CHAPTER 1

Basic chemistry

This chapter covers the following material which will help you prepare for all NCEA Level 1 Chemistry Achievement Standards.

- Nature of matter.
- States of matter.
- Types of matter – elements, compounds and mixtures.
- Symbols and formulae.
- Chemical reactions.
- Chemical equations.

The nature of matter

Chemistry is the study of 'matter'. Matter is the stuff of which all substances are made. All matter has mass (or weight). Matter is made up of **atoms** – these are the extremely tiny particles that form the building blocks of matter.

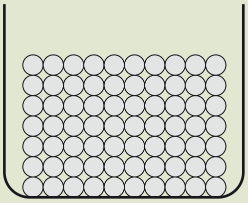
Because individual atoms and particles of substances cannot be seen, chemistry students carry out reactions and make observations of changes in the properties and behaviour of substances at a 'macroscopic' level – they make observations of what can be seen, heard, smelt or felt. Students must then interpret these observations in terms of what is happening at a 'sub-microscopic' or 'particle' level.

Chemistry students will also learn to use symbols to represent what is happening at a particle level.

States of matter

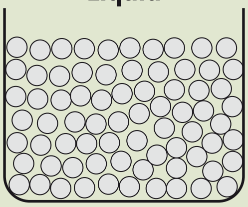
Matter can exist in any one of three states – solid, liquid or gas. These states may be given the symbols (*s*) for solid, (ℓ) for liquid and (*g*) for gas. The different arrangements of particles in each of these three states are shown.

Solid



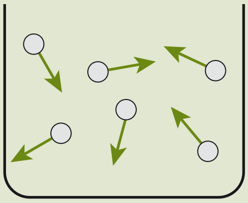
A close-packed collection of particles of regular arrangement (explains why solids are crystalline)

Liquid



A close-packed collection of particles of irregular arrangement (explains why liquids can flow)

Gas



An open, sparse collection of particles of irregular arrangement (explains why gases can be compressed)

CHAPTER 2: ACHIEVEMENT STANDARD 90944 (SCIENCE 1.5)

Externally assessed
4 credits

Demonstrate an understanding of aspects of acids and bases

This chapter covers the following.

- Atomic structure, isotopes.
- Electron arrangements.
- The periodic table.
- Ionic bonding.
- Names and formulae of ionic compounds.
- Particle collision theory and rates of reaction.
- Acids and bases.

Atomic structure

Atoms are made up of subatomic particles. There are three major types of subatomic particle.

- Protons (positive, + charge) are found in the nucleus.
- Neutrons (neutral, no charge) are found in the nucleus.
- Electrons (negative, – charge) are found in different **shells** or **energy levels** around the nucleus.

The nucleus is found at the centre of the atom and occupies about 1/100 000 of the volume of the atom.

Subatomic particle	Mass on the atomic scale	Charge
proton	1	1+
electron	0.0005	1–
neutron	1	zero

All atoms contain protons, electrons and neutrons, except hydrogen, which contains *no* neutrons.

Atoms can be represented in the following manner.

$$^{A}_{Z}\mathbf{X}$$

mass number (**A**) – indicates the number of protons *plus* neutrons in the nucleus of the atom

atomic number (**Z**) – indicates the number of protons *and* the number of electrons in the atom

X – the symbol used to represent one atom of the element

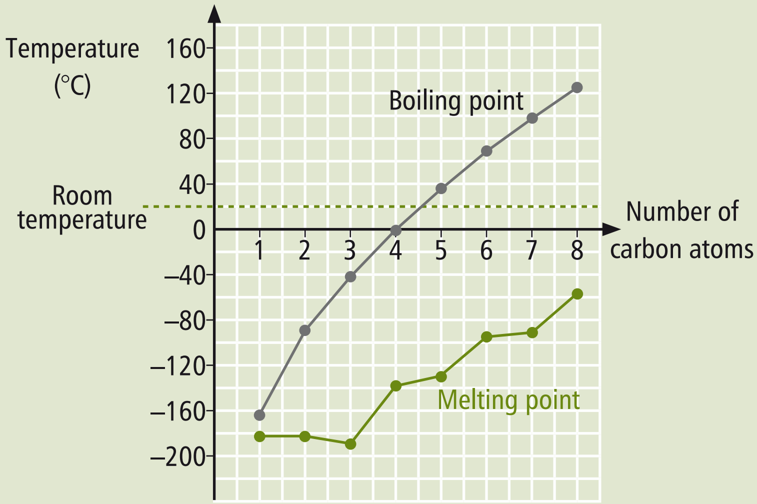
Atomic number = number of protons. Each different element has its own unique atomic number.

