Example

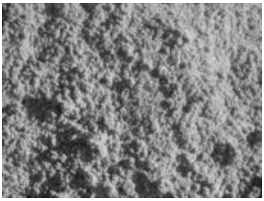
Iron oxide is a compound of iron and oxygen.

- Iron oxide has different properties from iron and oxygen.
- Iron oxide contains iron and oxygen in fixed proportions by mass.
- The iron and oxygen are chemically combined and cannot be easily separated from the compound.

Mixtures

The substances in a mixture can be separated by physical means. A mixture:

- retains the properties of the elements or compounds that it is made of
- contains any proportion of the elements or compounds within it.



Sand

Orange juice

Example

Air is a mixture of mainly nitrogen gas, oxygen gas and some carbon dioxide gas.

- The gases in air retain their own properties.
- The proportions of the gases in air can vary (e.g. the proportions of carbon dioxide and water vapour in the air can vary with time and location).
- The gases in air can be separated by physical means such as cooling and liquefying.

Pure substances

A **pure substance** is either a single element or a single compound. It can be identified by its distinct physical properties, such as melting point or boiling point (e.g. pure water has a fixed melting point of zero degrees Celsius).

Activity 1B: Types of matter

Ans p.175

1. Following is a list of substances:

ice | silver | sea water | chlorine | butter | mercury | common salt | sugar

a. Place each of the substances into one of the categories *Element*, *Compound* or *Mixture*.

b. Indicate which of the substances could be pure.

2. Choose the *correct words* for the following statements.

a. Sea water is a mixture because its composition *can vary / is always the same*.

b. Any substance that has a sharp and precise melting point could be an *element / compound / mixture*.

c. Milk straight from a cow is a *pure substance / mixture*.

d. Common salt (sodium chloride) is a *compound / mixture* because it always contains *the same / variable* proportions of sodium and chlorine.

Elements with eight electrons already have an 'octet' in the outer energy level, so the atoms are stable and do not react readily, if at all.

Example

Ar (2,8,8)

Trends down a group

Similarity of reaction

Elements within the same group have very similar reactions because elements within a group have the *same number* of valence electrons in their outer energy levels.

Group 1 elements – the metals lithium, sodium and potassium

Li (2,1)   Na (2,8,1)   K (2,8,1)

These elements have only one valence electron. This electron is very easily removed, so Li, Na and K are very reactive. The atoms readily undergo reactions where they lose the valence electron to form positive ions with a +1 charge:

- Li^+ (2) – in this case, the lowest energy level can hold just two electrons
- Na^+ (2,8) K^+ (2,8)

Sodium metal

Group 2 elements – the metals beryllium, magnesium and calcium

Be (2,2)   Mg (2,8,2)   Ca (2,8,8,2)

These elements have two valence electrons in their outer energy levels. It requires more energy to remove two electrons because there is greater attraction to the nucleus. These atoms undergo reactions where they lose the two outer electrons to form positive ions with a +2 charge:

Be^{2+} (2) Mg^{2+} (2,8) Ca^{2+} (2,8,8)

Magnesium metal

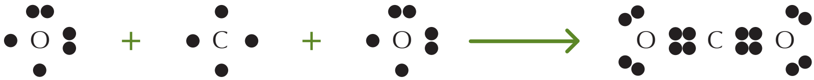
Group 17 elements – fluorine and chlorine

F (2,7)   Cl (2,8,7)

These elements have seven valence electrons in their outer energy level, just one short of a stable 'octet'. The atoms readily undergo reactions where they gain an electron to form negative ions with a –1 charge:

F^- (2,8) Cl^- (2,8,8)

Chlorine gas



An oxygen atom with six electrons in its outer energy level	A carbon atom with four electrons in its outer energy level	An oxygen atom with six electrons in its outer energy level	Molecule of carbon dioxide in which each oxygen atom shares two of its electrons with two electrons from the carbon atom – each atom achieves a stable outer energy level of eight electrons

Molecules with double bonds can also be represented in shorthand.

O=O

O_2

A molecule containing one double covalent bond

O=C=O

CO_2

A molecule containing two double covalent bonds

Triple bonds

Triple bonds are found between two nitrogen atoms in the nitrogen molecule, N_2, and between two carbon atoms in ethyne, C_2H_2.

Example

The nitrogen molecule, N_2

Each nitrogen atom has five electrons in its outer energy level. As each atom shares three of its electrons with the other atom, both N atoms achieve a stable octet of electrons in their outer energy level – a covalent triple bond is formed.

Two separate nitrogen atoms, each with five electrons in its outer energy level	A molecule of nitrogen in which each atom shares three electrons with the other atom – both atoms achieve a stable outer energy level of eight electrons

The nitrogen molecule can be represented as N≡N.

