as the correct formula for calcium carbonate.

____

Check your answers.

Electrolysis of water

The first activity you did in this part required heat energy to carry out the chemical change of burning candle wax. This activity requires electrical energy to carry out a chemical change and so is called an **electrolysis**.

You will need:

- a 9 V battery – even an old used one giving at least 6 V
- a terminal connector for a 9 V battery with a positive (red) and negative (black) wire; cut the insulation off each end to expose at least a centimetre of copper wire
- two lengths of pencil graphite at least 2 cm long as electrodes to transfer electrons in and out of the liquid. (The 'lead' inside a plastic retractable pencil is suitable; if you cut graphite from a wooden pencil be careful not to cut yourself.)
- a small transparent plastic or glass container to hold the water so that you can see what happens
- a small amount of table salt, (NaCl), to dissolve in the water and increase its conductivity. Add about a rice grain volume (an amount of salt equal to the volume of an uncooked rice grain) to 100 mL of water.

  Alternatively you can use: 'white' (colourless) vinegar instead of salty water. Ions from the added salt or the acid in vinegar will enable an electric current to flow through the water and speed up electrolysis of the water.

To make **electrodes** wind each metal wire around a piece of the pencil graphite. Make sure the positive and negative electrodes do not touch one another once you have attached the terminal connector to the battery.
If they do touch then the battery could short circuit and become useless.

Carefully place the positive and negative graphite electrodes into the salty water or vinegar. Electrons will now flow from the negative battery terminal to the negative electrode in the water. Ions from the salt or vinegar will flow between the electrodes (electrons cannot move through water). Electrons will move from the positive electrode to the positive terminal of the battery.

You are going to make observations. Observations are what you detect with your senses (sight, touch, hearing, smell, taste). Write observations after each of the questions below:

- Can you see bubbles of gas released from any electrode?

  ____

- What is the charge on the electrode where most gas bubbles are released?

  ___

- Are bubbles of gas on the two electrodes the same size?

  ___

- Can you make another observation?

  ___

  ___

  ___

Inferences

An **inference**, made after an observation, is what you think happened.

Inferences or interpretations can be based on your observations and the knowledge and understanding you have accumulated in life.

Here is an inference a student could make from this activity: 'I think two different gases are released at the two electrodes because the gas bubbles are different in size and behaviour.'

Can you make an inference based on an observation you made above?

I think ___

___

___

You can often make better inferences if you use second-hand information as well as first-hand observations.

1 Can you work out the names of the gas released at the negative electrode and the different gas released at the positive electrode using your first-hand observations and the secondary information below.

Gas	**Density of gas at 25°C (g/L)**	**Solubility at 20°C (g/kg water)**	**Solubility at 20°C (g/kg water)**
hydrogen H_2	0.08	0.00160	0.00154
oxygen O_2	1.31	0.0434	0.0393

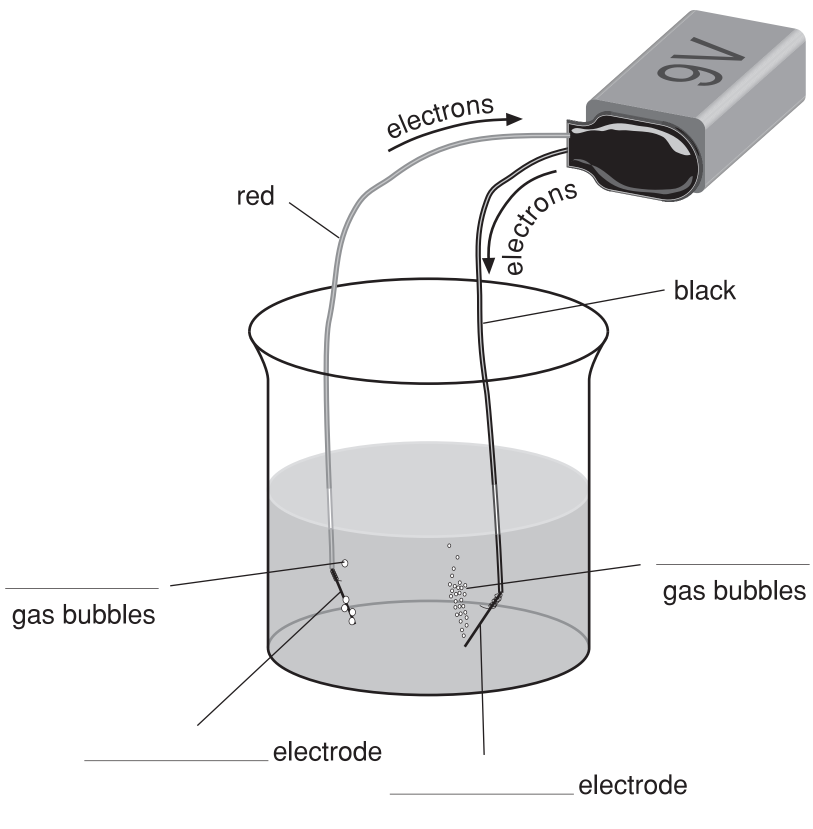
a) The less water soluble gas released at the negative electrode is ______________________________ .

b) The more water soluble gas, released at the positive electrode is ______________________________ .

c) The gas bubbles which rose to the surface of the water fastest were ______________________ gas bubbles.

d) I think they rose fastest because ______________ .

2 Can you complete the bottom four labels on the diagram for this experiment?



Experimental setup to demonstrate electrolysis.

Check your answers.

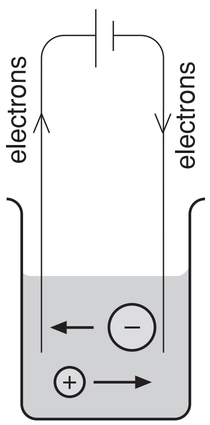
Current and electron flow

The current used in electrolysis is always **direct current** (DC) supplied by a battery or low voltage DC power supply. A direct current flows in one direction all the time so the chemical reaction goes in one direction and we can see change.

If an **alternating current** (AC) was used no change would be seen because the current alternates in direction many times each second. The reaction would go in one direction for about 0.01 s, then reverse and go in the opposite direction for the next 0.01 s and so on. These small micro level changes cannot be seen at the observable macro level.

A direct current always flows in one direction. Negative electric charges flow directly from the negative terminal with an excess of electrons to the positive terminal with a shortage of electrons.

Electrons move from the negative terminal to the negative electrode. These electrons react with molecules or positive ions in the **electrolyte** at the surface of the negative electrode. The movement of positive ions and negative ions in the electrolyte carries current between the electrodes. Electrons released by molecules or negative ions in the electrolyte at the surface of the positive electrode move to the positive terminal.



Electron flow in an electrolytic cell.

An equation for electrolysis of water

Electrons flowing from the battery can react at the negative electrode/water interface.

water molecules + electrons → hydrogen gas

If this equation is written using symbols you can see the equation is not balanced for atoms or electric charge (remember each electron e^- has a negative charge).

$H_2O + e^- \rightarrow H_2$

Adding a hydroxide ion OH^- to the RHS balances O atoms and charge but not H atoms.

$H_2O + e^- \rightarrow H_2 + OH^-$

Adding coefficients so the atoms and total charge on LHS and RHS are balanced gives:

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Each electron reacting at the negative electrode/water interface produces a hydroxide ion OH^- in the electrolyte solution.

At the positive electrode electrons are released from the electrolyte so oxygen gas and electrons are products. A positive H^+ is produced for each electron released at the positive electrode/water interface.

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

If the two gases released at the electrodes in the electrolysis of water can be collected it is found that there is twice as much hydrogen gas as oxygen gas

The overall equation for the electrolysis of water is:

$2H_2O \rightarrow 2H_2 + O_2$

A way of presenting more information in a balanced equation is to include (*s*) for solids, (*l*) for liquids, (*g*) for gases and (*aq*) for water (aqueous) solutions.

$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$

In industry surplus electrical energy can be used to carry out electrolysis of water and produce hydrogen and oxygen.

The hydrogen produced can be used for chemical reactions (such as changing liquid vegetable oils to solid margarine), as a non-polluting fuel ($2H_2 + O_2 \rightarrow 2H_2O$ + *energy*, water is the harmless product of this energy releasing reaction) or for filling high altitude weather balloons.

Can you list some possible uses for the oxygen produced?

____

____

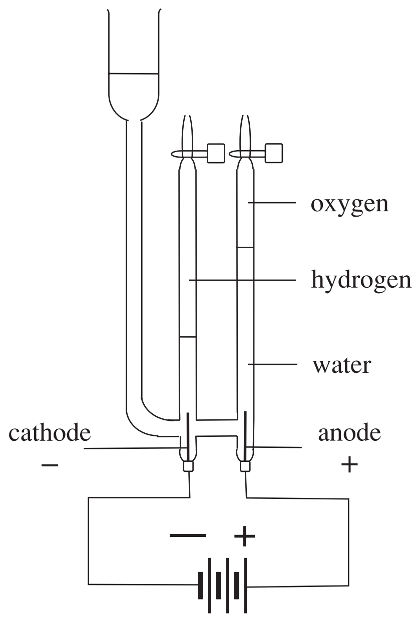
____

Check your answers.

The electrolysis of water produces only two products – hydrogen and oxygen. This indicates that water is a compound of hydrogen and oxygen only. Measurements such as finding that the volume of hydrogen released is twice the volume of oxygen released and other quantitative investigations provide evidence that there are two atoms of hydrogen to one atom of oxygen. Hence the formula H_2O.

A voltameter

The diagram below shows a piece of equipment called a **voltameter** that is used to carry out electrolysis of water in school laboratories.



A voltameter. This is used to carry out electrolysis of water.

In electrolysis the negative ________ is called the cathode.

Cations (________ ions) are attracted to the cathode.

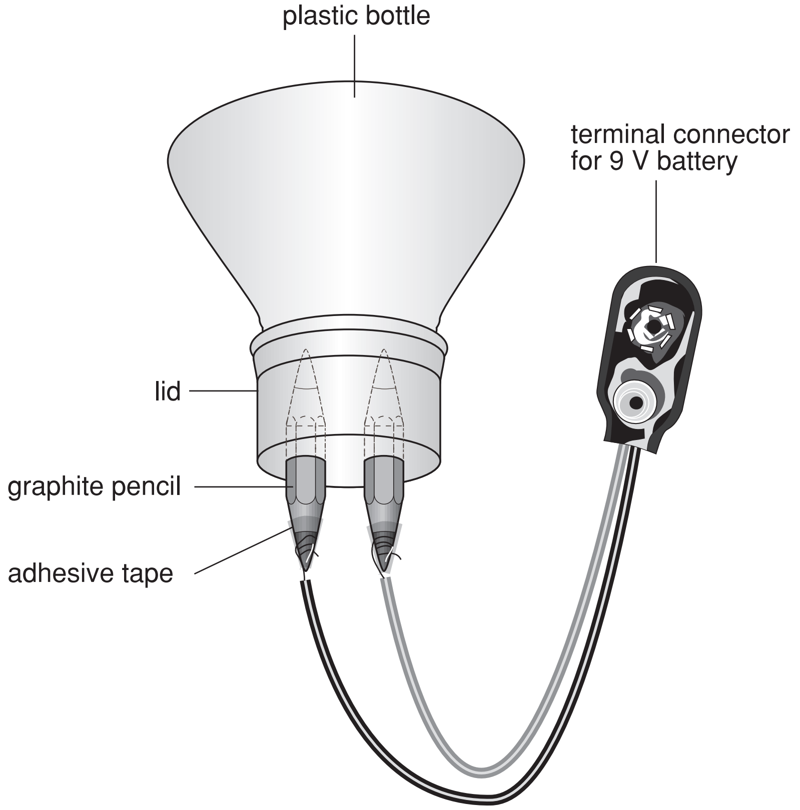
In electrolysis the ________ electrode is called the anode.

Negatively charge ions called ________ are attracted to the anode.

Check your answers.

The next diagram shows how a student made electrolysis of water apparatus from the following equipment:

- the lid and top section of a plastic drink bottle
- two short graphite pencils
- a terminal connector for a 9 V battery
- adhesive tape.



Equipment set up from household items to carry out electrolysis of water.

Draw an attached battery and a salt solution in the plastic bottle part. Label the negative battery terminal, the negative electrode and draw in what you would expect to see in the solution above both electrodes. Label the oxygen gas, hydrogen gas and direction of electron flow in the wires.

Modelling boiling and electrolysis of water

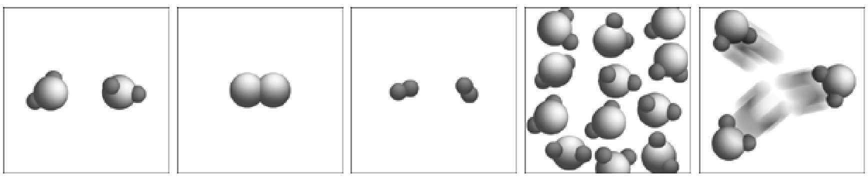
Use the diagrams cut out from the bottom of this page to model the boiling of water and the electrolysis of water in the spaces below.

Complete the missing words where you see .

Boiling of water (a change – no new substance produced).

Electrolysis of water (a change – at least one new substance produced).

Cut here……………………………………………………………………



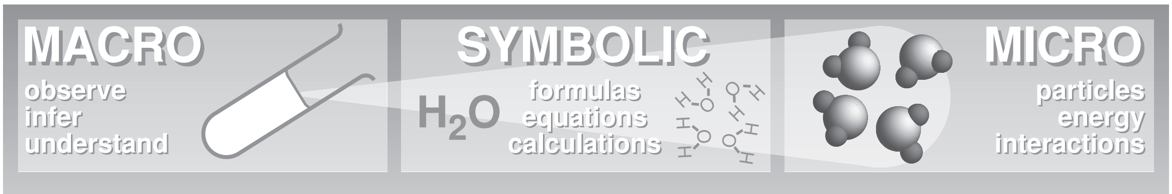
Summarising physical and chemical changes

Place one tick only in each row of this table to summarise the differences.

Feature	Boiling	Electrolysis
no new substance formed		
at least one new substance formed		
chemical change		
physical change		
heat energy required		
electrical energy required		
normally occurs at 100°C		
can occur at 25°C and 100 kPa (normal atmospheric pressure)		
one liquid gives one gas		
one liquid gives two gases		
$H_2O_{(l)} \rightarrow H_2O_{(g)}$		
$2\ H_2O_{(l)} \rightarrow 2H_{2\,(g)} + O_{2\,(g)}$		
attraction between molecules overcome		
covalent bonds broken and formed		

Check your answers.

If your answer is different look at the diagrams for the previous activity and think carefully about what is happening at the micro level.



Bond energy

In the last task you compared a physical change (boiling) and a chemical change (electrolysis) for the same substance (water).

When scientists make quantitative measurements of energy they use a unit called the joule (J). Because this represents such a small amount of energy measurements are often given in kilojoules (kJ), megajoules (MJ) or gigajoules (GJ).

1 kJ = 1 000 J   1 MJ = 1 000 000 J   1 GJ = 1 000 000 000 J

All types of energy such as chemical, heat, electrical and light, can be measured in joules.

Consider the amount of energy needed to:

- electrolyse one gram of water at 25°C (15.8 kJ)
- boil one gram of water at 100°C (2.3 kJ).

Much more energy is required to electrolyse water than boil water.

Electrolysis involves the breaking of bonds between H atoms and O atoms inside molecules. These covalent bonds are very strong and so large amounts of energy are usually needed for chemical changes since bonds are broken.

Boiling involves the overcoming of forces of attraction between molecules. These forces are called intermolecular ('inter' means between) forces of attraction. They require less energy to be overcome than the very strong forces of attraction (called covalent bonds) inside molecules.

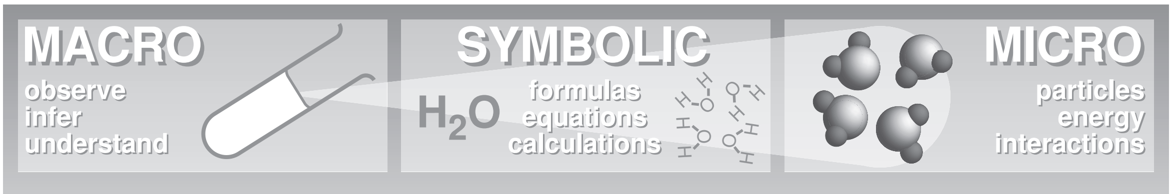
Measurements of energy changes in chemical changes can be used to calculate bond strengths. Bond strengths are also called **bond energies** or bond enthalpies and measured in kJ per mole of bonds. A mole is a very large number, fixed in value, that chemists use to compare the same number of bonds or particles. Bonds with higher energies are more difficult to break.

For example the bond energy of O – H is 463 kJ/mole while the bond energy of H – H is 436 kJ/mole. – represents the covalent bond between the atoms.

1 Which of these two bonds has the highest bond energy? ________

2 Which of these two bonds is more difficult to break? __________

Check your answers.



The mole concept

When you buy small objects you use special words for a certain number of the objects. If you buy eggs you probably buy them in dozen lots (1 dozen = 12).

Have you heard the phrase ‘three score and ten years’ for a life expectancy of 70 years? (1 score = 20)

Small objects like pins used to come in packets labelled one gross. A gross is 144 of anything. (1 gross = 144)

Paper for photocopiers and printers is usually bought in packets labelled one ream or 500 sheets. (1 ream = 500)

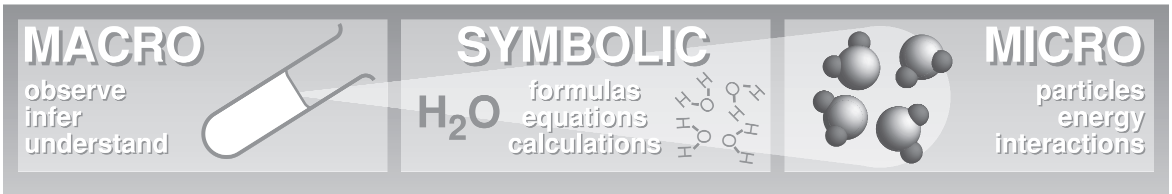
Chemists deal with extremely small particles. They need a special number to describe the quantity of the particles that they might use in a laboratory. This number is 1 mole which equals 602 200 000 000 000 000 000 000. (1 mole = 6.022×10^{23})

This fixed number, approximately 6×10^{23}, is also called Avogadro’s number or Avogadro’s constant.

The mole concept is an important symbolic link between the micro model of chemicals made up of particles and the macro world where you actually handle chemicals.

The average person absorbs one mole of oxygen per hour to keep alive. Chemists could measure this amount of oxygen as a weight (32 g), a volume of oxygen (25 L) or as part of a volume of air (125 L of air).

In the next module you will learn how to calculate and measure chemicals in moles.



Decomposition reactions

In a **decomposition** reaction one substance decomposes to two or more new substances. You have recently carried out two decomposition reactions.

Can you write balanced equations in symbols under their word equations?