All atoms are *electrically neutral*.

number of positive charges (protons) = number of negative charges (electrons) = atomic number

Melting points and boiling points of the first eight alkanes

The graph shows the melting points and boiling points of the first eight alkanes plotted against the number of carbon atoms in the alkane molecule.



The graph shows that the first eight alkanes melt at well below 20 °C (room temperature) and that the first four also boil below this temperature. This means that at room temperature:

- methane, ethane, propane and butane are gases
- pentane, hexane, heptane and octane are liquids.

Activity 5C: Trends in alkane melting and boiling points

1. Describe the trend in melting and boiling points for the first eight alkanes.

2. Use the preceding *Melting points and boiling points of the first eight alkanes* graph to identify the *state* (solid, liquid or gas) at room temperature (20 °C) of the alkane with:

   4 carbon atoms

   7 carbon atoms

3. Explain the trend that both the melting points and boiling points increase as the number of carbon atoms in the molecules of the alkanes increases.

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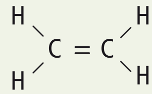
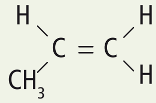
Alkenes – ethene and propene

Carbon atoms can form covalent *double bonds* (C=C) between two carbon atoms.

The **alkenes** make up a series of hydrocarbons that contain at least one carbon-carbon double bond per molecule. Alkenes are said to be **unsaturated** because one of the bonds in the double bond can be broken and further atoms can be added to the molecule – once this has occurred, the new molecule contains only single covalent bonds and is said to be **saturated**. Alkenes can be represented by the general formula $\mathbf{C_nH_{2n}}$

The first member of the alkene series is ethene. Propene is the second member.

Name	Molecular formula	Structural formula	Melting point (°C)	Boiling point (°C)
Ethene	C_2H_4		–170	–104
Propene	C_3H_6		–185	–48

Chemical and physical properties of ethene and propene

Each alkene fits the general formula C_nH_{2n}. Both alkenes are gases at room temperature.

The double bond in the alkene molecules makes them much more reactive than the alkanes.

Polymerisation

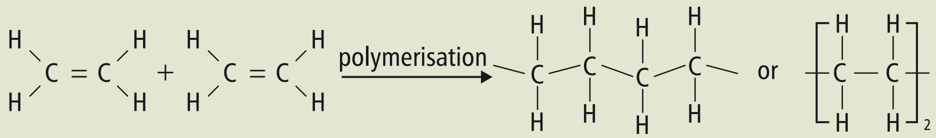
Polymers are very large molecules made up of many small repeating units.

Small alkene molecules are used as **monomers** to make a number of common and widely used polymers.

One bond in the double bond in an alkene molecule is broken by heat and the presence of a catalyst. Once the bond is broken, it is possible for the individual small molecules (monomers) to link together to produce a polymer.

Polymerisation of ethene molecules to produce polyethene

Polymerisation using ethene, $CH_2=CH_2$, as the monomer produces the polymer commonly called polyethene (or polythene):

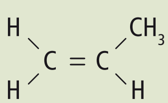


two ethene monomers   polyethene

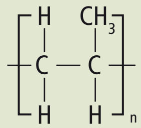
- The polymerisation process, where ethene monomers link together, is repeated many times.
- The number of ethene molecules used to make polythene could be several thousand.