Activity 3A: Covalent bonding	Ans p.179

1. Copy the section of the periodic table that follows, then, using different-coloured pens or different shading, show:
   - elements which have atoms with a complete outer energy level of electrons
   - elements which form covalent bonds with atoms of the same element, or with atoms of another element.

An equation is balanced by placing *whole numbers in front of* the reactant or product particles.

- The formulae of individual reactants and products must *not* be changed.
- The states of the reactants and products may be shown but are not required for NCEA Level 1 Chemistry.

The following state symbols may be used:

- (*s*) for solid – e.g. Cu(*s*)
- (ℓ) for liquid – e.g. $H_2O(\ell)$
- (*g*) for gas – e.g. $O_2(g)$
- (*aq*) for an aqueous solution – e.g. NaCl(*aq*)

In order to write a balanced symbol equation, you must know:

- the symbols for any atoms of elements that are involved in the reaction
- the formulae of any molecules or ions that are involved in the reaction
- the charge on any ions (at NCEA Level 1 Chemistry, a table of ions will be available for you to refer to)
- how to balance the equation.

Balancing equations

What makes an equation 'balanced'? A balanced symbol equation will show the same number of *each type of atom* on either side of the equation.

Examples

$CaCO_3 \longrightarrow CaO + CO_2$

The equation $CaCO_3 \longrightarrow CaO + CO_2$ contains Ca atoms, C atoms and O atoms. If you count the number of Ca, C and O atoms on either side of the arrow, you will find that the equation is 'balanced':

Type of atom	Number on left	Number on right
Ca	1	1
C	1	1
O	3	1 + 2 = 3

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

Counting the number of atoms on each side of the equation (and remembering that $(OH)_2$ means 2× everything inside the bracket), you will find that the equation is 'balanced':

Type of atom	Number on left	Number on right
Ca	1	1
H	2 × 1 = 2	2
O	2 × 1 = 2	1 + 1 = 2

Student completes an investigation plan

↓

Student develops a procedure for the investigation

↓

Student trials their procedure and modifies it if necessary

↓

Student carries out the investigation

↓

Student processes their results

↓

Student interprets their results and presents a report

The purpose of the investigation

The purpose of an investigation states the idea that is being tested. It should be based on a specific context or setting covered in Level 1 Chemistry (such as acid-base reactions, acid-metal reactions, rates of reactions, fermentation, energy of fuels, etc.), so you must have covered the relevant topics before you start.

Examples

'To find the effect on the rate of reaction when the concentration of one reactant changes.'

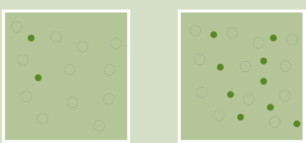
'To determine which antacid tablet neutralises the most acid.'

The purpose may be given in a variety of ways:

Examples

An aim.	Aim: 'To find the effect on the rate of reaction when the concentration of one reactant changes.'
Question to be tested.	'Does the rate of reaction change when the concentration of one reactant changes?'
Hypothesis to be tested.	Hypothesis: 'The reaction rate increases as the concentration of one reactant increases.'
Prediction to be tested.	'The rate of the reaction will increase as the concentration of one reactant increases.'

Variable is concentration of reactant •



Low and High

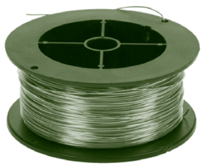
Variables in an investigation

A variable is any factor that can be changed during a chemistry investigation (e.g. temperature, time, concentration, amount of chemical, volume, size of container, brand of product).

- In any scientific investigation, only *one* variable is changed – this is called the **independent variable**.
- The purpose of any investigation is to find the effect of changing the independent variable on a second variable – called the **dependent variable**.

Properties, reactivity and uses of metals

Physical properties of metals


Copper wire


Magnesium ribbon


Wrought iron


Gold ring

Common physical properties, and their characteristics for metals, include the following.

- *Physical state* – solid, liquid or gas at room temperature.
  Most metals are solids at room temperature – the exception is mercury, which is a liquid.
- *Melting point* – pure metals have a precise melting point.
  The melting points of metals vary from below 100 °C to above 1 000 °C.
- *Boiling point* – pure metals have a precise boiling point.
  Most metals have high boiling points, above 1 000 °C.

A lump of lead is much heavier than a lump of rock of the same size because lead has a greater mass per unit volume.

- *Density* – density is mass per unit volume; the unit for density is **g mL^{-1}**.
  Most metals have high densities, above 3 g mL^{-1}.
  Exceptions are sodium and lithium, which float on water.
- *Colour* is related to the ability of a substance to reflect visible light.
  Most metals are silver-grey in colour. Exceptions are copper (pink) and gold (yellow).
- *Lustre* describes how well the substance shines (reflects light).
  Metals are capable of being polished to a high lustre and therefore are shiny. (Non-metals tend to be dull.)