1 Thermal decomposition caused by heat energy:

copper carbonate $\rightarrow$ copper oxide + carbon dioxide

2 Electrolytic decomposition caused by electrical energy:

water $\rightarrow$ hydrogen + oxygen

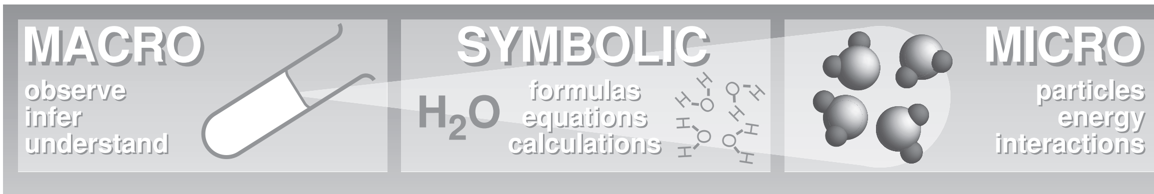
Notice how using a balanced equation in symbols makes it easier for you to see rearrangement of particles.

Check your answers.

When water undergoes electrolysis

- bonds are broken between H atoms and O atoms in water molecules – this step absorbs energy
- new bonds are formed when H atoms combine into H_2 and new bonds are formed when O atoms combine into O_2 – these steps release energy

For this reaction the total energy absorbed in breaking bonds is greater than the total energy released in forming bonds so that overall energy is absorbed in the electrolysis of water.



Effect of light on silver salts

There are two different ways you can investigate the effect of light on silver salts. You can approach the activity by:

- doing an experiment first-hand to observe the effect of light on silver salts
- gathering information from secondary sources such as books, encyclopedias or the internet.

Doing an experiment first-hand

1 Handle silver salts and silver salt solutions with care; they are corrosive to skin and eyes and stain skin black.

Prepare a small amount of soluble silver salt solution by dissolving a rice grain volume of silver nitrate or silver acetate salt in about 5 mL of distilled water.

2 Add about 5 mL of sodium chloride solution prepared in a similar way (about one rice grain volume of sodium chloride dissolved in 5 mL of water) to the silver salt solution.

3 When you mix the two colourless solutions together you should see a colour change as a reaction occurs, for example:

$$AgNO_3 + NaCl \rightarrow AgCl(s) + NaNO_3$$

4 Quickly divide the white suspension of silver chloride particles into two approximately equal volumes in identical containers. Place one container in the dark, eg. a closed cupboard, while the other container is left exposed to light.

5 After 15 minutes briefly bring the two containers side by side and compare. Has the light changed the white silver chloride salt AgCl? If there is no difference between the containers place them back in the dark and light and compare after 60 minutes.

Do you know a use for the reaction of silver salts with light? If not either read about the chemistry of photography or do the second activity below.

Secondary sources

You can gather information from secondary souces such as a book, encyclopedia or the world wide web (www). The www is a world wide collection of information files stored on computers, linked together so they are accessible to users from all over the world.

Here is how you can use search engines to search the www for information.

1 Locate a computer that has access to the internet or world wide web. This could be at a school, a TAFE, a public library, an internet cafe or a private home.

2 If you do not know how to connect to the www seek the help of somebody who can help you.

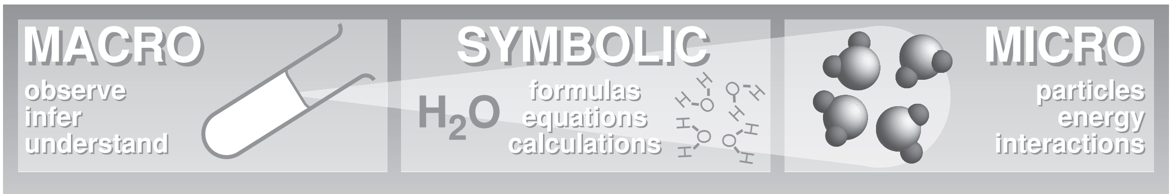
3 Type in the address of a search engine such as one of the following:

- http://www.ask.com
- http://www.google.com

4 Use the search function to find information about the 'effect of light on silver salts'. If you have not used a particular search engine before look for advice at Tips or Help.

5 Investigate web sites which appear to have some connection with photography or chemistry.

6 Using simple labelled diagrams explain how silver salts are used in black and white photography. (There is a drawing in the answer pages.)



Energy change and chemical reactions

Synthesis is the building up of a pure substance from simpler substances. The simpler substances could be elements or simple compounds. The substance built up is a compound. This substance that has been synthesised is more complex than the substances it was formed from.

Do you remember how in a decomposition reaction one substance decomposes to two or more new substances? This is the reverse of synthesis because the substance decomposing is more complex than the new substances formed.

You have studied the decomposition of water:

$2H_2O \rightarrow 2H_2 + O_2$

The decomposition of water absorbs electrical energy (electricity).

The synthesis of water occurs when a mixture of hydrogen and oxygen gas is exploded:

$2H_2 + O_2 \rightarrow 2H_2O$

The synthesis of water releases heat, light and sound energy.

Careful measurements show that, for the same quantity of water, the amount of electrical energy absorbed in decomposition equals the amount of energy released in synthesis.

Decomposition and synthesis can be represented as a forward and a reverse reaction by arrows in opposite directions:

$$\text{energy} + \text{water} \underset{\text{decomposition}}{\overset{\text{synthesis}}{\rightleftarrows}} \text{hydrogen} + \text{oxygen}$$

This equation demonstrates the law of conservation of energy. Energy can neither be created nor destroyed. When energy changes occur the total amount of energy remains the same.

The electrical energy put into decomposing water is stored in the hydrogen and oxygen gas mixture as chemical potential energy. This stored energy is released when the mixture explodes. Can you name the three types of energy released?

Check your answers.

Reactions involving light energy

Photosynthesis

Green plants use green chlorophyll to trap light energy and use this energy to synthesise glucose sugar from CO_2 and H_2O.

light energy $+ 6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Photography

A crystal (grain) in the layer of silver bromide on a photographic film can be changed by light.

light energy $+ Ag^+Br^- \rightarrow Ag + Br$ (silver atom and a bromine atom)

Fireworks

Fireworks are mixtures of chemicals which when ignited produce high temperatures that cause metals in the chemicals to emit light.

Chemiluminescence

Chemiluminescence reactions emit light without heating at room temperature. In nature chemiluminescence occurs in glow-worms, fireflies and some marine organisms.

Light sticks contain chemicals which react emitting light. You may have seen these used as light emitting bracelets and bangles, as lures for fish when night fishing or used to light caves or campsites at night.

Small chemical lights can be purchased for about a dollar each at some fishing stores. The chemical light is made up of a flexible plastic tube containing a thin-walled glass tube. When the chemical light is bent so that the glass tube breaks the hydrogen peroxide H_2O_2 solution inside the glass tube mixes with the chemicals outside in the flexible plastic tube. The chemical reaction that occurs releases a yellow-green light. The tubes must not be cut open; water and carbon dioxide in the air stop the chemiluminescent reaction.

Chemiluminescence information and movies can be seen through the chemistry page of http://www.lmpc.edu.au/science

Reactions involving heat energy

Synthesis of a compound from its elements

When a mixture of iron powder with sulfur powder is heated iron(II) sulfide is formed. (II) indicates that the iron in the iron sulfide consists of Fe^{2+} ions. As the FeS forms a red glow is seen and more heat energy is released than was needed to start the reaction.

$Fe_{(s)} + S_{(s)} \rightarrow Fe^{2+}S^{2-}{}_{(s)}$ + heat energy

Decomposition of explosives

Explosives are chemicals that contain a large amount of chemical potential energy compared to their decomposition products. When detonated chemical potential energy is changed to heat energy in a short period of time. The rapid expansion of the resulting decomposition products is called an explosion.

Ammonium nitrate is used in large amounts by the mining industry as an explosive because it is cheap and normally stable. This solid decomposes to two hot gases thus causing a rapid increase in volume ie explosion.

$NH_4NO_{3(s)} \rightarrow N_2O_{(g)} + 2H_2O_{(g)}$ + heat energy

Have you heard of the Nobel Prizes? These have been awarded annually since 1901 in the fields of chemistry, physics, medicine and physiology, literature and peace. The money awarded with these prizes came from the will of the Swede Alfred Nobel. Despite his brother's death in an early experiment, Nobel persevered in developing dynamite explosive for mining and the construction of highways, railroads and dams.

Nobel found a way of making the unstable explosive nitroglycerine safe to handle. A mixture of three parts of liquid nitroglycerine with one part of diatomaceous earth produced a stable dry powder called dynamite. The dynamite could be exploded from a distance, electrically, using detonators.

The unstable nitroglycerine decomposes producing many gas molecules and a lot of heat:

$$4C_3H_5(NO_3)_{3(l)} \rightarrow 12CO_{2(g)} + 10H_2O_{(g)} + 6N_{2\,(g)} + O_{2\,(g)}$$

Reactions involving electrical energy

An electric cell is an arrangement of chemicals to use or produce electricity.

Cells which take in electrical energy are called **electrolytic cells**. Cells which produce electrical energy are called **galvanic cells** ('batteries').

cells

electrolytic	galvanic
uses electricity to cause a reaction	produces electricity from a reaction

Any liquid or moist solid in which ions can move is called the electrolyte. Any metal or graphite parts taking electrons into or out of electrolyte are called electrodes.

Electrolysis to make aluminium metal

Aluminium oxide Al_2O_3 is a solid. Molten aluminium oxide contains moving Al^{3+} and O^{2-} ions which can react at graphite electrodes. What is happening at the electrodes can be represented by half equations:

Positive electrode: $2O^{2-} \rightarrow O_2 + 4e^-$

Negative electrode: $Al^{3+} + 3e^- \rightarrow Al$

The total number of electrons leaving the electrolyte must equal the total number of electrons entering the electrolyte. The half equations need to be multiplied so they show the same number of electrons leaving as entering:

$3 \text{ x } (2O^{2-} \rightarrow O_2 + 4e^-) = 6O^{2-} \rightarrow 3O_2 + 12e^-$

$4 \text{ x } (Al^{3+} + 3e^- \rightarrow Al) = 4Al^{3+} + 12e^- \rightarrow 4Al$

adding LHSs and RHSs: $4Al^{3+} + 12e^- + 6O^{2-} \rightarrow 4Al + 3O_2 + 12e^-$

cancelling electrons on each side: $4Al^{3+} + 6O^{2-} \rightarrow 4Al + 3O_2$

that is: $2Al_2O_3 \rightarrow 4Al + 3O_2$

Lead-acid cell in a car battery

A galvanic cell is an arrangement of chemicals structured to give a useful potential difference (voltage). Six lead-acid cells, each providing about 2 volts, make up a 12 V car battery. In a lead-acid cell a lead plate is the negative electrode while a lead dioxide plate is the positive electrode. The electrodes sit in a sulfuric acid, H_2SO_4, solution.

The negative electrode in a galvanic cell is a source of negative electrons.

Negative electrode: $Pb \rightarrow Pb^{2+} + 2e^-$

The positive electrode in a galvanic cell receives negative electrons.

Positive electrode: $PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$

Adding LHSs and RHSs of the two half equations.

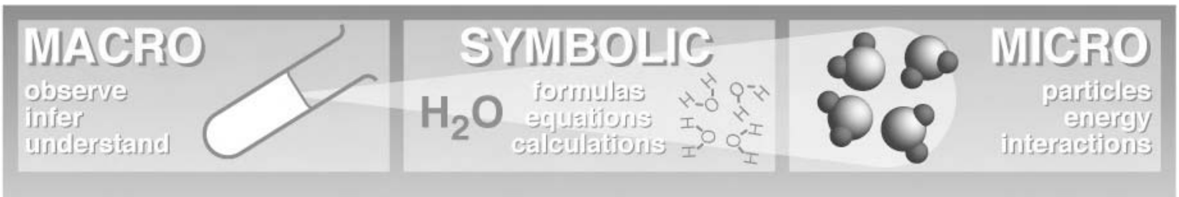
$PbO_2 + 4H^+ + 2e^- + Pb \rightarrow Pb^{2+} + 2H_2O + Pb^{2+} + 2e^-$

Cancelling the same number of electrons on each side of the equation.

$PbO_2 + 4H^+ + Pb \rightarrow 2Pb^{2+} + 2H_2O$

This equation shows the overall change in a lead cell as it provides electricity. Chemical energy stored in the reactants is lost as this reaction proceeds. This chemical energy changes to electrical energy which pushes electrons through electrical circuits in the car. These moving electrons change their energy into moving energy in the car starter motor, light energy in car lights and heat energy in car electric heaters.

The chemical reaction in the lead-acid cells can be reversed by electricity supplied by the generator/alternator operated by a fan belt from the engine. This equipment enables the car battery to be recharged with chemical energy for next time it is used.

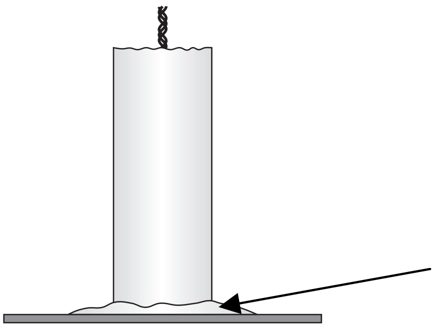


Suggested answers

Physical and chemical changes

1 Liquid wax solidifying to *solid* wax.

Liquid wax contains *more* heat energy than solid wax



2 The water evaporates changing from *liquid* to gas

This physical change will enable more liquid water to enter the paper at the bottom as liquid water escapes from the top by changing to *gas*.

3 When you hold a lit match flame beside the wick then solid wax nearby melts to *liquid* wax.

When the liquid wax reaches the top of the wick the wax will change from liquid to *gas* and then mixes with the air surrounding the top of the wick.

The changes:

a) Solid wax melting to liquid wax.

b) Liquid wax changing to *gas* wax.

These are both *physical* changes

4 Did you see liquid wax form and move up the wick? *yes*

What happened when liquid wax at the top of the wick changed to gas then mixed with air near the lit match? Did a candle flame appear? *gas, wax and oxygen in the air reacted forming the flame*

Five observations could include:

flame was 2 cm high and 1 cm wide

when the flame flickers more soot is formed

it feels hotter 5 cm above the flame than 5 cm to the side of the flame

most of the flame is yellow except for blue at the base

after 10 minutes 5 mm of the candle height had burned

5 A new substance you can observe being produced in a candle flame is the black element *carbon*.

Three new substances produced by the chemical changes in a candle flame are:

a) *carbon (soot)*

b) *water*

c) *carbon dioxide*

d) *carbon monoxide*

An example of a physical change involving candle wax is *melting of wax* or *solidification of wax* or *evaporation of wax.*

An example of a chemical change involving candle wax is *burning (combustion) of wax in the oxygen of air.*

Decomposition of a carbonate by heat

1 *Copper* carbonate undergoes a chemical *change* when heated forming two new substances:

Copper oxide which is a *black* coloured solid and *carbon* dioxide gas which turns colourless *limewater* cloudy.

2 Copper carbonate $\rightarrow$ copper(II) oxide + carbon dioxide

3 $CuCO_3 \rightarrow CuO + CO_2$

Inferences

1 a) The less water soluble gas released at the negative electrode is *hydrogen*.

b) The more water soluble gas, released at the positive electrode is *oxygen*.

c) The gas bubbles which rose to the surface of the water fastest were *hydrogen* gas bubbles.

d) I think they rose fastest because *they were less dense*.

The red wire leads to the *positive electrode* which releases *oxygen* gas.

The black wire leads to the *negative electrode* which releases *hydrogen.*

An equation for electrolysis of water

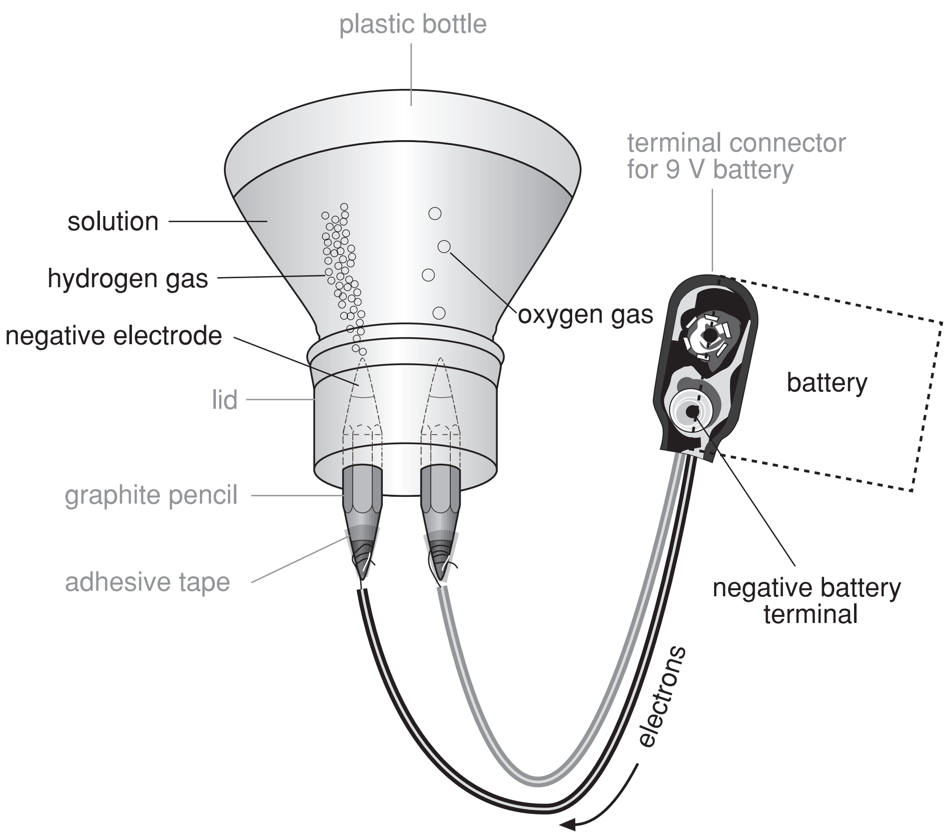
Some possible uses for the oxygen produced are:

- oxygen cylinders for resuscitation of patients
- steelmaking
- oxy-acetylene welding
- rocket fuel reactant.

A voltameter

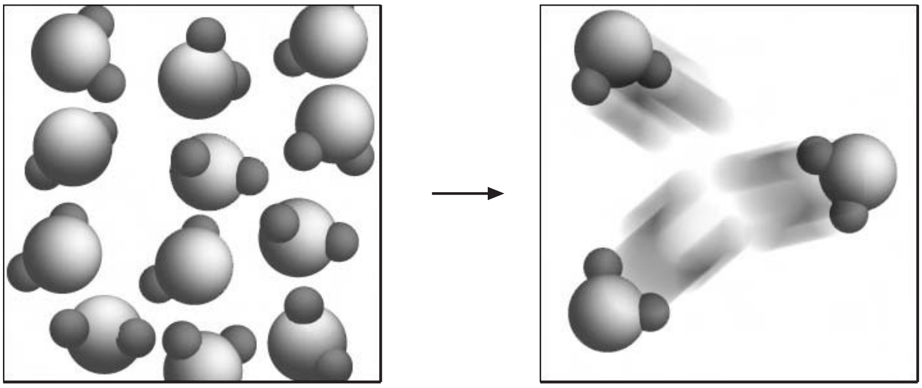
In electrolysis the negative *electrode* is called the cathode. Cations (*positive* ions) are attracted to the cathode.