Polymerisation of *propene* to produce *polypropene*

When propene, $CH_3CH=CH_2$, polymerises, the double bond breaks and the molecules link together to form polypropene (also known as polypropylene).



propene



polypropylene

Production and uses of carbon-containing compounds

Carbon as a fuel

Carbon-containing compounds are used as fuels to produce heat energy and light. Carbon is contained in fuels such as coal, coke, petroleum and natural gas.

Sources of alkanes

Alkanes occur naturally in fossil fuels:

- natural gas – mainly made up of methane, but also contains ethane
- crude oil (petroleum) – a mixture of hydrocarbons containing up to thirty carbon atoms in the molecules.

Fractional distillation of crude oil

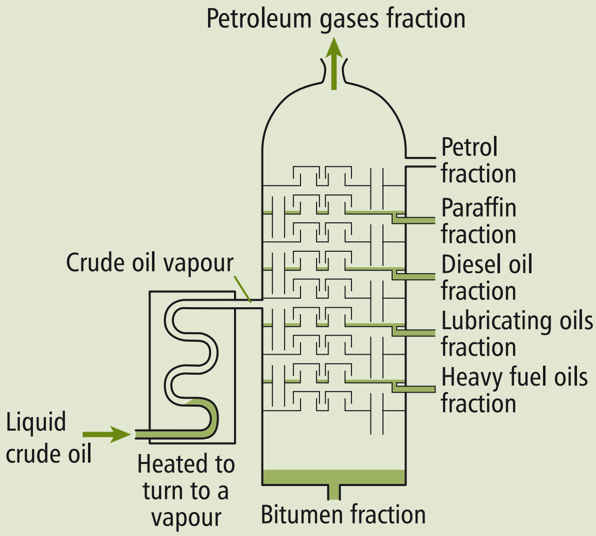
Crude oil requires treatment because it contains a large number of hydrocarbons with molecules of different sizes. These are a mixture of gases, liquids and solids.

Fractional distillation is used – a process of separation based on the different boiling (and condensation) temperatures of molecules with different sizes.

Distillation separates the hydrocarbons into useful fractions (groups of alkanes with similar-sized molecules) – such as petrol, diesel, kerosene, jet fuel.

In the fractionating column, the following occurs.

- Hydrocarbons of around 20 carbon atoms per molecule do not vaporise at the temperatures used, and are collected at the bottom. These hydrocarbons are found in tar and bitumen.
- The crude oil is heated to above the boiling point of most of the hydrocarbons, so they vaporise.
- As the vapours pass up the tower, they are progressively cooled.
- Compounds containing the largest molecules (which have the highest boiling point) condense first, and are removed as liquids at the bottom of the tower.
- Compounds containing the smaller molecules condense at lower temperatures further up the tower and are successively removed as liquids.



- Compounds containing the smallest molecules (e.g. methane, ethane, propane, butane (which have the lowest boiling points)) remain as gases and are removed at the top.

Cracking of fractions

Cracking is the process in which long-chain hydrocarbon molecules are broken down into shorter hydrocarbons by the breaking of carbon-carbon bonds.

- Cracking uses high temperatures and pressures (or a catalyst).
- Cracking (also known as *pyrolysis*), involves the breakdown of large alkane molecules into smaller, more useful alkanes and alkenes.

Example

Butane, $CH_3–CH_2–CH_2–CH_3$, may be broken down into ethane, $CH_3–CH_3$, and ethene, $CH_2=CH_2$

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Activity 5G: Separation of crude oil

1. Describe the composition of crude oil.

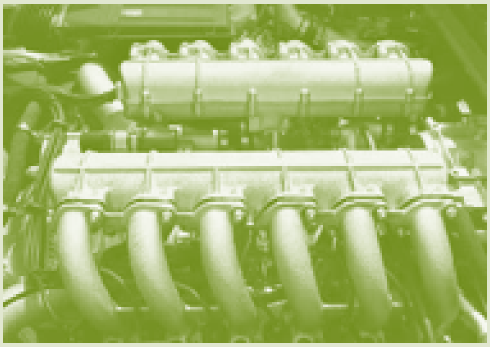
2. a. Explain how the physical properties of hydrocarbon gases allow them to be separated by fractional distillation.

   b. Explain how these physical properties are related to the structure of the hydrocarbons.