In electrolysis the *positive* electrode is called the anode. Negatively charge ions called *anions* are attracted to the anode.

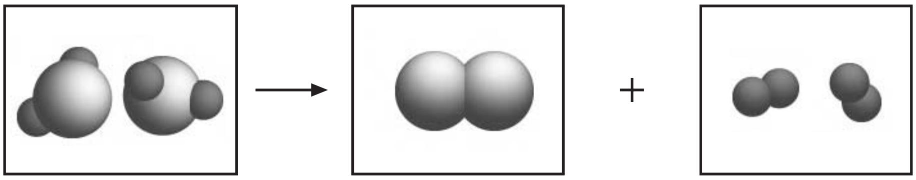


Modelling boiling and electrolysis of water

Boiling of water (a *physical* change – no new substance produced).



Electrolysis of water (a *chemical* change – at least one new substance produced).



Summarising physical and chemical changes

Feature	**Boiling**	**Electrolysis**
no new substance formed	√	
at least one new substance formed		√
chemical change		√
physical change	√	
heat energy required	√	
electrical energy required		√
normally occurs at 100°C	√	

can occur at 25°C and 100 kPa (normal atmospheric pressure)		✓
one liquid gives one gas	✓	
one liquid gives two gases		✓
$H_2O(l) \longrightarrow H_2O\ (g)$	✓	
$2H_2O(l) \longrightarrow 2H_2\ (g) + O_2\ (g)$		✓
attraction between molecules overcome	✓	
covalent bonds broken and formed		✓

Bond energy

Which of these two bonds has the highest bond energy? O – H

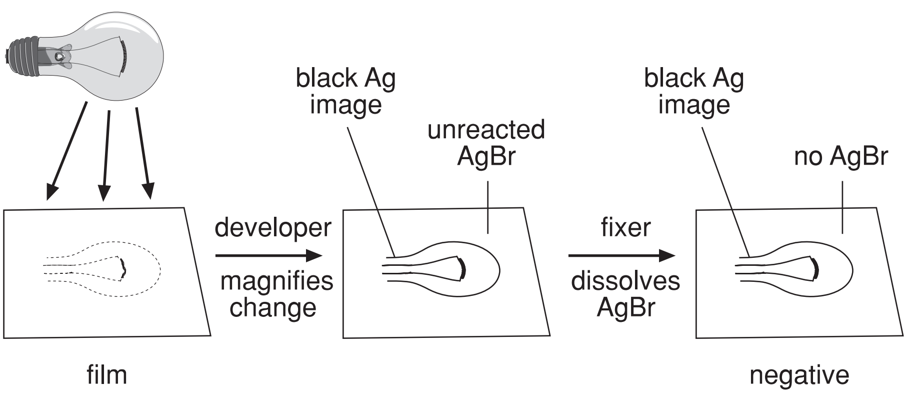
Which of these two bonds is more difficult to break? O – H

Decomposition reactions

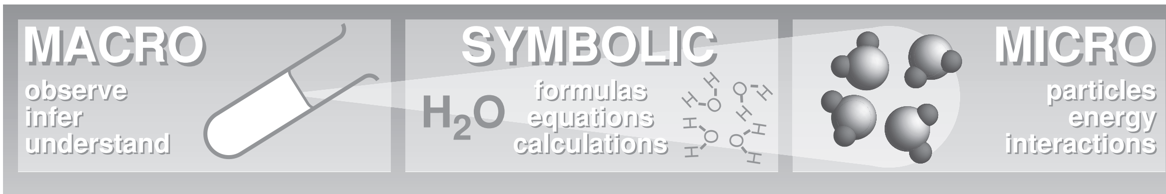
1 $CuCO_3 \rightarrow CuO + CO_2$

2 $2H_2O \rightarrow 2H_2 + O_2$

Effect of light on silver salts



Light is shone through the negative onto print paper and the developing and fixing repeated to produce a positive (the photograph).



Exercises – Part 4

Exercises 4.1 to 4.5 Name: ________________________________

Exercise 4.1: The energy used to extract oxygen

Right now, as you breathe, you are using energy to extract an element from a naturally occurring source called air.

The element you extract from air is called ________________________ .

The energy of movement of your lungs, diaphragm and rib muscles comes from ________________ potential energy in food that you have eaten.

Most food is changed to glucose sugar in living cells. The glucose reacts with oxygen to release energy in a process called respiration:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy

Name the two products of respiration:

________________ and ________________.

In green plants these two products of respiration are reactants for photosynthesis. Look back in your notes and copy out the equation for photosynthesis.

____

Photosynthesis is a reaction that absorbs energy.

Respiration is a reaction that ________________ energy.

Use the information above to explain how energy from the sun changes to energy that you use to move muscles so you can breathe.

____

____

____

____

____

Exercise 4.2: Physical and chemical changes

The kitchen is a place where a lot of physical and chemical changes occur. The physical changes are easily reversed by adding or removing heat. The chemical changes are difficult to reverse in order to obtain the reactants again.

Label each of these kitchen changes as physical or chemical:

- freezing of water
- melting of butter
- boiling an egg until it is hard-boiled
- dissolving salt in a saucepan of water
- boiling the salty water
- baking a cake from cake mixture
- blending dried fruit
- making an omelette from eggs and other food
- preparing plain rice for eating
- melting and reshaping chocolate in moulds
- making soup
- filtering coffee

Exercise 4.3: Iron in food

Iron in food can be as the element or as part of a compound. If the iron is part of a compound it is usually as iron (II) ions Fe^{2+} or iron (III) ions Fe^{3+}.

The average human body contains 4 g of iron. How big an iron nail can be made from 4 g of iron? Next time you see iron nails for sale use the information on the packet giving total mass and the number of nails to estimate the size of a 4 g iron nail.

Most human body iron is in the oxygen carrying part of haemoglobin protein molecules in red blood cells. If not enough iron is absorbed into your body or you lose too much blood you can suffer from the tiredness symptoms of the disease anaemia.

Some dry breakfast cereals contain iron as the element. Look at breakfast cereal packets at home or in a supermarket and find out how much iron is in certain cereals:

Name of cereal	**Amount of iron/amount of cereal**

(Did you remember to show units in the second column?)

If you have a magnet you can try to extract iron from dry breakfast cereal featuring iron in its advertising or contents! Your magnet could be:

- a pair of scissors that attract pins
- a refrigerator magnet
- a metal or ceramic magnet covered in some plastic.

You should aim to carry out a fair, that is well-controlled, experiment. Make sure the magnet is clean and there are no particles stuck to the magnet before you start.

1. Crush dry breakfast cereal into small pieces.
2. Add enough water to just cover the cereal.
3. Stir the cereal/water mix with the magnet for 10 minutes.
4. Gently shake off excess cereal then wash the magnet gently in a bowl of water
5. Examine the pointed tips of the scissors/edge and surface of the refrigerator magnet/plastic near the poles of the magnet.

6 Wipe any small dark pieces onto a sheet of paper. What happens when you bring the magnet near them? Draw and describe what you can see including a scale in your diagram.

Exercise 4.4: Balancing synthesis equations

Complete and balance the following synthesis equations.
(Remember oxygen, iodine, hydrogen and nitrogen elements are all diatomic molecules and should be written as O_2, I_2, H_2 and N_2 in equations).

a) iron + sulfur → iron(II) sulfide

Fe + S →

b) magnesium + oxygen → magnesium oxide

+ → MgO

c) hydrogen + oxygen → water

+ →

d) zinc + iodine → zinc iodide

+ → ZnI_2

e) aluminium + iodine → aluminium iodide

+ → $Al\ I_3$

f) iron + oxygen → iron(III) oxide

+ → Fe_2O_3

g) carbon + oxygen → carbon dioxide

+ →

h) carbon + oxygen → carbon monoxide

+ →

Exercise 4.5: Balancing decomposition equations

Complete and balance the following decomposition reactions. Remember to use H_2, O_2 and N_2 for hydrogen, oxygen and nitrogen.

a) water → hydrogen + oxygen

→ +

b) sodium carbonate → sodium oxide + carbon dioxide

→ +

c) mercury (II) oxide → mercury + oxygen

HgO → +

d) magnesium carbonate → magnesium oxide + carbon dioxide

$MgCO_3$ → +

e) lead azide → lead + nitrogen

PbN_6 → +

f) calcium carbonate → calcium oxide + carbon dioxide

$CaCO_3$ → CaO +

g) sodium hydrogen carbonate → sodium oxide + water + carbon dioxide

$NaHCO_3$ → + +

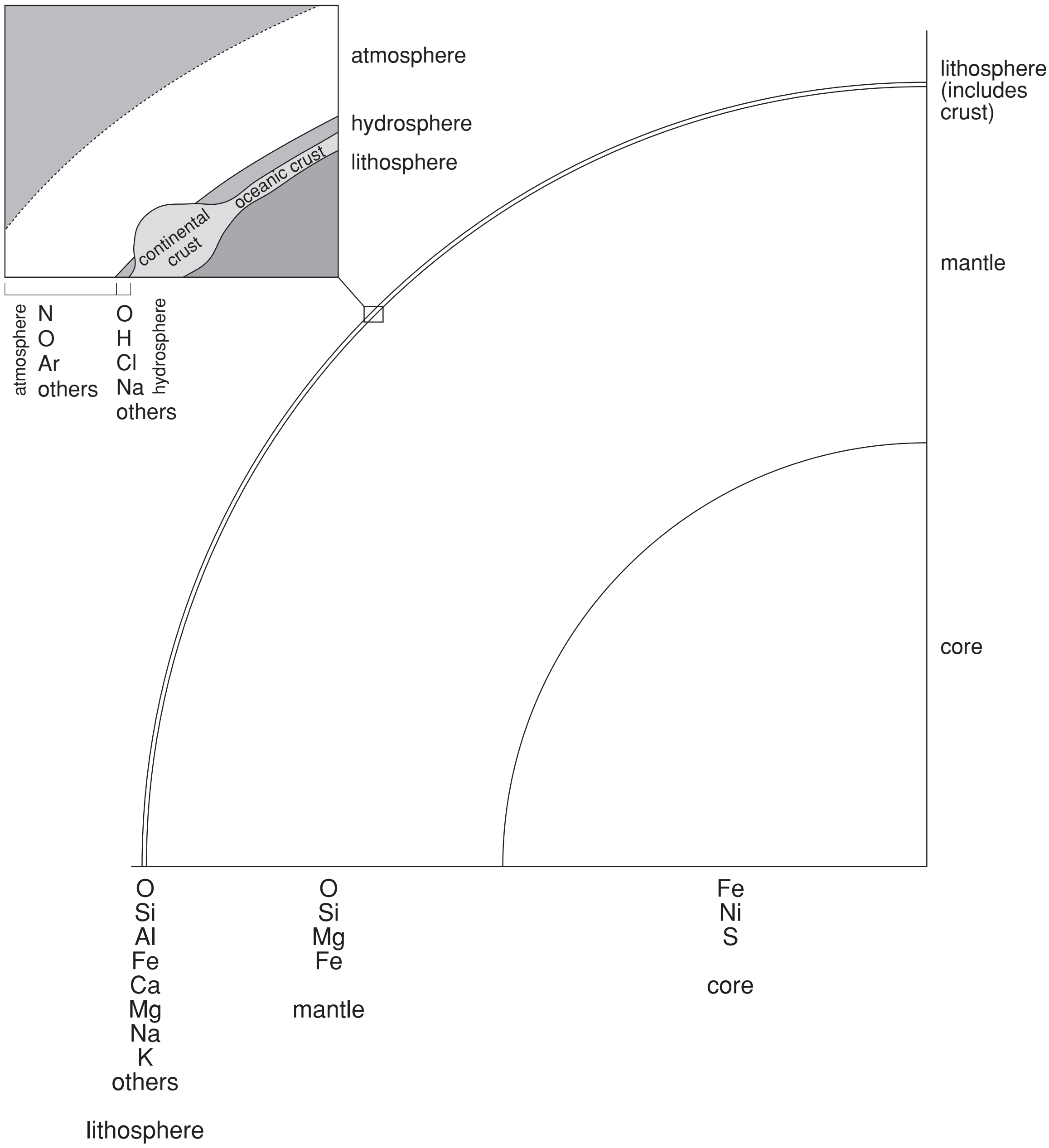
Chemistry
Preliminary Course
Stage 6

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING
TAFE NSW
OPEN TRAINING AND EDUCATION NETWORK - DISTANCE EDUCATION

The chemical earth

Part 5: Bonding and structure models

Incorporating October 2002
AMENDMENTS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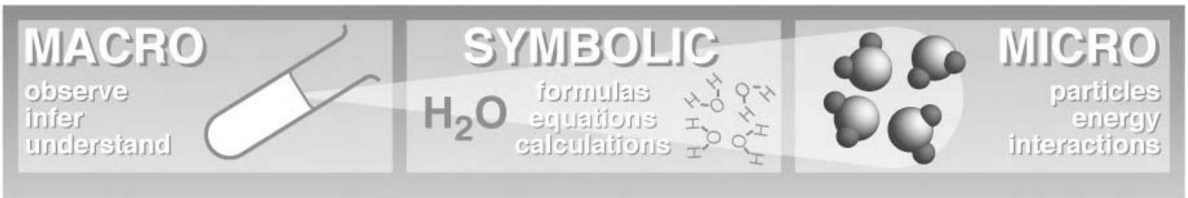
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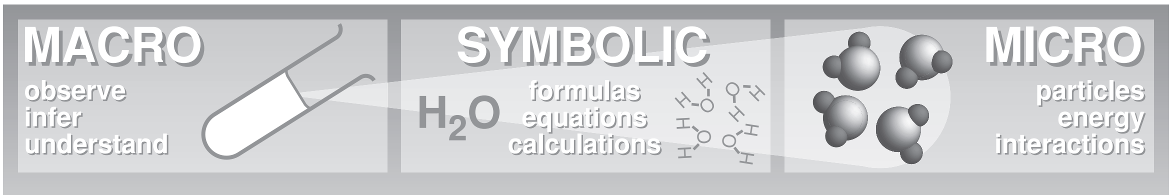
Contents



Introduction

During this part you will investigate the properties of elements and compounds and learn how these are determined by their bonding and structure.

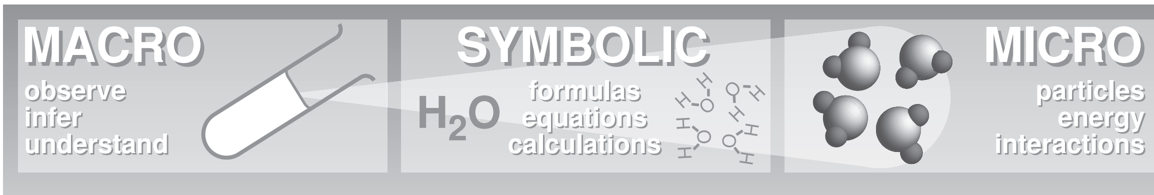
In Part 5 you will be given opportunities to learn to:

- identify differences between physical and chemical properties of elements, compounds and mixtures
- describe the physical properties used to classify compounds as ionic or covalent molecular or covalent network
- distinguish between metallic, ionic and covalent bonds
- describe metals as three-dimensional lattices of ions in a sea of electrons
- describe ionic compounds in terms of repeating three-dimensional lattices of ions
- identify common elements that exist as molecules or as covalent lattices
- explain the relationship between the properties of conductivity and hardness and the structure of ionic, covalent molecular and covalent network structures.

In Part 5 you will be given opportunities to:

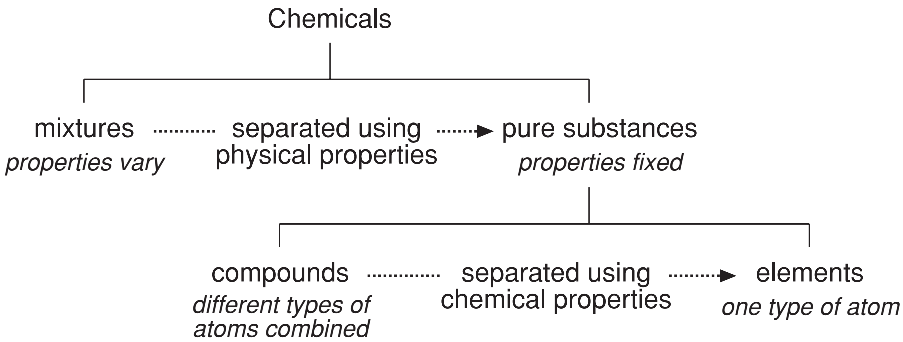
- perform a first-hand investigation to compare the properties of some common elements in their elemental state with the properties of the compound(s) of these elements (eg magnesium and oxygen)
- choose resources and process information from secondary sources to construct and discuss the limitations of models of ionic lattices, covalent molecules and covalent and metallic lattices

- perform an investigation to examine the physical properties of a range of common substances in order to classify them as metallic, ionic or covalent molecular or covalent network substances and relate their characteristics to their uses.



Properties of substances

In Part 1 of this module you compared the different type of chemicals found in nature.



Fill in the spaces in the summary below.

1 You have learnt:

- that the __________________ (chemical and physical) of mixtures varied
- how differences in _________________ properties were used to separate mixtures into pure substances
- that the _________________ (chemical and physical) of pure substances are fixed
- how chemical changes can be used to separate a compound into its elements such as in the decomposition of water to _______________ and oxygen.

2 You also learned that a _________________ property is a property of a substance by itself whereas a ________________ property is a property of the substance reacting with another chemical.

Check your answers.

Compounds and their elements

For this activity you will be burning magnesium in the oxygen of air.
It is very important that you do not look directly at burning magnesium.
Ultra-violet radiation emitted from the burning magnesium may cause eye damage.

You will need:

- about 5 cm length of magnesium ribbon
- a wooden peg or metal tweezers to hold an end of the magnesium ribbon
- a box of matches and a candle on a piece of cardboard.

What you will do:

Read through all the numbered instructions below before carrying out the activity:

1 Light the candle.

2 Holding one end of the magnesium ribbon in the peg or tweezers, place the other end in the flame about half a centimetre above the top of the wick.

3 Observe closely what happens to the magnesium but as soon as it starts to burn and give out a white light look away and move the burning magnesium out of the flame.

4 When the chemical change is complete look at the new substance, magnesium oxide, that was produced.

magnesium + oxygen $\longrightarrow$ magnesium oxide

$2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$

a) Write a sentence describing the appearance of the product of this chemical change.

b) You have just described a synthesis reaction. The table on the next page contains physical and chemical properties of the two reactants and the single product. Six parts of the table have been left for you to complete.

Chemical	magnesium		
State at 25°C		gas	
Colour			white
MP (°C)	650	-219	2852
BP (°C)	1110	-183	3600
Density (g cm^{-3})	1.74	1.15 (l)	3.6
Electrical conductivity	very high	negligible	negligible
Solubility in water	insoluble	slightly soluble	reacts giving $Mg(OH)_2$
Reaction with hydrochloric acid	reacts giving H_2 gas	no reaction	reacts giving $MgCl_2$

c) How many of the eight properties listed are physical properties?

____

d) Choose one of the answers in brackets in the sentence below.

When an element goes from being a pure element to being part of a compound its properties (stay the same/change).

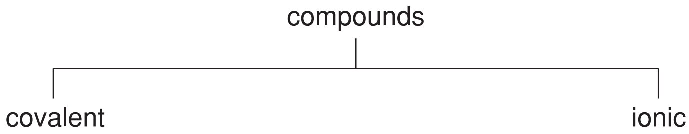
e) Here is another table comparing two elements and the compound formed when they combine. Can you fill in the three vacant parts?

Chemical		hydrogen	
State at 25°C	liquid		gas
MP (°C)	0	-259	-219
BP (°C)	100	-253	-183

Check your answers.

Classifying using physical properties

In Part 1 of this module you learnt that one way of classifying compounds was into ionic compounds and covalent compounds. This way of classifying is based on physical properties, especially electrical conductivity and melting point.



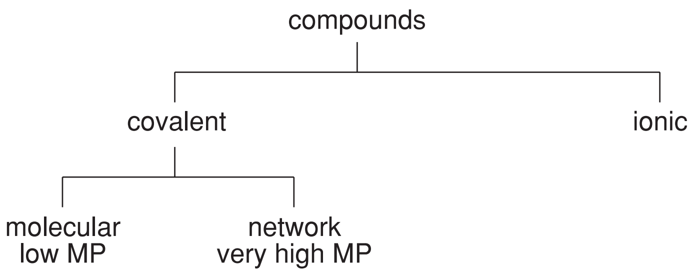
Covalent:

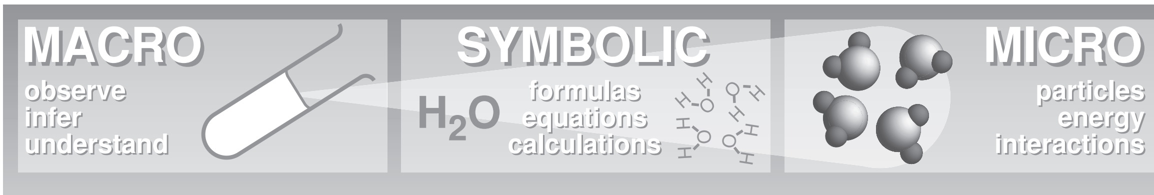
- non-conductors of electricity when liquid or dissolved in water
- low MP or very high MP
- usually gas, liquid or low MP solid; sometimes very high MP solid
- solids are soft and pliable or extremely hard

Ionic:

- conductors of electricity when liquid or dissolved in water
- high MP
- always solid at room temperature
- brittle solids

In this Part 5 you will learn why melting point is a useful physical property to classify covalent compounds as either covalent molecular or covalent network.





Bonding and structure

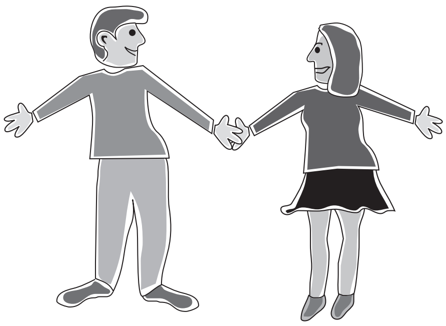
The Earth's natural resources are the source of chemicals. Natural resources extracted from the biosphere, lithosphere, hydrosphere and atmosphere are rarely pure. They need to be separated to provide pure chemical substances which have fixed properties and more predictable reactions than impure substances. The properties of pure substances can be understood in terms of bonding and structure.

Bonding refers to the strong interactions between:

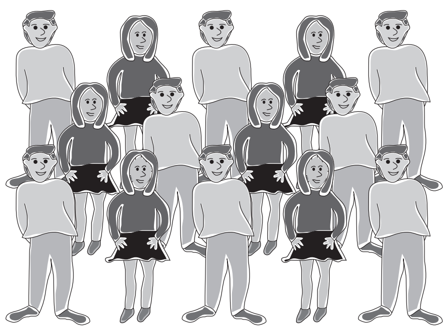
- atoms in metallic elements – known as metallic bonding
- ions in ionic compounds – known as ionic bonding
- atoms in covalent elements and compounds – known as covalent bonding.

Structure refers to the ways particles are arranged, particularly in the solid state where particles have fixed positions. It is very important that you understand the difference between bonding and structure.

Sometimes the same words are used to describe bonding and structure. For example a metal is said to have metallic bonding and a metallic structure. If you are asked to describe a metallic structure make sure your answer describes the way particles are arranged and not the interactions between particles. A question about ionic structure must be answered in terms of the arrangement of particles in an ionic compound and not just in terms of ionic bonding.



students "bonding"



student structure

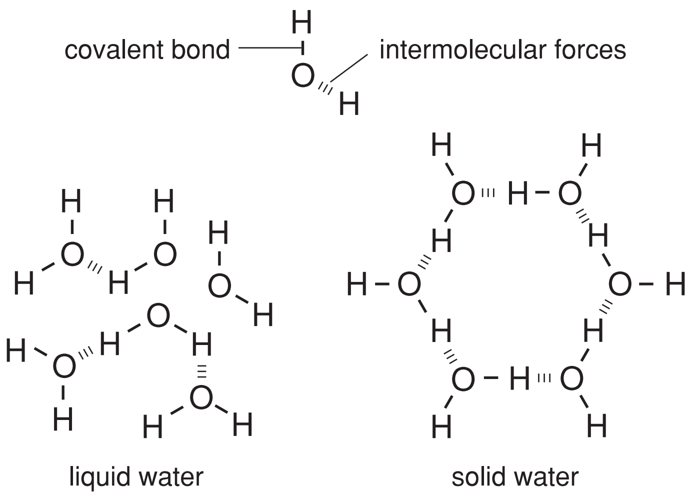
Explaining physical properties

The (macro level) properties of a substance that you can observe can be explained by (micro level) models of bonding and structure.

Bonding in covalent substances

Consider the majority of covalent substances – those that have a low MP. They are either gas, liquid or low MP solid at room temperature.

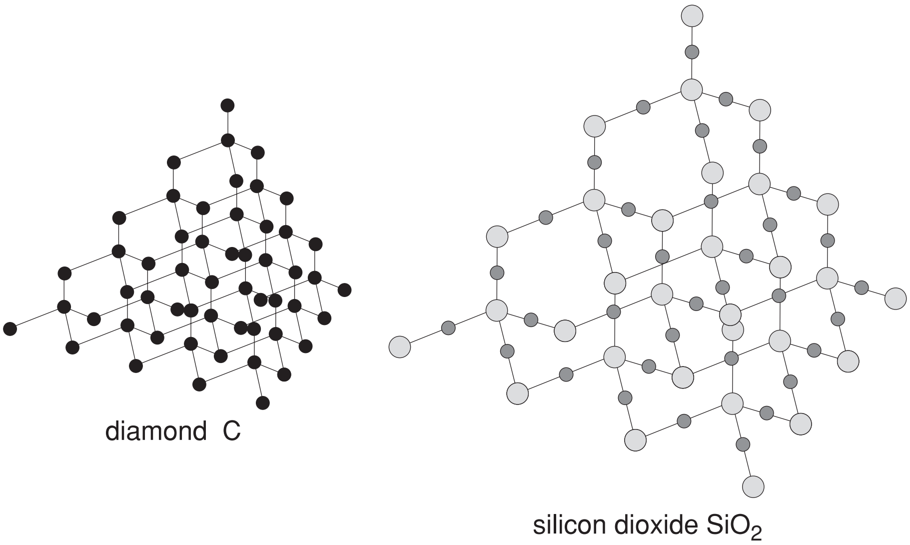
Most covalent molecular substances are made up of molecules with weak intermolecular forces. Strong covalent bonds keep the atoms together within the molecules but the covalent bonds do not need to be overcome to separate the molecules.



The atoms in water molecules are covalently bonded. There are also forces between molecules.

A minority of covalent substances, such as diamond and silicon dioxide, have very high MPs and are extremely hard solids.

The very high MP covalent solids are said to have covalent lattice or covalent network structures. A huge number of atoms are covalently bonded into giant three-dimensional structures. Melting these structures requires a lot of energy as many covalent bonds need to be broken.



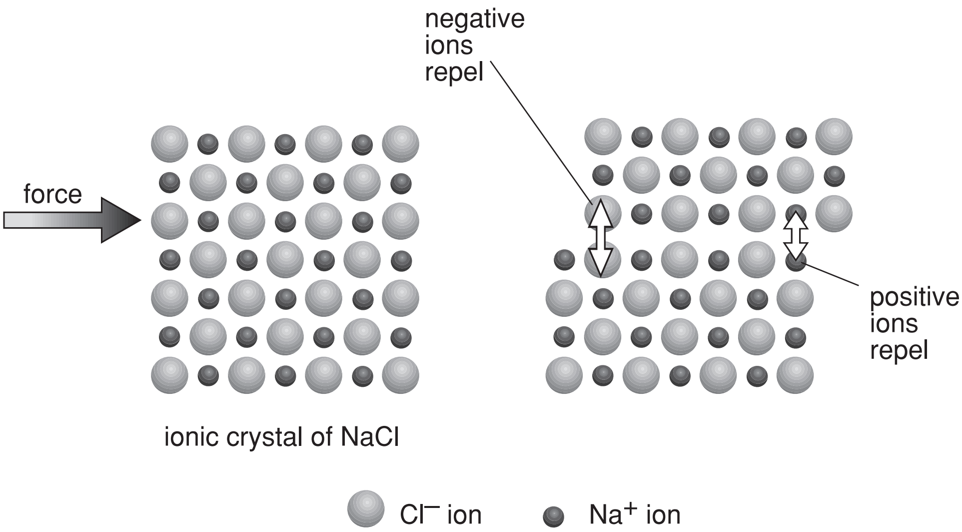
Covalent lattice or covalent network structures.

Bonding in ionic compounds

Ionic compounds are made up of charged particles called _______.
Ionic compounds are always solids with ______ MPs because a lot of energy is needed to separate the oppositely charged particles.

Check your answers.

The diagram below explains why ionic solids are brittle and their crystals shatter easily.



Why ionic solids shatter

The forces of attraction between molecules are weak intermolecular forces while the forces between ions are strong ionic bonds.

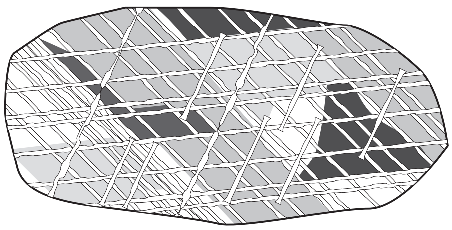
The weak intermolecular forces between molecules explains why covalent solids such as candle wax are soft and pliable (easily shaped).

Covalent substances are non-conductors because they are made up of neutral particles (molecules or atoms) or covalently bonded into fixed positions in a covalent network.

Metal bonding and structure

In part 2 of this module you saw how a dividing line could be drawn in the periodic table between metals and non-metals. This division was based upon observable (macro level) physical properties. The (micro level) explanation for the different physical properties of metals and non-metals is based on the presence or absence of metallic bonds.

The simplest model for metals that you can use pictures a three-dimensional regular arrangement (lattice) of metal atoms – the metal lattice model. This model is based on observations made on the polished and etched surfaces of iron meteorites and on microscope examination of clean metal surfaces.



Patterns on the etched surface of a polished iron meteorite section.

The straight lines seen on etched meteorites and straight edges seen on metal crystal (grain) boundaries led scientists to a model suitable for explaining the regular shape of metal crystals (grains).

Making a metallic lattice model

For this activity you need round lollies such as orange jaffas® or white koolmints® or the many colours in koolfruits®.

1 Find a tray or lid with sides in which you can place layers of the round lollies.

2 Fill the bottom layer of the tray with one colour and shake and tap until the lollies ('metal atoms') line up.

3 a) Can you see a regular array?______________________________

b) Add another layer and tap the tray/lid. Where does this second layer fit in? ____

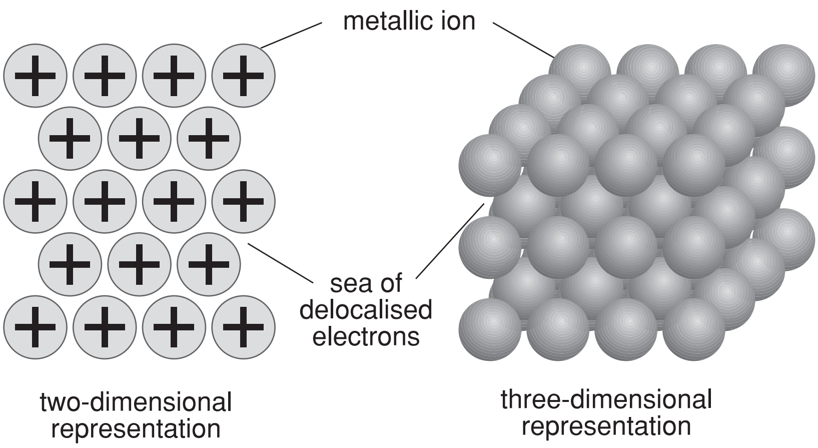
c) Finally add a third layer, tap and look at where this third layer fits in. Draw a section showing the three layers as seen from the side.

Check your answers.

Metallic bond model

Consideration of the physical properties of metals and the forces between metal atoms led scientists to a more powerful model – the metallic bond model. The metallic bond model pictures a three-dimensional lattice of positive ions in a sea of electrons.

Quantitative measurements show that the outer (valence) electrons of metal atoms are loosely held. Thus each metal atom can be represented by a positive ion and a loosely held electron. The electrons are said to be delocalised ie not attached to any particular positive ion. The positive ion lattice is surrounded by a sea of electrons able to move freely through the lattice.

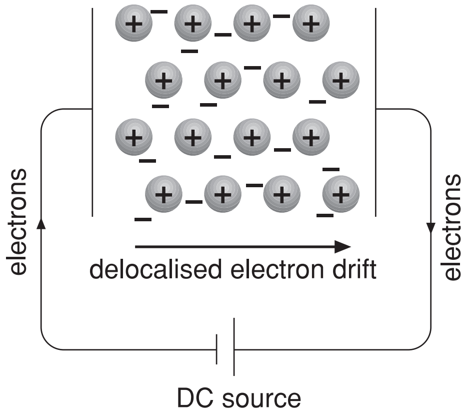


Metallic bond model shown in 2-D and 3-D representations

Models are useful for explaining, making predictions and suggesting new directions for scientific thought and experimentation. Models arise, work or don't work, are challenged, can be superseded and replaced. Sometimes a number of models are available for a scientist to choose from. The simpler metallic lattice model is good for explaining regular shape in metals but physical properties are best explained by the metallic bond model.

The metallic bond model can be used to explain the properties of metals.

- Metals are good conductors of electricity

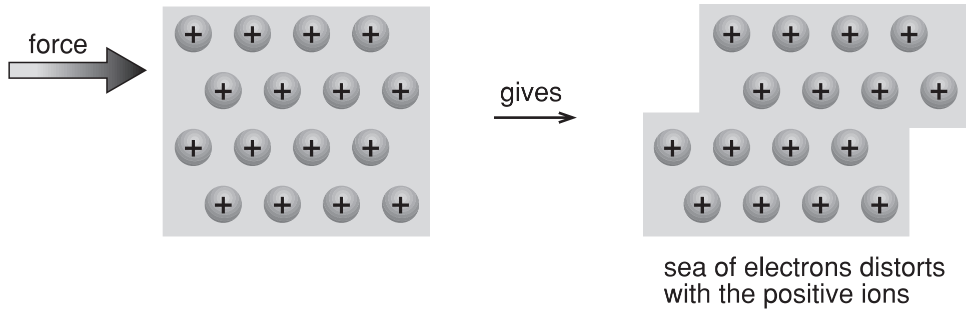


- Metals are good conductors of heat.

  Delocalised electrons are very mobile and can move quickly from high temperature to low temperature carrying energy of vibration with them. The energy of vibration (heat) of the mobile electrons can be transferred to the surrounding positive metal ions.

- Metals are malleable (easily shaped by compression forces) and ductile (easily drawn into wire by stretching forces).

  The metal structure can be distorted without shattering because the positive ions are held together by a sea of electrons. These delocalised electrons move freely so the positive ions are always surrounded by attracted negative electrons. This 'glue' of delocalised electrons prevents the positive ions from repelling one another.



- Metals have a shiny surface (called a lustre). The electrons absorb light that falls on the metal surface and re-emit the light so the surface appears shiny.

Summary of strong chemical bonds

There are three types of strong chemical bonds– metallic, ionic and covalent.

Using the knowledge and understanding you have developed about bonding complete the summary table below using the following terms.

any metal

atoms

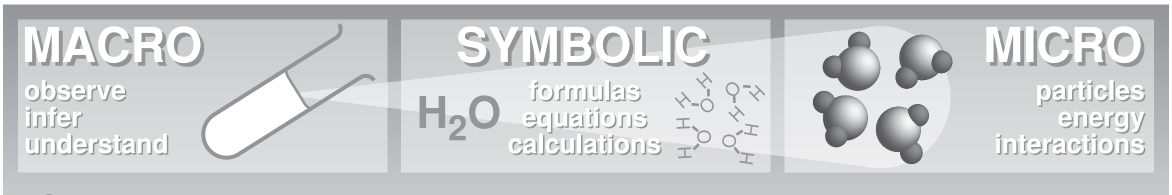
cations (+) and anions (–)

ionic lattices

metallic lattices.

Bond name:	**metallic**	**ionic**	**covalent**
found in:			• covalent molecules • covalent lattices
particles bonded:	cations(+) and electrons(–)		
examples:		any salt	H_2O, CO_2, I_2 C(diamond), SiO_2
energy absorbed to break one mole of bonds (kJ)	75–1000	400–4000	150–1100
energy released if one mole of bonds is formed (kJ)	75–1000	400–4000	150–1100

Check your answers.



Chemical structure

Ionic structure

Ionic compounds have many uses. Below is a list of readily available ionic compounds. Tick any that you have seen at home or at suppliers.

Common name	**Chemical name**	**Chemical formula**	**Where purchased**
sulfate of ammonia	ammonium sulfate	$(NH_4)_2SO_4$	garden supplies
animal shells, marble chips	calcium carbonate	$CaCO_3$	building supplies
plaster, gypsum	calcium sulfate	$CaSO_4$	building supplies
bluestone	copper(II) sulfate	$CuSO_4$	garden supplies
red iron oxide	iron(III) oxide	Fe_2O_3	building supplies
Epsom salts	magnesium sulfate	$MgSO_4$	pharmacy
‘No Salt’	potassium chloride	KCl	supermarket
baking soda, bicarb soda	sodium hydrogen carbonate	$NaHCO_3$	supermarket
washing soda	sodium carbonate	Na_2CO_3	supermarket
table salt	sodium chloride	NaCl	supermarket

Note that in chemical names:

- metal names come before non-metal names
- metals which can form more than one ion have the ion charge shown in roman numerals inside brackets
- compounds of two elements only end in -ide
- the ending -ate indicates a third element, usually oxygen.