Uses of alcohols

Methanol, CH_3OH, and ethanol, CH_3CH_2OH, are excellent fuels. Methanol and ethanol:

- evaporate easily (i.e. have low *volatility*) and readily undergo complete combustion, so they are clean-burning fuels – sometimes used in high-performance cars
- are used as starter chemicals to make many other carbon-containing compounds
- are found as components (90% ethanol and 9.5% methanol) of **methylated spirits**, a very useful solvent and fuel.



Ethanol is used as the 'alcohol' in alcoholic drinks. In moderation, it has no lasting toxic effects on the human system. In excess, it is a poison.

Energy level	Number of electrons
1	Maximum of 2
2	Maximum of 8
3	Maximum of 8
4	Two electrons (for elements up to 20 electrons) – elements with atomic number above 20 have more electrons in this energy level

Students need to know the electron arrangements of elements 1–20 only.

- Elements with the maximum number of electrons in the outer energy level are particularly stable. This means helium: 2, neon: 2,8 and argon: 2,8,8 are found to be chemically unreactive. They are called the 'inert' gases.
- With the exception of hydrogen, helium, lithium and beryllium, all the atoms of the first 20 elements of the periodic table will become most stable when their outer energy level contains *eight* electrons – this is the **'octet' rule**. Hydrogen, helium, lithium and beryllium will have a stable arrangement with *two* (or sometimes *zero* for hydrogen) electrons in the outer energy level.
- The loss or gain of electrons in order to reach a stable electron arrangement is the basis of all chemical reactivity.

The periodic table

The modern periodic table was developed with the elements listed in order of *increasing atomic number*.

- Elements with similar properties are placed in the same column of the table.
- Patterns of chemical behaviour fall into place within columns and across rows.
- Trends (gradual changes) observed in the properties of elements are consistent with the place of each element in the table.

A section of the periodic table is shown below. It contains:

- the symbols of the first twenty elements
- the atomic number for each element (above the symbol)
- the electron configuration of an atom of the element (below the symbol)

Group numbers

Period numbers	1	2	13	14	15	16	17	18
I	1 **H** 1							2 **He** 2
II	3 **Li** 2,1	4 **Be** 2,2	5 **B** 2,3	6 **C** 2,4	7 **N** 2,5	8 **O** 2,6	9 **F** 2,7	10 **Ne** 2,8
III	11 **Na** 2,8,1	12 **Mg** 2,8,2	13 **Al** 2,8,3	14 **Si** 2,8,4	15 **P** 2,8,5	16 **S** 2,8,6	17 **Cl** 2,8,7	18 **Ar** 2,8,8
IV	19 **K** 2,8,8,1	20 **Ca** 2,8,8,2						

Metals

Non-metals

Properties of sulfuric acid

Sulfuric acid is referred to as the 'king of the acids', due to its varied properties which make it an extremely useful chemical in many industries. More of it is made each year than of any other manufactured chemical.

Chemical properties of sulfuric acid

- Acidic properties (forms hydrogen ions) when in aqueous (water) solution:

  H_2SO_4 (in water) $\longrightarrow 2H^+ + SO_4^{2-}$
- Turns blue litmus red.
- Releases hydrogen gas when magnesium (and other reactive metals) is added to it, e.g.:

  $H_2SO_4 + Mg \longrightarrow MgSO_4 + H_2$
- Neutralises bases to form salts, e.g.:

  $H_2SO_4 + NaOH \longrightarrow Na_2SO_4 + H_2O$
- Dehydrates (remove water from) other chemical substances.
- Oxidises (remove electrons from) metals and non-metals.
- Sulfonates organic molecules (to make detergents).
- Acts as a catalyst in many chemical reactions.

Uses of sulfuric acid

Sulfuric acid has widely varied uses and plays some part in the production of nearly all manufactured goods.