You will be asked to find samples of some of these ionic compounds. Make sure you ***read and heed any warnings*** on the label before using the sample.

Look closely at some samples and their crystals. A magnifying glass or microscope will give a better view.

If the crystals are too small, water soluble crystals [any of the samples in the table except calcium carbonate, calcium sulfate or iron (III) oxide] can be dissolved in a small amount of water and slowly evaporated to form large crystals.

Hopefully you noticed regular shapes in the crystals.

Draw the shapes of crystals you looked at using a graphite ('lead') pencil. Label the drawing shapes with the chemical name of the crystal. Include an indication of the size of the crystals in your drawings.

Table salt, sodium chloride, crystals vary a lot but regularities can be seen in their shape. The straight edges and regularities in shape are produced by the regular arrangement or structure of the ions that make up the crystal.

The particular shape characteristic of an ionic crystal depends on the relative sizes of the cations and anions. Anions are usually significantly larger than the cations. The micro level packing of larger anions around the smaller cations determines the macro level appearance of the crystal.

Sodium chloride crystals. Scale 1 : 50 = magnification 50 X.

Covalent molecules

Over 90% of the chemicals listed by the Chemical Abstracts Service consist of molecules. In molecules, atoms are covalently bonded so these chemicals are said to consist of covalent molecules.

The intermolecular (‘between molecules’) forces are much weaker than the intramolecular (‘within molecules’) covalent bonds. The strength of these weak intermolecular forces determines whether the covalent molecular substance is a gas, a liquid or a low melting point solid at room temperature.

Covalent networks (covalent lattices)

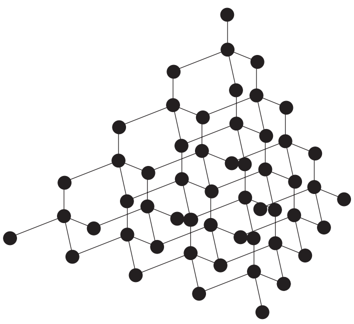
Less than 1% of the chemicals listed by the Chemical Abstracts Service consist of covalent networks. Covalent networks can also be called covalent lattices or continuous lattices. Each atom is covalently bonded to a number of other atoms in a three-dimensional network.

Covalent network substances:

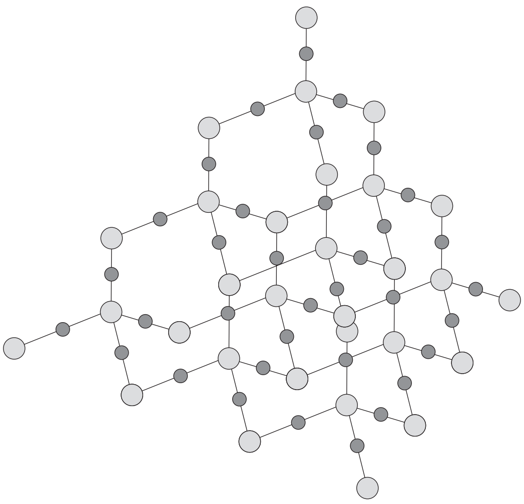
- have very high melting points because each atom has several covalent bonds which all have to be broken for atoms to move freely over one another
- are hard because each atom has strong covalent bonds pointing in particular directions producing a rigid structure.

Gemstones are rare, attractive minerals which are hard and durable. The hardness and durability is due to their covalent network structure.

Diamond is a covalent network of carbon atoms while ruby and sapphire are different coloured forms of the covalent network Al_2O_3. The red of ruby is produced by chromium impurity while the blue of sapphire is caused by iron and titanium impurities.

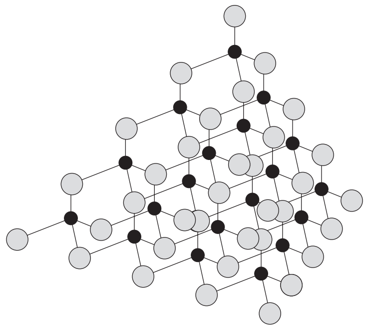


diamond C



silicon dioxide SiO_2

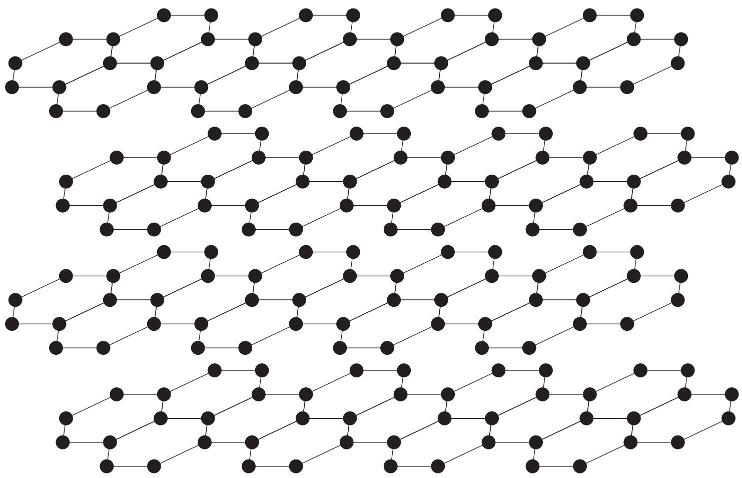
Diamond and silicon dioxide are examples of covalent network substances.



silicon carbide SiC

Silicon carbide forms a covalent network structure.

All covalent networks are poor electrical conductors except for the graphite form of carbon. Graphite consists of layers where the carbon atoms are covalently bonded together within a layer. However the layers are held together by weak forces produced by delocalised electrons between the layers. These delocalised electrons move freely between the layers.



graphite C

Graphite has a covalent network structure. It is a form of carbon that conducts electricity.

1 Take a graphite ('lead') pencil and run its tip over a paper surface.

2 If you have an electrical multimeter measure the conductivity or the resistance of the graphite of the pencil.

3 What happens to the tip of the pencil if you draw a lot of lines with it?

____

4 Good conductors of electricity will give high conductivity measurements or low resistance measurements on a multimeter. Poor conductors of electricity will give low conductivity measurements or high resistance measurements on a multimeter. Is graphite a good conductor or a poor conductor or something else? Give a reason in your answer.

____

5 Which of your observations is best explained by:

- graphite consisting of layers which can slide over one another

  ____

- delocalised electrons free to move between the layers in graphite?

  ____

6 The first zippers used in clothing were made of metal. Explain how running a graphite pencil between the metal surfaces lubricated metal zippers.

____

____

Check your answers.

Structure and hardness

The physical hardness of a solid depends on its structure.

Covalent network structures such as diamond and silicon dioxide are very hard. These structures have strong covalent bonds pointing in fixed directions in space. It is very difficult to bend or break these bonds.

Ionic substances such as sodium chloride are hard. The ionic bonds are strong. Although hard, if a force is exerted along a defect in the crystal, slight movement of one layer relative to other layers can cause repulsion and shattering of the crystal.

Metallic crystals have low to moderate hardness. Metallic bonds act in all directions, not just one direction. The sea of electrons moves with the metal cations and stops them from repelling one another. Metal crystals bend rather than shatter.

Covalent molecular solids are soft and pliable because only weak intermolecular forces keep the particles together.

Compare the hardness of substances

On a piece of paper place a small piece of pencil graphite and a small grain of silica sand.

Separately hit each with a hammer.

Which of these covalent networks is:

a) soft because it consists of two dimensional layers able to move over one another

____

b) hard because it consists of a three dimensional network of atoms

____

Check your answers.

Different structures of elements

The elements shown below have covalent bonding between their atoms:

												B	C_n	N_2	O_n	F_2	
													Si	P_n	S_8	Cl_2	
													Ge	As_n	Se_n	Br_2	
														Sb_n	Te	I_2	
																At_2	

Periodic table showing elements with covalent bonding.

Elements having the letter n with their symbol exist in different structures. These different structures are called allotropes of the element.

1 Can you give the two formulas for the allotropes of oxygen? ____ ____

2 C_n indicates that different structures (allotropes) of carbon exist. Can you name the two structures of carbon you have already studied? One of these is the hardest material known while the other is one of the softest!

____

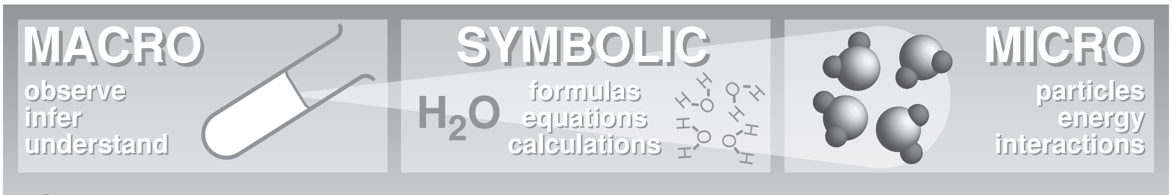
Check your answers.

Other structures of carbon – the fullerenes

Since 1990 a number of carbon structures such as C_{60}, C_{70}, and C_{540} have been discovered.

- C_{60} is shaped like a soccer ball and has been given various names such as buckminsterfullerene, buckyball and 'soccerball carbon'.
- C_{70} is like a rugby ball in shape.
- A diagram of C_{540} looks like a ball-shaped roll of chicken wire netting!

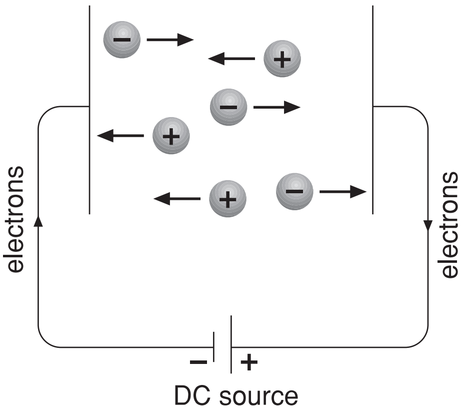
Web sites showing some of these structures can be found at the chemistry section of http://www.lmpc.edu.au/science.



Structure and physical properties

The most useful properties for determining the structure of a pure substance are:

- electrical conductivity in the solid state and the liquid state
- melting point
- hardness.

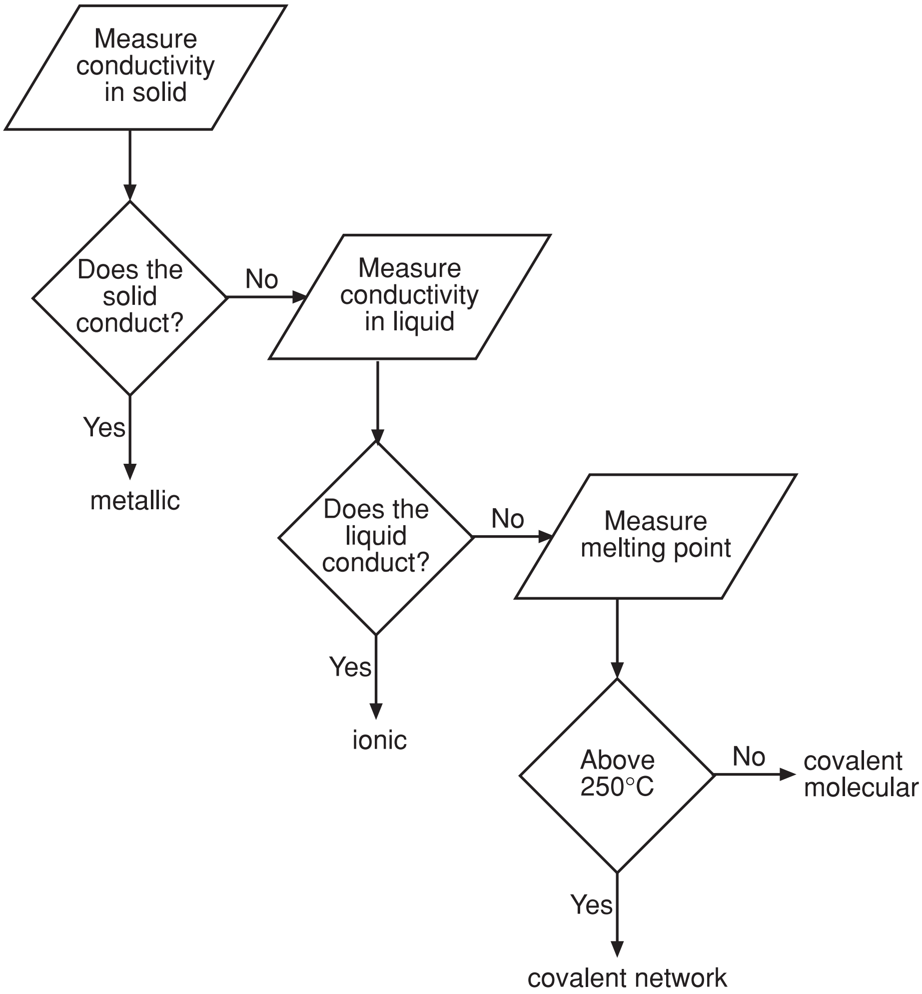


Ionic compounds conduct when liquid or in aqueous solution and ions are free to move

Solid ionic compounds do not conduct because their ions are in fixed positions

Covalent molecular and covalent network compounds cannot conduct at all because there are no charged particles present.

Here is one possible scheme for deciding on structure:



Using physical properties to classify

Use the flow chart on the previous page to complete the structure column of the table, *Properties of chemicals* in the Appendix. Use the properties to decide if the substance's structure is metallic, ionic, covalent network or covalent molecular. In the last column write metallic/ionic/covalent network/covalent molecular.

D = density in g cm^{-3} (*l*) = liquid MP = melting point in ^{o}C

s = sublimes d = decomposes deh = dehydrates (loses water)

Check your answers.

Relating properties to uses

In the previous activity you should have found six substances with a metallic structure. These metals all conduct in the solid state and in the liquid state.

1 Electrolysis of sodium chloride solutions sometimes requires an electrode that is fluid, ie can flow. Which of these six metals would you use and why?

2 Electrolysis often requires an inert electrode that will not react with acid. Rather than using a metal for the electrode which other substance could be used that is a good conductor in the solid state?

3 Unlike most metals this non-metallic substance does not react with acids and alkalis and so is often used in electrolysis (changing electrical energy into chemical energy) and batteries (changing chemical energy into electrical energy). If you ever see the inside of a battery look for the graphite parts.

How could you test a substance to see if it is graphite by using

a) a multimeter

b) a piece of paper ?

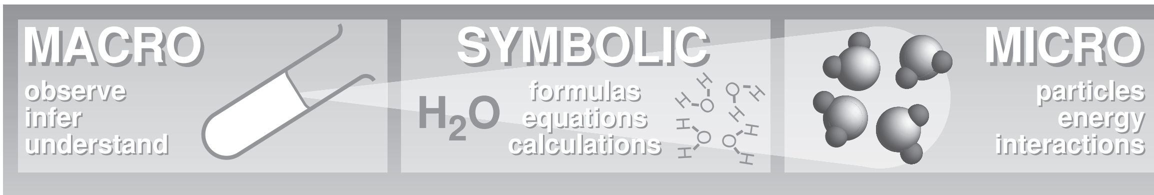
4 a) The covalent network substance shown in the table which is the strongest substance in nature and is used for cutting steel is:

b) Another covalent network substance in the table is a compound made from two elements in the same group (vertical column) of the periodic table. Small pieces of this substance are used on cutting and grinding tools and on abrasive paper. The substance is:

5 Name the two ionic substances with the highest MPs (both are oxides).

Both can be used in bricks to build high temperature kilns. They are strong and unreactive to the air even when heated above 1500°C.

Check your answers.



Appendix

Properties of chemicals

D = density in g cm^{-3} (*l*) = liquid MP = melting point in ^{o}C

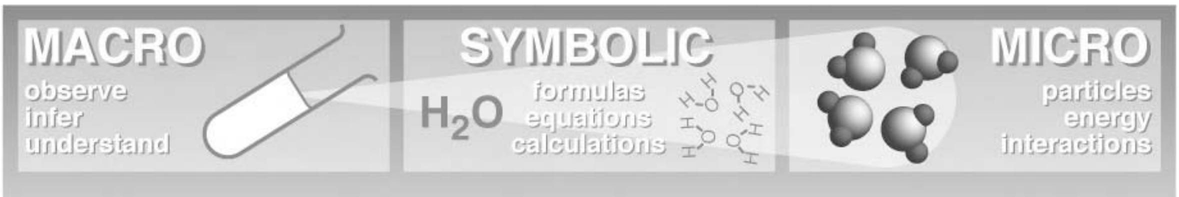
s = sublimes d = decomposes deh = dehydrates (loses water)

Chemical name	Formula	Common name	D	MP	Conducts		Structure
					solid	liquid	
ammonia	NH_3	ammonia		-78	no	no	
bromine	Br_2	bromine	2.9	-7	no	no	
calcium carbonate	$CaCO_3$	limestone, garden lime	2.7	d899	no	-	ionic
calcium oxide	CaO	lime, quicklime	3.4	2850	no	yes	
diamond	C	diamond	3.5	3547	no	-	
graphite	C	graphite	2.3	3974	yes	-	covalent network
carbon dioxide	CO_2	carbon dioxide		s-79	no	no	
carbon monoxide	CO	carbon monoxide		-205	no	no	
chlorine	Cl_2	chlorine		-103	no	no	
copper	Cu	copper	8.9	1083	yes	yes	

Chemical name	Formula	Common name	D	MP	Conducts		Structure
					solid	liquid	
blue basic copper(II) carbonate	$2CuCO_3$, $Cu(OH)_2$	blue azurite	3.9	d220	no	-	ionic
green basic copper(II) carbonate	$CuCO_3$, $Cu(OH)_2$	green malachite	4.0	d200	no	-	ionic
copper (II) sulfate	$CuSO_4$	anhydrous copper sulfate	3.6	d560	no	-	ionic
copper (II) sulfate-5-water	$CuSO_4.5H_2O$	hydrated copper sulfate	2.3	d110	no	-	ionic
ethanoic acid	CH_3COOH	glacial acetic acid	1.0	17	no	no	
ethanol	C_2H_5OH	alcohol	0.8	-114	no	no	
D-glucose	$C_6H_{12}O_6$	glucose	1.6	d146	no	no	
helium	He	helium		-272	no	no	monatomic molecule
hydrogen	H_2	hydrogen		-259	no	no	
hydrogen bromide	HBr	hydrogen bromide		-87	no	no	
hydrogen chloride	HCl	hydrogen chloride		-115	no	no	
hydrogen oxide	H_2O	water	1.0	0	no	no	
hydrogen sulfide	H_2S	rotten egg gas		-89	no	no	
iodine	I_2	iodine	4.9	s113	no	no	

Chemical name	**Formula**	**Common name**	**D**	**MP**	**Conducts**		**Structure**
					solid	**liquid**	
iron(III) oxide	Fe_2O_3	red ochre	5.2	1565	no	yes	
lead	Pb	lead	11.3	327	yes	yes	
magnesium	Mg	magnesium	1.7	651	yes	yes	
magnesium oxide	MgO	magnesium oxide	3.6	2852	no	yes	
hydrated magnesium sulfate	$MgSO_4.7H_2O$	Epsom salts	1.7	deh 150	no	yes	ionic
mercury	Hg	mercury	13.6	-39	yes	yes	
oxygen (diatomic)	O_2	oxygen	1.1 (*l*)	-219	no	no	
oxygen (triatomic)	O_3	ozone	1.6 (*l*)	-193	no	no	
potassium chloride	KCl	potassium chloride	2.0	770	no	yes	
silicon	Si	silicon	2.3	1410	no	no	
silicon carbide	SiC	carborundum	3.2	2986	no	no	
silicon dioxide	SiO_2	silica sand	2.3	1713	no	no	
sodium	Na	sodium	0.97	98	yes	yes	
sodium carbonate	Na_2CO_3	soda ash	2.5	851	no	yes	
sodium carbonate-10-water	$Na_2CO_3.10H_2O$	washing soda	1.4	d34	no	-	ionic
sodium chloride	NaCl	table salt	2.2	801	no	yes	

Chemical name	Formula	Common name	D	MP	Conducts		Structure
					solid	liquid	
sodium hydroxide	NaOH	caustic soda	2.1	318	no	yes	
sucrose	$C_{12}H_{22}O_{11}$	cane sugar	1.6	186	no	no	
sulfur	S	rhombic S	2.1	s113	no	no	
sulfur dioxide	SO_2	sulfur dioxide		-73	no	no	
zinc	Zn	zinc	7.1	420	yes	yes	



Suggested answers

Properties of substances

1
- that the *properties* (chemical and physical) of mixtures varied,
- how differences in *physical* properties were used to separate mixtures into pure substances,
- that the *properties* (chemical and physical) of pure substances are fixed
- how chemical changes can be used to separate a compound into its elements such as in the decomposition of water to *hydrogen* and oxygen.

2 You also learned that a *physical* property is a property of a substance by itself whereas a *chemical* property is a property of the substance reacting with another chemical.

Compounds and their elements

4 a) White solid. In powder form, that is, very small pieces.

b)

Chemical	magnesium	*oxygen*	*magnesium oxide*
State at 25^{o}c	*solid*	gas	*solid*
Colour	*silvery*	*colourless*	white
MP (°c)	650	-219	2852
BP (°c)	1110	-183	3600
Density (g cm^{-3})	1.74	1.15 (*l*)	3.6
Electrical conductivity	very high	negligible	negligible
Solubility in water	insoluble	slightly soluble	reacts giving $Mg(OH)_2$
Reaction with hydrochloric acid	reacts giving H_2 gas	no reaction	reacts giving $MgCl_2$

c) How many of the eight properties listed are physical properties? *6 (the first 6)*

d) When an element goes from being a pure element to being part of a compound its properties *change*.

e)

chemical	*water*	hydrogen	*oxygen*
state at 25^{o}c	liquid	*gas*	gas
MP (°c)	0	-259	-219
BP (°c)	100	-253	-183

Bonding in ionic compounds

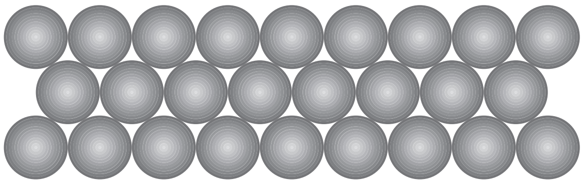
Ionic compounds are made up of charged particles called *ions*. Ionic compounds are always solids with *high* MPs because a lot of energy is needed to separate the oppositely charged particles.

Metal bonding and structure

3 a) Yes, the lollies fit close together.

b) The second layer particles fit into the holes of the first layer.

c) A section showing the three layers as seen from the side is shown below.



Three types of strong chemical bonds

Bond name:	**metallic**	**ionic**	**covalent**
found in:	*metallic lattices*	*ionic lattices*	• covalent molecules • covalent lattices
particles bonded:	cations(+) and electrons(–)	*cations (+) and anions (–)*	*atoms*
examples:	*any metal*	any salt	H_2O, CO_2, I_2 C (diamond), SiO_2
energy absorbed to break one mole of bonds (kJ)	75–1000	400–4000	150–1100
energy released if one mole of bonds is formed (kJ)	75–1000	400–4000	150–1100

Covalent networks (covalent lattices)

1 The pencil tip gets smaller if you draw a lot of lines with it.

4 Graphite is a good conductor. The delocalised electrons move freely between the covalently bonded layers.

5 • Graphite consisting of layers which can slide over one another explains why the pencil tip gets smaller.

- Delocalised electrons free to move between the layers in graphite explains why graphite is a good conductor.

6 Layers of graphite deposited on metal slide over one another reducing friction between the hard metal surfaces.

Compare the hardness of substances

a) Graphite is soft because it consists of two dimensional layers able to move over one another.

b) Silica sand is hard because it consists of a three dimensional network of atoms

Different structures of elements

1 Two formulas for the allotropes of oxygen are O_2 and O_3

2 Diamond and graphite are two structures of carbon.

Classifying structures using physical properties

CM = covalent molecular I = ionic M = metallic CN = covalent network

Chemical name	Formula	Common name	D	MP	Conducts		Structure
					s	l	
ammonia	NH_3	ammonia		-78	no	no	*CM*
bromine	Br_2	bromine	2.9	-7	no	no	*CM*
calcium carbonate	$CaCO_3$	limestone, garden lime	2.7	d899	no	-	ionic
calcium oxide	CaO	lime, quicklime	3.4	2850	no	yes	/

Chemical name	Formula	Common name	D	MP	Conducts		Structure
					s	l	
diamond	C	diamond	3.5	3547	no	-	*CN*
graphite	C	graphite	2.3	3974	yes	-	covalent network
carbon dioxide	CO_2	carbon dioxide		s-79	no	no	*CM*
carbon monoxide	CO	carbon monoxide		-205	no	no	*CM*
chlorine	Cl_2	chlorine		-103	no	no	*CM*
copper	Cu	copper	8.9	1083	yes	yes	*M*
blue basic copper(II) carbonate	$2CuCO_3$, $Cu(OH)_2$	blue azurite	3.9	d220	no	-	ionic
green basic copper(II) carbonate	$CuCO_3$, $Cu(OH)_2$	green malachite	4.0	d200	no	-	ionic
copper (II) sulfate	$CuSO_4$	anhydrous copper sulfate	3.6	d560	no	-	ionic
copper (II) sulfate-5-water	$CuSO_4$. $5H_2O$	hydrated copper sulfate	2.3	d110	no	-	ionic
ethanoic acid	CH_3COOH	glacial acetic acid	1.0	17	no	no	*CM*
ethanol	C_2H_5OH	alcohol	0.8	-114	no	no	*CM*
D-glucose	$C_6H_{12}O_6$	glucose	1.6	d146	no	no	*CM*
helium	He	helium		-272	no	no	monatomic molecule
hydrogen	H_2	hydrogen		-259	no	no	*CM*

Chemical name	**Formula**	**Common name**	**D**	**MP**	**Conducts**		**Structure**
					s	**l**	
hydrogen bromide	HBr	hydrogen bromide		-87	no	no	CM
hydrogen chloride	HCl	hydrogen chloride		-115	no	no	*CM*
hydrogen oxide	H_2O	water	1.0	0	no	no	*CM*
hydrogen sulfide	H_2S	rotten egg gas		-89	no	no	*CM*
iodine	I_2	iodine	4.9	s113	no	no	*CM*
iron(III) oxide	Fe_2O_3	red ochre	5.2	1565	no	yes	*I*
lead	Pb	lead	11.3	327	yes	yes	*M*
magnesium	Mg	magnesium	1.7	651	yes	yes	*M*
magnesium oxide	MgO	magnesium oxide	3.6	2852	no	yes	*I*
hydrated magnesium sulfate	$MgSO_4.7H_2O$	Epsom salts	1.7	deh 150	no	yes	ionic
mercury	Hg	mercury	13.6	-39	yes	yes	*M*
oxygen (diatomic)	O_2	oxygen	1.1 (*l*)	-219	no	no	*CM*
oxygen (triatomic)	O_3	ozone	1.6 (*l*)	-193	no	no	*CM*
potassium chloride	KCl	potassium chloride	2.0	770	no	yes	*I*
silicon	Si	silicon	2.3	1410	no	no	*CN*
silicon carbide	SiC	carborundum	3.2	2986	no	no	*CN*

Chemical name	Formula	Common name	D	MP	Conducts		Structure
					s	l	
silicon dioxide	SiO_2	silica sand	2.3	1713	no	no	*CN*
sodium	Na	sodium	0.97	98	yes	yes	*M*
sodium carbonate	Na_2CO_3	soda ash	2.5	851	no	yes	*I*
sodium carbonate-10-water	$Na_2CO_3.10H_2O$	washing soda	1.4	d34	no	-	ionic
sodium chloride	NaCl	table salt	2.2	801	no	yes	*I*
sodium hydroxide	NaOH	caustic soda	2.1	318	no	yes	*I*
sucrose	$C_{12}H_{22}O_{11}$	cane sugar	1.6	186	no	no	*CM*
sulfur	S	rhombic S	2.1	s113	no	no	*CM*
sulfur dioxide	SO_2	sulfur dioxide		-73	no	no	*CM*
zinc	Zn	zinc	7.1	420	yes	yes	*M*

Relating properties to uses

1 Mercury could be used as it is the only liquid metal at room temperature.

2 Graphite could be used for the electrode.

3 Testing a substance to see if it is graphite.

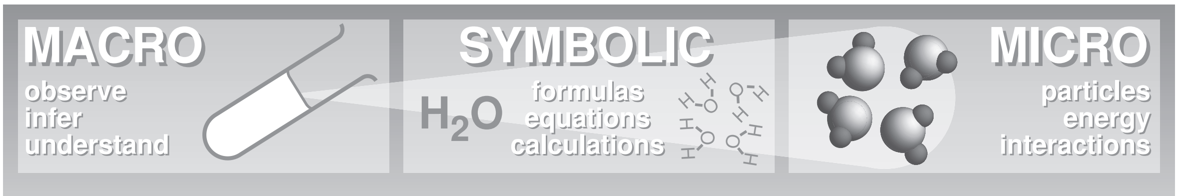
a) A multimeter shows high electrical conductivity and low resistance for graphite.

b) Run graphite over paper - should leave trail of layers.

4 a) The covalent network substance shown in the table which is the strongest substance in nature and is used for cutting steel is diamond.

b) The substance is silicon carbide.

5 Two ionic substances with the highest MPs, both oxides, calcium oxide and magnesium oxide.



Exercises – Part 5

Exercises 5.1 Name: ________________________________

Exercise 5.1: Limitations of models

In Part 3 you constructed models showing the structure of: metals, ionic compounds and covalent molecules.

a) Now you will construct at least one model of a covalent lattice (eg diamond, graphite, silicon dioxide, silicon carbide). Report on how you made this model.

b) Discuss the limitations of the models you made of:

i an ionic lattice

ii a metallic lattice

iii a covalent lattice

iv covalent molecules.

Chemistry
Preliminary Course
Stage 6

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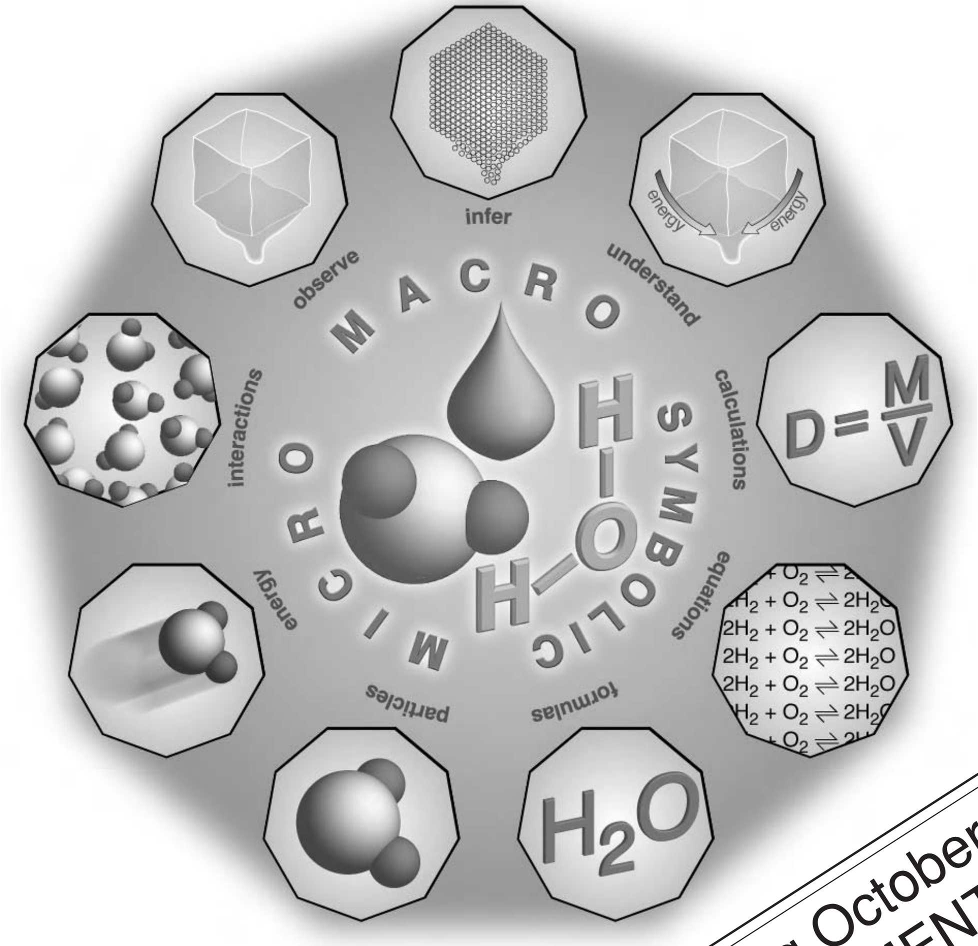
The chemical earth

Part 6: Review of chemical ideas



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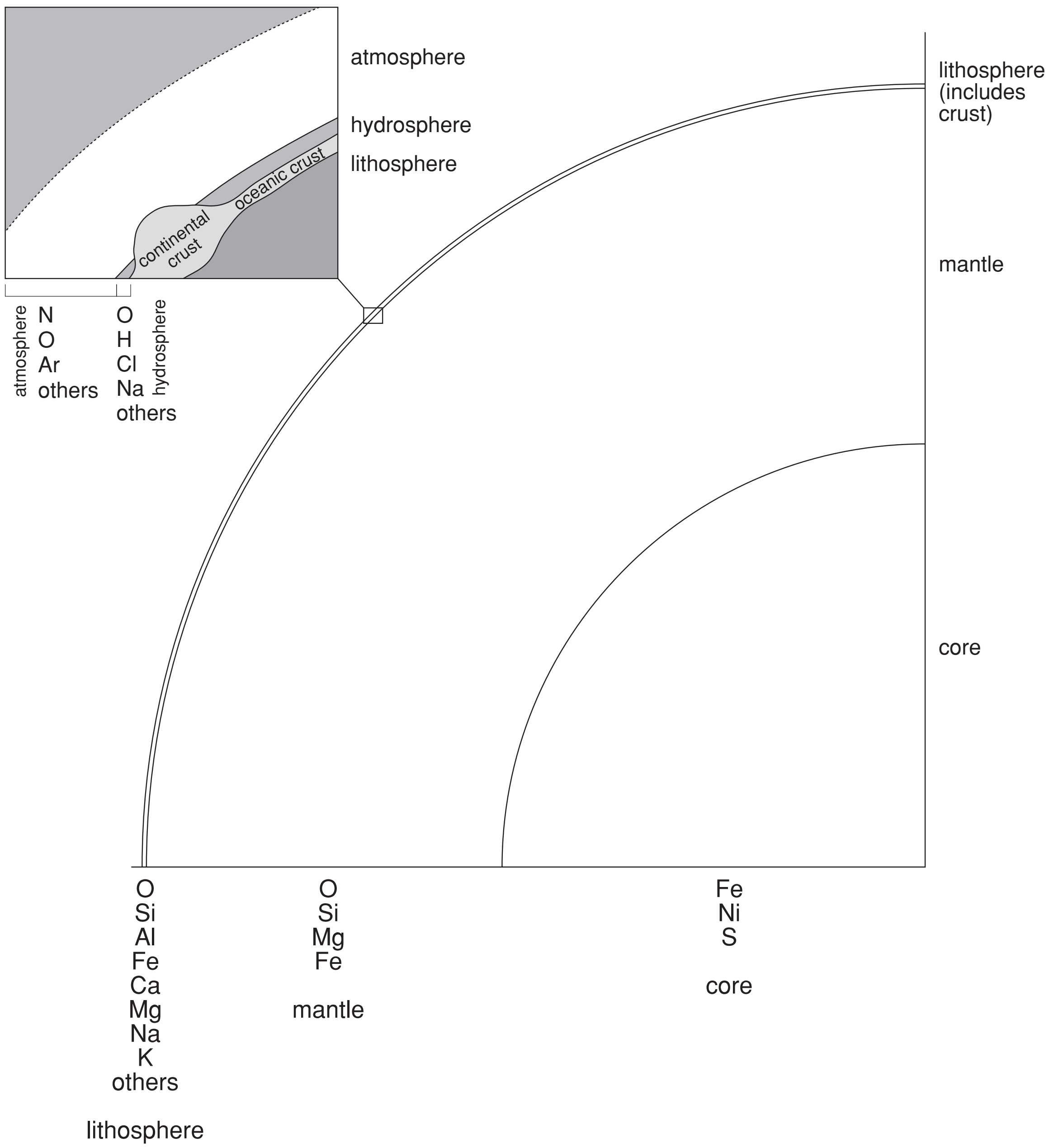
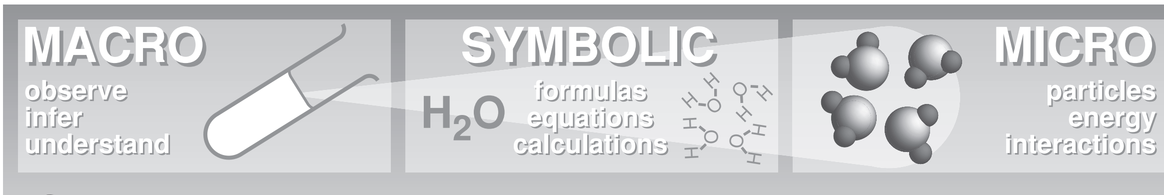
AMENDMENTS


atmosphere
hydrosphere
lithosphere
oceanic crust
continental crust
atmosphere
N
O
Ar
others
O
H
Cl
Na
others
hydrosphere
lithosphere (includes crust)
mantle
core
O
Si
Al
Fe
Ca
Mg
Na
K
others
lithosphere
O
Si
Mg
Fe
mantle
Fe
Ni
S
core


MACRO
observe
infer
understand
SYMBOLIC
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equations
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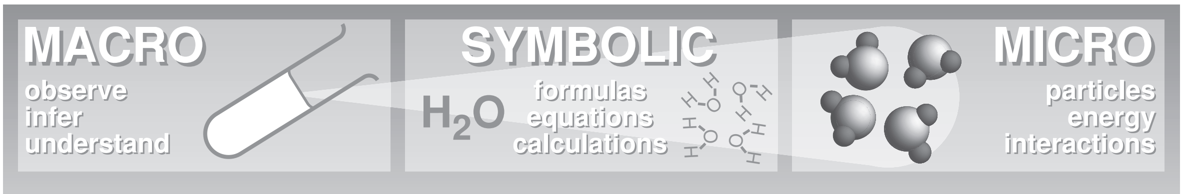
MICRO
particles
energy
interactions

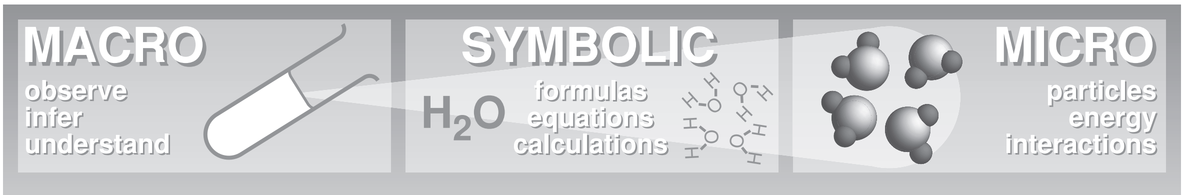
Contents



Introduction

In this part you will review the ideas you encountered in the first five parts of this module. You will complete a summary by:

- naming compounds
- writing chemical formulas
- writing chemical equations
- completing descriptions of chemical concepts
- assessing your understanding of key chemical ideas by determining if statements are true or false
- completing an exercise that draws on the knowledge gained throughout this part.