- The major use of sulfuric acid is in the production of fertilisers – e.g. superphosphate and ammonium sulfate.
- Widely used in the manufacture of chemicals – e.g. making hydrochloric acid, nitric acid, sulfate salts, synthetic detergents, dyes and pigments, explosives, drugs.
- Used in petroleum refining to wash impurities out of gasoline and other refinery products.
- Used in processing metals – e.g. cleaning iron and steel before plating them with tin or zinc.
- Used in manufacture of synthetic fibres – e.g. terylene and rayon.

- Serves as electrolyte in the lead-acid storage battery commonly used in motor vehicles (acid for this use, containing about 33% H_2SO_4, is often called *battery acid*).

Car battery contains 'battery acid'

Metal carbonates

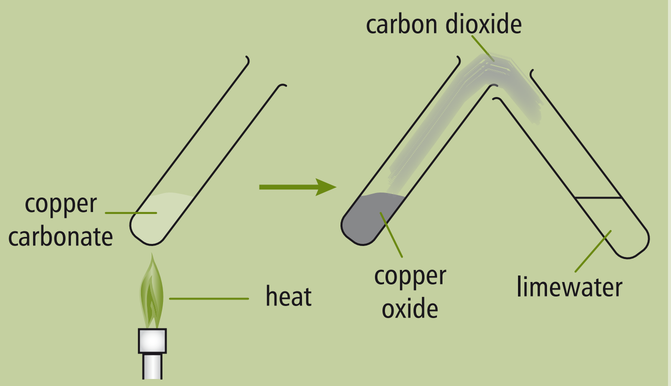
Example

Copper carbonate is heated:

- the green solid begins to bubble
- a new black solid is formed (copper oxide).

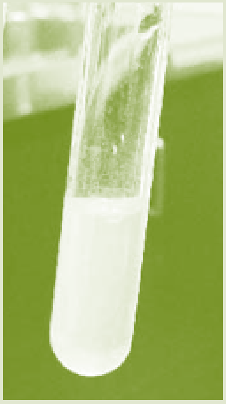
Is copper oxide the only product? Bubbles of gas indicate there is *another* product – a gas – formed.

Test the gas by holding a test-tube containing **limewater**, $Ca(OH)_2$, at the mouth of the test-tube.



The colourless limewater solution turns cloudy white (due to insoluble calcium carbonate, $CaCO_3$, being formed). This is a *positive test* for carbon dioxide.

Limewater



Limewater with CO_2 bubbled in

Equation for the decomposition of copper carbonate is:

$CuCO_3$ (green solid) $\longrightarrow$ CuO (black solid) + CO_2 (colourless gas)

Thus a *metal carbonate* decomposes to form a *metal oxide* and *carbon dioxide gas*.

Metal hydroxides

When **metal hydroxides** are heated, steam (water in the gaseous state) is given off.

- Steam might appear as a cloudy vapour or as a colourless liquid which condenses at the top of the test-tube.
- A reliable test for water is to use cobalt chloride paper which changes colour:
  from blue (dry) $\longrightarrow$ pink (water present)
- A test-tube of limewater held to the mouth of the test-tube shows no change in the limewater, indicating there is *no* carbon dioxide gas given off.

Calcium hydroxide decomposes to calcium oxide (a white solid) and water (steam):

$Ca(OH)_2 \longrightarrow CaO + H_2O$

Thus a *metal hydroxide* decomposes to form the *metal oxide* and *water*.

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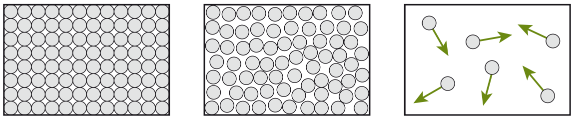
Answers

If there are no answers or no answers to specific questions in an Activity, it is because student-centred, individualised responses are required. In other words, there is no 'correct' answer as such.

Chapter 1: Basic chemistry

Activity 1A: Nature and states of matter (page 3)

1.



Solid Liquid Gas

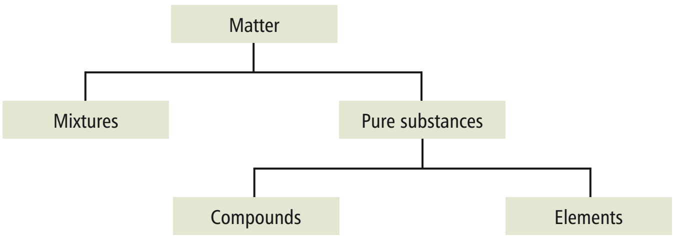
2.