Naming compounds

Naming inorganic compounds

In Part 1 you started to learn how to name binary compounds, that is, compounds of two elements. In this part you will complete a summary.

There are many self-correcting questions in the summary below. Don't forget to check your answers as you go.

1 Compounds of two elements only usually end in -ide; the metal name comes first, the non-metal name last eg. sodium chloride.

What would you call the compound formed from reaction between:

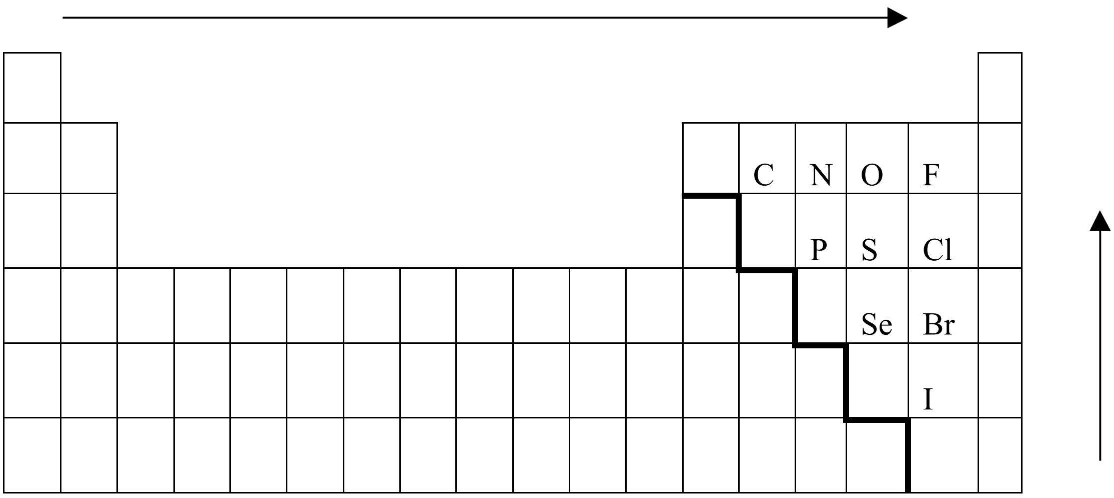
a) oxygen and magnesium ________________________________

b) zinc and iodine ____

c) sulfur and lead ____

d) copper and chlorine ____________________________________

2 In compounds of two non-metals the most non-metallic element is named last. Non-metallic character increases across a period and increases up a group. The most non-metallic element of all is fluorine. The further the non-metal is from the metal/non-metal dividing line then the more non-metallic it is.



Examples of compounds of two non-metals:

- carbon disulfide, CS_2
- nitrogen trichloride, NCl_3
- carbon tetrachloride, CCl_4
- phosphorus pentachloride, PCl_5
- sulfur hexafluoride, SF_6

Name the compounds made up of the following non-metal combinations.

a) one oxygen and one carbon ____________________________

b) one carbon and four fluorines ____________________________

c) two oxygens and one nitrogen ____________________________

3 Compounds of two non-metals have prefixes- showing the number of atoms.

Prefix	**Number of atoms**
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8

4 Metals which can have more than one charge on their ions have a Roman numeral equal to the charge placed in brackets after the metal name.

The Roman numeral in brackets is called the oxidation state.

Metal	Ions	Oxide formula and name
copper	Cu^{+}	Cu_2O copper (I) oxide
	Cu^{2+}	CuO copper (II) oxide
iron	Fe^{2+}	FeO iron (II) oxide
	Fe^{3+}	Fe_2O_3 iron (III) oxide
lead	Pb^{2+}	PbO lead (II) oxide
	Pb^{4+}	PbO_2 lead (IV) oxide
tin	Sn^{2+}	SnO tin (II) oxide
	Sn^{4+}	SnO_2 tin (IV) oxide

Name the metal compounds below using Roman numerals in brackets. (Remember you do not use prefixes - they are only used for compounds of non-metals with non-metals; knowing that the sulfide ion is S^{2-} and the chloride ion is Cl^{-} should help.)

a) CuS ____________________

b) Cu_2S ____________________

c) $FeCl_3$ ____________________

d) $PbCl_2$ ____________________

e) $SnCl_4$ ____________________

5 Compounds of three elements often end in -ate; the -ate usually indicates that the third element is oxygen.

Examples:

$PbSO_4$ lead(II) sulfate

KNO_3 potassium nitrate

$CaCO_3$ calcium carbonate

$NaClO_3$ sodium chlorate

Name these compounds.

a) $MgSO_4$ ____________________

b) $NaNO_3$ ____________________

c) $BaCO_3$ ________________________________

d) $KClO_3$ ________________________________

6 Polyatomic ions are ions made up from more than one atom.
For example:

– NH_4^+ ammonium ion

– SO_4^{2-} sulfate ion

– NO_3^- nitrate ion

– CO_3^{2-} carbonate ion

– ClO_3^- chlorate ion.

When there is more than one of a polyatomic ion in a formula the polyatomic ion is surrounded by brackets.

Examples

– $(NH_4)_2SO_4$ ammonium sulfate

– $Pb(NO_3)_2$ lead(II) nitrate

Name these compounds containing polyatomic ions.

a) NH_4NO_3 ________________________________

b) $(NH_4)_2SO_4$ ________________________________

c) Na_2CO_3 ________________________________

d) $Al_2(SO4)_3$ ________________________________

7 Some of the -ate polyatomic ions can have less or more oxygen.
If they have less oxygen the ending -ite is used.

For example:

– KNO_3 potassium nitrate but

– KNO_2 potassium nitrite

a) Write the formula for ammonium nitrite. ________________

b) $CaSO_4$ is calcium sulfate while $CaSO_3$ is ________________

If there is even less oxygen the prefix hypo- (meaning under) is used

Examples

$NaClO_3$	sodium chlorate
$NaClO_2$	sodium chlorite
$NaClO$	sodium hypochlorite

c) The white powder called 'pool chlorine' that is added to swimming pools is $Ca(ClO)_2$ called ______________ hypochlorite.

If there is more oxygen than normal the prefix per- may be used

Examples

– $NaClO_4$ sodium perchlorate

– barium oxide is BaO while barium peroxide is BaO_2

– water is H_2O while hydrogen peroxide is H_2O_2.

d) Peroxides are reactive compounds that contain a O — O covalent bond. Can you name this peroxide? H — O — O — H

____

e) Chemiluminescence reactions (reactions that emit ___________ energy without heating) often involve reaction of chemicals with hydrogen peroxide or involve the decomposition of organic peroxides.

Acne treatment creams and solutions usually have a peroxide as their active ingredient.

8 Some polyatomic ions are made up of a common polyatomic ion and hydrogen ions (H^+).

$CO_3^{2-} + H^+ \rightarrow HCO_3^-$

carbonate ion   hydrogen carbonate ion

Examples:

– Na_2CO_3 sodium carbonate

– $NaHCO_3$ sodium hydrogen carbonate.

Many cola drinks contain a dilute (small concentration) solution of phosphoric acid in water. The phosphoric acid produces the following ions in water:

– PO_4^{3-} phosphate ion

– HPO_4^{2-} hydrogen phosphate ion

– $H_2PO_4^-$ dihydrogen phosphate ion.

a) Name these salts.

i Na_3PO_4 ____

ii NaH_2PO_4 ______________________________________

b) The hydrogen carbonate ion is sometimes called the bicarbonate ion.

Bicarbonate of soda, baking soda and sodium hydrogen carbonate are names for the same chemical.

i Which of these names is most useful for working out the formula?____

ii Use this name to write the formula.

____

Naming carbon compounds

Carbon forms more compounds than any other element because:

- carbon atoms can join to form stable chains of carbon atoms of any length
- a carbon atom can form four covalent bonds with other atoms.

The International Union of Pure and Applied Chemistry has developed a systematic approach to naming carbon compounds.

1 Choose the longest continuous chain of carbon atoms.

2 Count the number of carbon atoms *n* in this chain.

n	Stem name
1	meth
2	eth
3	prop
4	but
5	pent
6	hex
7	hept
8	oct

You will need to learn the stem names for n = 1 to 4. The more familiar stem names for n = 5 to 8 are used in terms like pentagon and hexagon.

3 Use a suffix (ending) to show the family of carbon compounds the molecule belongs to.

If the carbon compound is a hydrocarbon and only contains single covalent bonds between the carbon atoms the family suffix is -ane. This family is called the alkane family and has the general formula C_nH_{2n+2}.

Complete the table below.

n	C_nH_{2n+2}	Alkane name	Structure	Structural formula
1	CH_4	methane		CH_4
2	C_2H_6	ethane		CH_3CH_3
3	C_3H_8	propane		$CH_3CH_2CH_3$
4	C_4H_{10}	butane		$CH_3CH_2CH_2CH_3$
5		pentane		$CH_3CH_2CH_2CH_2CH_3$
6	C_6H_{14}			$CH_3CH_2CH_2CH_2CH_2CH_3$
7	C_7H_{16}	heptane		
8	C_8H_{18}			$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

In the structure column each line represents a carbon to carbon bond. In the actual molecules adjoining bonds are arranged at an angle of about 109.5° (actually $109^\circ 28'$) to one another.

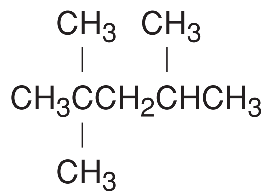
$CH_3CH_2CH_2CH_3$ is called a condensed structural formula.

A full structural formula shows every one of the bonds in a molecule.

$$
\begin{array}{ccccccccc}
 & & H & & H & & H & & H & & \\
 & & | & & | & & | & & | & & \\
H & - & C & - & C & - & C & - & C & - & H \\
 & & | & & | & & | & & | & & \\
 & & H & & H & & H & & H & &
\end{array}
$$

The structural formula for butane.

If an alkane is branched it consists of a 'backbone' with side chains. The side chains are called alkyl groups.



This alkane is a branched molecule with three side chains.

Each side chain contains one carbon and is called a methyl group. The stem contains five carbons and so is based on pentane.

The structure shown above is 2,2,4-trimethylpentane. Trimethyl indicates there are three methyl (CH_3) as side chains. The numbers 2,2,4 indicate the carbons of the backbone to which these side chains are attached.

The table below shows common side chain alkyl groups.

Alkyl group formula	**Name**
CH_3 —	methyl
CH_3CH_2 —	ethyl
$CH_3CH_2CH_2$ —	propyl
$CH_3CH_2CH_2CH_2$ —	butyl
$CH_3CH_2CH_2CH_2CH_2$ —	pentyl

The next time you are looking at the contents label for medicines see if any of the names include an alkyl group.

What could that chemical name mean?

The different parts of a chemical name often give you some idea of the elements or groups of atoms present.

Here are some examples:

- -ol alcohol group –OH
- -ine amino group $–NH_2$
- -ose sugar containing many –OH groups
- -ate salt, particularly if there is a metal name at the beginning
- phenyl- a special hydrocarbon group $C_6H_5–$
- -oxo- oxygen
- -azo- nitrogen
- -thio- sulfur

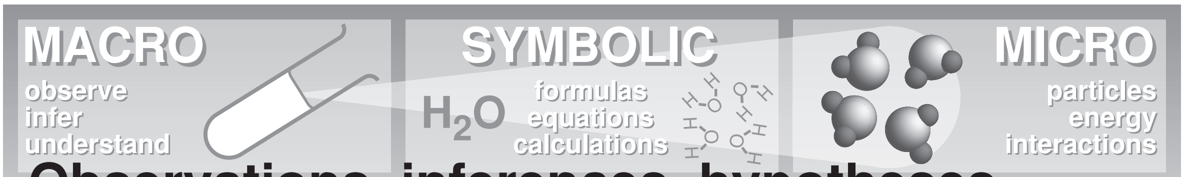
Match the parts of column I with the parts of column II by writing a letter after each number in the answer column

Column I	**Where found**	**Column II**	**Answer column**
1 calcium cyclamate	sweetener in cola drinks	a amine	1b
2 cholesterol	animal fats	b salt	2
3 phenylalanine	many foods	c sugar	3
4 glucose	lollies	d alcohol	4
5 quinine	bitter drinks		5
6 sodium acetylsalicylate	soluble aspirin		6

The insecticide name DDT is used for 1,4 -dichlorodiphenyltrichloroethane.

The most bitter compound known is N-[2-(2,6-Dimethylphenyl)amino-2-oxoethyl]-N,N-diethylbenzenemethanaminium benzoate (it is sometimes added to methylated spirits).

Can you work out what some parts of these chemical names mean?



Observations, inferences, hypotheses and theories

In Part 4 you learned that:

- observations are what you detect with your senses (sight, touch, hearing, smell, taste)
- inferences, based on observations and your experiences of life are what you think happened.

Inferences can be used to develop hypotheses (singular: hypothesis) or explanations. If a hypothesis provides satisfactory explanations for a variety of observations it can change to a theory. In this module you have seen how the particle theory can explain many observations that chemists make.

If further observations or experiments show that a hypothesis is wrong the hypothesis has to be changed and a new hypothesis developed. Sometimes a hypothesis works well and becomes a theory. But new observations or experiments that cannot be explained by that theory may require that the theory be discarded.

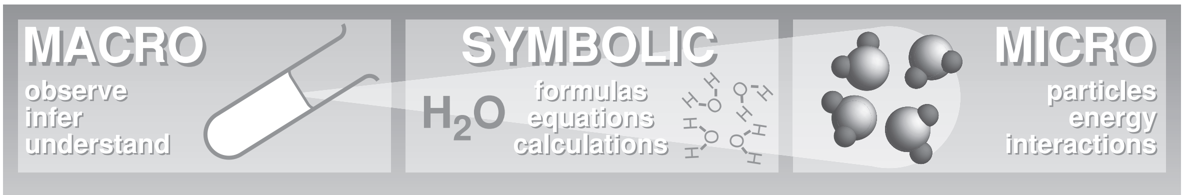
Take, for example, the Father Xmas Visit theory about Xmas presents.

Young children *observe* Xmas presents appearing on Xmas day.

1. Influences such as decorations, cards and stories lead them to *infer* that Father Xmas and_____________ presents are connected.
2. Young children develop a *first hypothesis* to explain Xmas presents. Father Xmas visits and gives Xmas presents to good ____________.
3. Older children who think about how many children are in the world and the chances of Father Xmas visiting them all on one night can produce a *better hypothesis*: Father Xmas and his helpers visit all good children on _____________ night.

   As these older children stay up late at night, make more observations and compare their observations with those of other older children a ______________ about Xmas presents develops: Older members of the house buy and give presents to children (even if the children are not real good).

Can you think of other theories that you may have heard about when you were younger? Perhaps theories concerning Easter bunnies or storks? Have you needed to change these theories as you grew older and observed and thought more?



Key ideas

Assess your understanding of this module by answering these true/false statements one section at a time. Write T or F at the end of each statement. If you answer with F rewrite the statement so that it is true. Check your answers for each part before attempting the next part.

Separating mixtures

- When a liquid changes to a gas the gas takes up more space than the liquid.
- When a liquid changes to a gas the particles increase in size.
- When a liquid changes to a gas the gas particles have more energy than the liquid particles did.
- The size of a particle depends on whether it is in the solid, liquid or gas state.
- There is a lot of space between the particles in a liquid.
- Ice floats on liquid water because ice is less dense than liquid water.
- Steam bubbles rise to the surface of boiling water because gas is less dense than liquid.
- Mixtures have fixed properties.
- Mixtures can be separated into pure substances by using differences in physical properties.
- A compound can be separated into elements using differences in chemical properties.
- The properties of a mixture vary as the components (parts) vary.
- The lithosphere consists of the earth's crust only.
- Density = mass x volume.
- Gravimetric analysis is quantitative analysis carried out by weighing.

Elements

- Nitrogen is the most abundant element by weight in the atmosphere.
- The more reactive an element the more often it is found uncombined.
- A semi-metal's properties are exactly half the properties of a metal.
- Most of the elements are non-metals.
- Most of the elements are solids.
- Metals are malleable, ductile and electrical conductors.
- Solid non-metals are usually brittle and non conductors of heat.
- The most active non-metals are found in the top left hand corner of the Periodic Table.
- The most active metals are found in the bottom left hand corner of the Periodic Table.
- Most physical properties, except MP and BP, are measured at $25^{o}C$ and normal atmospheric pressure of 100 kPa.

Compounds

- The subatomic particles used by chemists to model atomic structure are protons, neutrons and electrons.
- Electrons are arranged around the nucleus in energy level shells.
- The electrons of an atom with the most energy are in the shell closest to the nucleus.
- An ionic bond forms by two atoms sharing a pair of electrons.
- The formula for an ionic compound is empirical.
- All molecules contain covalent bonds.
- In an equation the products are always on the left hand side.
- Ionic compounds are usually formed from a metal and a non-metal.