	Solid	Liquid	Gas
Energy	Low	Medium	High
Movement	Vibrations about a fixed position	Independent movement	Free and independent movement in any direction
Closeness	Close contact between particles	Close contact between particles	Large distances between particles
Order	Ordered arrangement in a lattice	No order	No order
Compressible?	No	No	Yes

3. As a solid is heated, the particles begin to vibrate more strongly. Once the temperature reaches the melting point, the particles have sufficient energy to break away from the ordered arrangement of the solid and can move independently within the liquid.
4. As a liquid reaches boiling point, the particles have enough energy to break away from the liquid and become freely-moving gas particles.

Activity 1B: Types of matter (page 5)

1.



2. a. *can vary* b. *element* or *compound* c. *mixture* d. *compound* *the same*

Activity 1D: Formulae of ionic compounds (page 7)

1. a. KCl b. Na_2S c. Fe_2O_3 d. $PbCl_2$ e. Li_2O
2. a. Na_2CO_3 b. $Al(NO_3)_3$ c. NH_4Cl d. $Ca(HCO_3)_2$ e. $(NH_4)_2SO_4$

Activity 1E: Identifying chemical changes (page 8)

1. Not a chemical change – it is a change of state (solid to liquid), but the substance (water, H_2O) remains the same; the change can be easily reversed.
2. Chemical change – a new substance (carbon) is formed; the change cannot be reversed; the change requires a lot of heat to make the change.
3. Chemical change – a new substance (toffee) is formed; the change cannot be reversed; the change requires a lot of heat to make the change.
4. Not a chemical change – the substance (glass) remains the same; the change can be reversed by melting the glass and reforming the bottle.
5. Chemical change – new substances are formed (carbon dioxide and water); the change cannot be easily reversed; heat is given off.

Activity 3B: Diluting solutions and procedure (page 30)

Volume of 2 g L^{-1} acid solution taken (mL)	Volume of water to add to make 100 mL of solution (mL)	Total volume of solution (mL)	Concentration of prepared solution (g L^{-1})
a. 100	0	100	**2**
b. 80	**20**	100	**1.6**
c. **40**	**60**	100	0.8
d. 5	**95**	100	**0.1**

Activity 3F: Accuracy and reliability (page 35)

1. Accuracy could be improved by:
   - using accurate measuring equipment
   - repeating a test and finding the average of the measurements
   - controlling other variables as much as possible.
2. By repeating the test and obtaining consistent results.

Chapter 5: Achievement Standard 90932 (Chemistry 1.3)

Activity 5A: Covalent bonding (page 45)

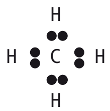
1.

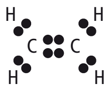
H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar
K	Ca						

Elements which have a complete outer energy level of electrons

Elements which form covalent bonds

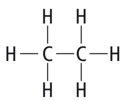
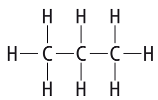
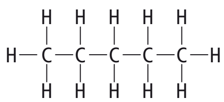
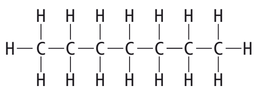
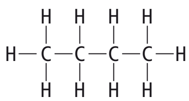
2. *Hydrogen* is an element with one electron in its outer *energy* level. By *sharing* this electron with another hydrogen atom, both atoms obtain a stable outer energy level containing *two* electrons. The particle formed is called a *molecule*. All atoms involved in forming a covalent bond have a *complete* outer energy level once the bond is formed.

3. a. 

b. 

c. 

Activity 5B: Formulae and structures of alkanes (page 48)

Name	Molecular formula	Structural formula
ethane	**C_2H_6**	
propane	C_3H_8	
pentane	**C_5H_{12}**	
heptane	**C_7H_{16}**	
butane	C_4H_{10}	

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