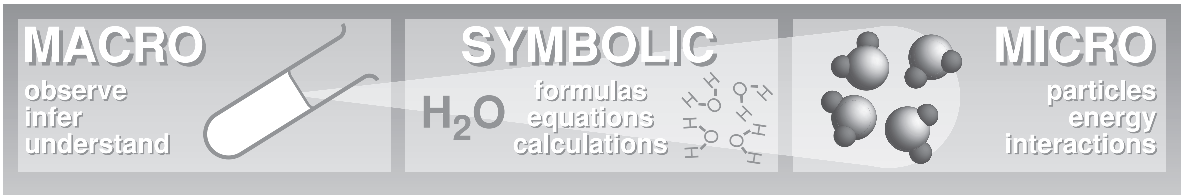
Extraction requires energy

- Melting of candle wax is a physical change.
- Decomposition reactions require energy because bonds have to be broken.
- Decomposition of a compound always produces the separate elements that make up the compound.
- Stronger bonds require less energy to be broken.
- When a bond forms energy is released to the surroundings.
- Less energy is needed to boil water than to electrolyse water.
- More energy is released by burning candle wax than cooling candle wax.
- Cations are attracted to the positive electrode in electrolysis.
- The charged particles that move through a conducting metal are electrons.
- The charged particles that move through a conducting solution are electrons.

Bonding and structure models

- The properties of an element in a compound are the same as the properties of the pure element
- Ionic compounds are brittle solids which conduct electricity when liquid or dissolved in water
- Metallic bonds act in all directions around metal atoms
- Ionic bonds act in all directions around ions
- Covalent bonds act in all directions around atoms
- Metals conduct in both the solid and liquid states
- Ionic compounds conduct in both the solid and liquid states
- Covalent molecular compounds do not conduct in any state
- The majority of compounds contain ionic bonds
- The majority of elements contain covalent bonds.

Do Exercise 6.1 now to complete your work on this module.



Appendices

Appendix 1: Number prefixes

In this first module you have seen three different number prefix systems used - for naming newly discovered elements, for naming compounds of non-metals and for naming carbon compounds.

Number	Newly discovered elements	Compounds of non-metals	Carbon compounds
0	nil		
1	un	mono	meth
2	bi	di	eth
3	tri	tri	prop
4	quad	tetra	but
5	pent	penta	pent
6	hex	hexa	hex
7	sept	hepta	hept
8	oct	octa	oct
9	enn	nona	non
10		deca	dec

Appendix 2: Ion charges

1+	2+	3+	4+	3–	2–	1–
hydrogen H	Mg	Al		nitride N	oxide O	hydride H
Li	Ca				sulfide S	fluoride F
Na	Ba					chloride Cl
K	Zn					bromide Br
Cu	Cu					iodide I
Ag	Fe	Fe				
	Pb		Pb			
	Sn		Sn			
					carbonate CO_3	hydroxide OH
					sulfate SO_4	nitrate NO_3
					sulfite SO_3	nitrite NO_2
ammonium NH_4				phosphate PO_4		hydrogen carbonate HCO_3

When talking about the metal ions shown by a symbol only in this table just use the metal name eg Ag^+ is the 'silver ion'.

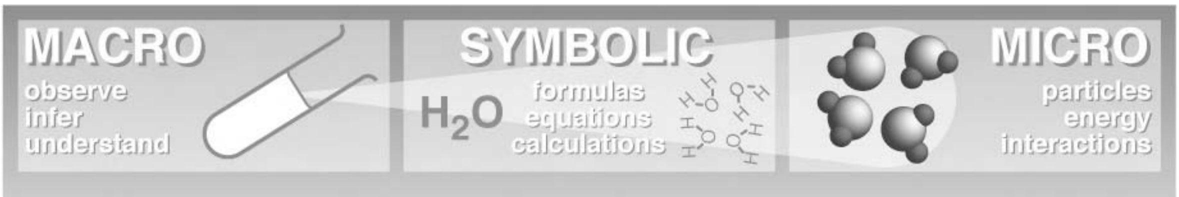
When talking about a metal ion which can have more than one charge follow the name of the metal with the number for its charge eg Cu^+ is the 'copper one ion' while Cu^{2+} is the 'copper two ion'.

Appendix 3: Names of compounds

A systematic name enables you to work out the formula of a compound eg dihydrogen oxide. A trivial name is commonly used for a compound but does not enable you work out the formula from the name eg. water.

The table below gives the formula, systematic name and trivial name for some compounds listed in the Stage 6 chemistry syllabus

Formula	**Systematic name**	**Trivial name**
$NaCl$	sodium chloride	(table) salt
H_2O	dihydrogen oxide	water
$CuCO_3$	copper(II) carbonate	copper carbonate
NH_3	nitrogen trihydride	ammonia
H_2S	dihydrogen sulfide	hydrogen sulfide
SiO_2	silicon dioxide	silica
C_2H_5OH	ethanol	(drinking) alcohol
O_2	diatomic oxygen	oxygen
O_3	triatomic oxygen	ozone
CH_3COOH	ethanoic acid	acetic acid
$C_3H_6O_6$	2-hydroxypropanoic acid	lactic acid
$C_6H_8O_7$	2-hydroxypropane-1,2,3-tricarboxylic acid	citric acid
$C_3H_8O_3$	1,2,3-trihydroxypropane	glycerol/glycerin
$NaHCO_3$	sodium hydrogencarbonate	sodium bicarbonate



Suggested answers

Naming inorganic compounds

1 a) magnesium oxide

b) zinc iodide

c) lead sulfide

d) copper chloride

2 a) carbon monoxide

b) carbon tetrafluoride

c) nitrogen dioxide

4 a) copper(II) sulfide

b) copper(I) sulfide

c) iron(III) chloride

d) lead(II) chloride

e) tin(IV) chloride

5 a) magnesium sulfate

b) sodium nitrate

c) barium carbonate

d) potassium chlorate

6 a) ammonium nitrate

b) ammonium sulfate

c) sodium carbonate

d) aluminium sulfate

7 a) NH_4NO_2

b) calcium sulfite

c) $Ca(ClO)_2$ is calcium hypochlorite

d) hydrogen peroxide

e) light

8 a) i sodium phosphate

ii sodium dihydrogen phosphate

b) i sodium hydrogen carbonate

c) ii $NaHCO_3$

Naming carbon compounds

n	C_nH_{2n+2}	Alkane name	Structure	Structural formula
1	CH_4	methane	•	CH_4
2	C_2H_6	ethane		CH_3CH_3
3	C_3H_8	propane		$CH_3CH_2CH_3$
4	C_4H_{10}	butane		$CH_3CH_2CH_2CH_3$
5	C_5H_{12}	pentane		$CH_3CH_2CH_2CH_2CH_3$
6	C_6H_{14}	hexane		$CH_3CH_2CH_2CH_2CH_2CH_3$
7	C_7H_{16}	heptane		$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
8	C_8H_{18}	octane		$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

Observations, inferences, hypotheses and theories

1 Xmas

2 children

3 Xmas

4 theory

What could that chemical name mean?

1 b) 2 d) 3 a) 4 d) 5 a) 6 b)

Separating mixtures

- When a liquid changes to a gas the gas takes up more space than the liquid. T
- When a liquid changes to a gas the particles increase in size. F *Particles do not change in size between solid, liquid and gas states.*
- When a liquid changes to a gas the gas particles have more energy than the liquid particles did. T
- The size of a particle depends on whether it is in the solid, liquid or gas state. F. *Particles do not change in size between solid, liquid and gas states*
- There is a lot of space between the particles in a liquid. F. *Particles in a liquid are close together; this is why liquids are difficult to compress.*
- Ice floats on liquid water because ice is less dense than liquid water. T
- Steam bubbles rise to the surface of boiling water because gas is less dense than liquid. T
- Mixtures have fixed properties. F. *The properties of a mixture depend on the proportions of the parts of the mixture.*
- Mixtures can be separated into pure substances by using differences in physical properties. T
- A compound can be separated into elements using differences in chemical properties. T
- The properties of a mixture vary as the components (parts) vary. T
- The lithosphere consists of the earth's crust only. F. *The Earth's crust is the top only of the rigid rock layer called the lithosphere.*
- Density = mass x volume. F. *Density = mass/volume*
- Gravimetric analysis is quantitative analysis carried out by weighing. T

Elements

- Nitrogen is the most abundant element by weight in the atmosphere. T
- The more reactive an element the more often it is found uncombined. F. *Reactive elements are found combined with other elements.*
- A semi-metal's properties are exactly half the properties of a metal. F. *Semi-metals have properties intermediate to (between) those of metals and non-metals.*
- Most of the elements are non-metals. F. *Most elements are metals.*

- Most of the elements are solids. T
- Metals are malleable, ductile and electrical conductors. T
- Solid non-metals are usually brittle and non conductors of heat. T
- The most active non-metals are found in the top left hand corner of the Periodic Table. F. *Fluorine, the most active non-metal and other active non-metals are towards the top right hand corner.*
- The most active metals are found in the bottom left hand corner of the Periodic Table. T
- Most physical properties, except MP and BP, are measured at 25^{o}C and normal atmospheric pressure of 100 kPa. T

Compounds

- The subatomic particles used by chemists to model atomic structure are protons, neutrons and electrons. T
- Electrons are arranged around the nucleus in energy level shells. T
- The electrons of an atom with the most energy are in the shell closest to the nucleus. F. *Electrons with the least energy are closest to the nucleus.*
- An ionic bond forms by two atoms sharing a pair of electrons. F. *An ionic bond forms from the attraction of oppositely charged ions.*
- The formula for an ionic compound is empirical. T
- All molecules contain covalent bonds. F. *Most do, but not monatomic molecules of noble gases.*
- In an equation the products are always on the left hand side. F. *Reactants are on the LHS, products are on the RHS.*
- Ionic compounds are usually formed from a metal and a non-metal. T

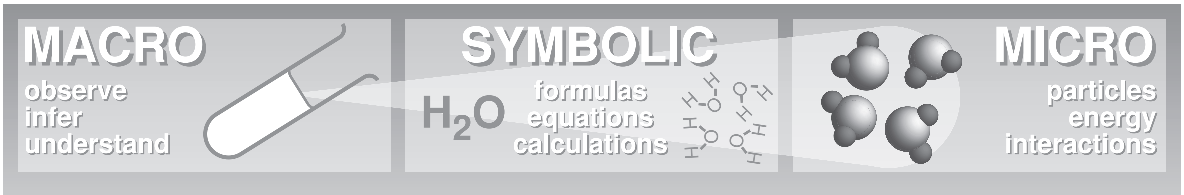
Extraction requires energy

- Melting of candle wax is a physical change. T
- Decomposition reactions require energy because bonds have to be broken. T
- Decomposition of a compound always produces the separate elements that make up the compound. F. *Sometimes this happens (eg water→ hydrogen + oxygen) but often compounds are formed (eg metal carbonate → metal oxide + carbon dioxide).*
- Stronger bonds require less energy to be broken. F. *Stronger bonds require more energy to be broken.*
- When a bond forms energy is released to the surroundings. T

- Less energy is needed to boil water than to electrolyse water. T
- More energy is released by burning candle wax than cooling candle wax. T
- Cations are attracted to the positive electrode in electrolysis. F. *Cations (positive ions) are repelled by a positive electrode.*
- The charged particles that move through a conducting metal are electrons. T
- The charged particles that move through a conducting solution are electrons. F. *Ions move through a conducting solution.*

Bonding and structure models

- The properties of an element in a compound are the same as the properties of the pure element. F. *Properties of an element are different in a compound compared with the pure element.*
- Ionic compounds are brittle solids which conduct electricity when liquid or dissolved in water. T
- Metallic bonds act in all directions around metal atoms. T
- Ionic bonds act in all directions around ions. T
- Covalent bonds act in all directions around atoms. F. *A covalent bond acts in a particular direction in space between the joined atoms.*
- Metals conduct in both the solid and liquid states. T
- Ionic compounds conduct in both the solid and liquid states. F. *Solid ionic compounds do not conduct because their ions are in fixed positions.*
- Covalent molecular compounds do not conduct in any state. T
- The majority of compounds contain ionic bonds. F *Most compounds are carbon compounds and these are covalent molecular.*
- The majority of elements contain covalent bonds. F. *The majority of elements are metals containing metallic bonds.*



Exercises – Part 6

Exercises 6.1 Name: ______________________________

Exercise 6.1

1 The Australian Geological Survey Organisation (AGSO) has reported that Australia is one of the world's top six producers of bauxite, copper, diamond, gold, iron ore, lead, lithium, manganese, mineral sands, nickel, silver, tantalum, tin, uranium and zinc.

Sort these mineral resources into mixtures, metals and non-metals in the table below:

Mixtures	**Metals**	**Non-metals**

2 a) Hospitals can use large amounts of oxygen gas to help patients with breathing problems. Using your knowledge of particle theory explain the advantage of storing oxygen as a liquid rather than a gas.

____

____

____

b) Name another chemical which is stored as a liquid but changed into gas before being used. If you can't then look at some fire extinguishers, cigarette lighters and gas cylinders.

____

3 Use drawings of particles to explain the following observations:

a) A bottle of perfume is opened. Within seconds a person standing metres away can smell the perfume.

b) Two identical balloons are filled - one with air and the other with 'party balloon gas' (recycled helium gas). All balloons have some extremely small holes through which particles can move. The helium filled balloon loses volume more quickly than the air filled balloon. What does this observation suggest about the speed of helium molecules compared with the speed of oxygen and nitrogen molecules in air?

4 When you write formulas it is very important that you use upper case and lower case letters correctly. Can you write different names for Co and CO?

a) Co = ____

b) CO = ____

c) Which is the element and which is the compound?

____

5 In Australia the National Occupational Health and Safety Commission NOHSC (formerly called Worksafe Australia) leads and coordinates national efforts to prevent workplace death, injury and disease. NOHSC uses a scale to describe the level of toxicity of chemicals.

harmless – allowed ingredient in human foods; human metabolite or known to be inert in the body eg. table salt, sodium chloride.

harmful – intake of a small amount would probably not cause sickness eg. Epsom salt, magnesium sulfate.

slightly toxic – intake of large amounts may cause sickness eg. copper(II) sulfate.

moderately toxic – intake of a small amount may cause sickness eg. borax, sodium tetraborate $Na_2B_4O_7$

highly toxic – effective controls must be in place when this chemical is used eg. mercury(II) chloride.

extremely toxic – handle with great caution eg. sodium cyanide NaCN.

If the toxicity of a chemical has not been fully assessed and detailed information is not available the general term *toxic* is used to warn of a possible hazard.

The phrase *toxic by all routes of exposure* indicates the substance is toxic by ingestion (mouth), inhalation (lungs) and skin contact.

Chemists need to be very careful in reading and writing labels as many chemicals are toxic to humans. For example: mercury(I) chloride has low toxicity while mercury(II) chloride is highly toxic; potassium cyanate is moderately toxic while potassium cyanide is extremely toxic.

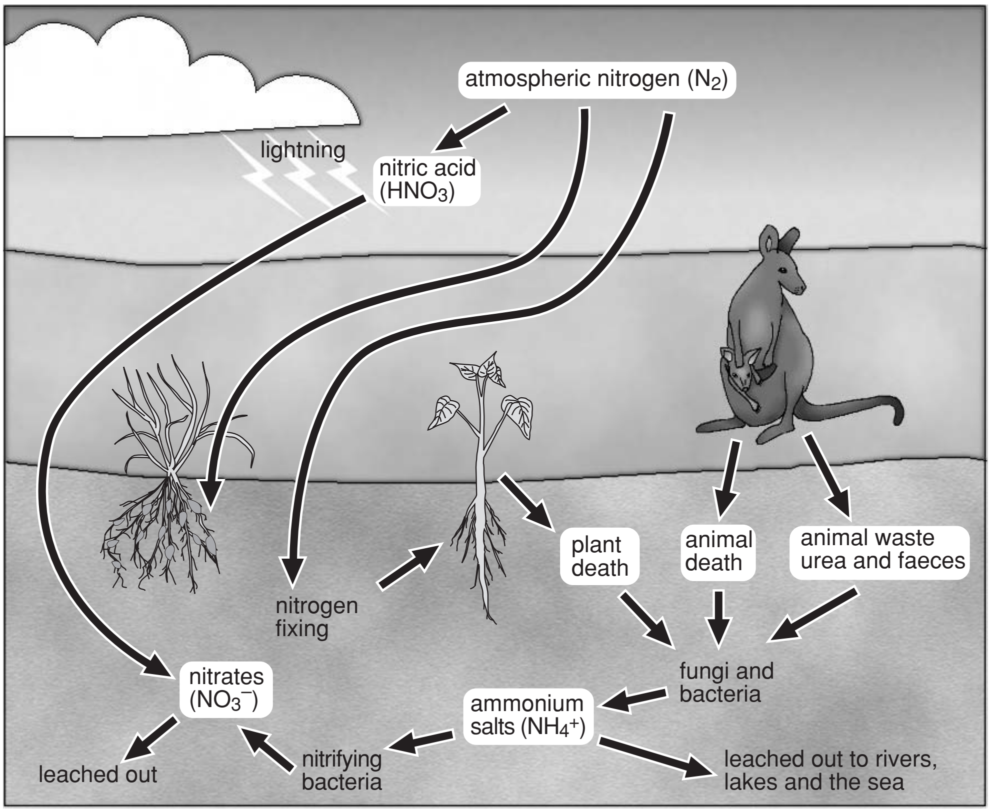
If both sodium cyanide (NaCN) and potassium cyanide (KCN) are extremely toxic which part must be extremely toxic – the sodium, the potassium or the cyanide? ______________________________

Can you work out the formulas for the four chemicals named, but without formulas, in the scale. Appendix 2 giving ion charges could be useful in working out the formulas.

____

____

6 The diagram on the next page shows how nitrogen atoms can change from one form to another.



Nitrogen movement in nature.

The movement of atoms from one form to another requires energy. Most of the energy that drives atoms around cycles could be called solar energy as this energy ultimately comes from the ________________ .

Four formulas include nitrogen.

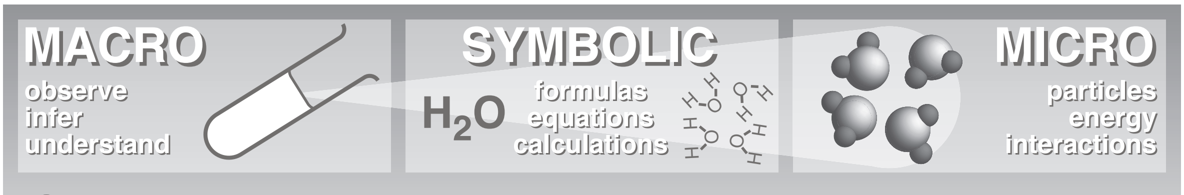
Which formula shows nitrogen as

- the element ____
- part of a cation____
- part of an anion ____
- part of a compound molecule? ____________________________

In all of these forms the nitrogen is joined to other atoms by _________ bonds

To change nitrogen in the air into nitric acid _______________ energy is needed.

Apart from oxygen what other chemical, present in air (especially during electrical storms), would be needed to form nitric acid? ____________



Student evaluation of the module

Name: ________________________ Location: ______________________

We need your input! Can you please complete this short evaluation to provide us with information about this module. This information will help us to improve the design of these materials for future publications.

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2 What did you most like learning about? Why?

3 Which sort of learning activity did you enjoy the most? Why?

4 Did you complete the module within 30 hours? (Please indicate the approximate length of time spent on the module.)

5 Do you have access to the appropriate resources? eg. a computer, the internet, scientific equipment, chemicals, people that can provide information and help with understanding science.

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