  All pure metals have a high lustre. However, some metals have a dull appearance due to their reaction with oxygen or water in the atmosphere.
- *Electrical conductivity* is the ability of a substance to allow an electric current to pass through it. Metals are very good conductors of electricity (i.e. they have high electrical conductivity).
- *Thermal conductivity* is the ability of a substance to allow heat to pass through it.
  Metals are very good conductors of heat (i.e. they have high thermal conductivity).
- *Malleability* is the ability of a substance to be beaten into a sheet.
  Most metals are readily hammered or pressed into sheets (i.e. high malleability).
- *Ductility* – the ability of a substance to be drawn into wire.
  Most metals are readily drawn into wire (i.e. high ductility).
- *Hardness* is a measure of how easily a material can be scratched or cut with a knife.
  Many pure metals (e.g. magnesium, aluminium or iron), are too soft to be used for engineering purposes and are hardened by making an **alloy** of the metal. Lithium and sodium are soft enough to be cut by a knife.

Alkanes

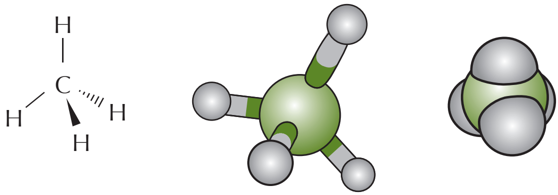
Some of the simplest organic compounds are **hydrocarbons** – compounds made up only of hydrogen and carbon.

Alkanes are a series (or family) of hydrocarbons with the **general formula** C_nH_{2n+2}, where *n* can be any number (1, 2, 3, 4, … etc.).

Each compound can be represented by a:

- **molecular formula** – indicates the number and type of atoms in one molecule, e.g. methane, CH_4
- **structural formula** – indicates the arrangement of atoms in one molecule, e.g. methane, $\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{H} - \mathrm{C} - \mathrm{H} \\ | \\ \mathrm{H} \end{array}$

The actual arrangement of atoms in a molecule takes a *3-dimensional* form, as shown below.



Representations of the 3-dimensional structure of methane, CH_4

Systematic naming of alkanes

The naming of the alkanes with four or fewer carbon atoms per molecule is based on their historical discovery and not connected to their structure. For alkanes with more than four carbon atoms, the naming is based on the number of carbon atoms in the molecule.

Examples

A pentane molecule contains five carbon atoms (Greek *pent* means five).
A hexane molecule contains six carbon atoms (Greek *hex* means six).

Name	Molecular formula	Structural formula	Melting point (°C)	Boiling point (°C)	Physical state at 20 °C
Methane	CH_4	$\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{H} - \mathrm{C} - \mathrm{H} \\ | \\ \mathrm{H} \end{array}$	–182	–164	Gas
Ethane	C_2H_6	$\begin{array}{ccc} & \mathrm{H} \quad \mathrm{H} & \\ & | \quad\;\; | & \\ \mathrm{H} - & \mathrm{C} - \mathrm{C} & - \mathrm{H} \\ & | \quad\;\; | & \\ & \mathrm{H} \quad \mathrm{H} & \end{array}$	–183	–88	Gas

Ionic equations and spectator ions

The equation $Ca(NO_3)_2 + Na_2SO_4 \longrightarrow CaSO_4(s) + 2NaNO_3$ can be simplified by eliminating any ions that do not change in the reaction. These are called **spectator ions**.

Since ions *in solution* are separate from one another, the equation:

$$Ca(NO_3)_2 \quad + \quad Na_2SO_4 \quad \longrightarrow \quad CaSO_4(s) \; + \; 2NaNO_3$$

can be written as:

$$Ca^{2+} + 2NO_3^- + 2Na^+ + SO_4^{2-} \longrightarrow CaSO_4(s) + 2Na^+ + 2NO_3^-$$

The NO_3^- and SO_4^{2-} ions remain unchanged on the right-hand side of the equation, so they can be eliminated from both sides:

$$Ca^{2+} + \cancel{2NO_3^-} + \cancel{2Na^+} + SO_4^{2-} \longrightarrow CaSO_4(s) \cancel{+ 2Na^+} \cancel{+ 2NO_3^-}$$

The equation becomes:

$$Ca^{2+} + SO_4^{2-} \longrightarrow CaSO_4(s)$$

The final equation is called an **ionic equation** – it shows *only* the ions which have been changed in some way.

Note:

- $CaSO_4(s)$ is *not* written as separate ions, because in the ionic solid the ions are joined together
- as there is no change in the NO_3^- and the Na^+ ions, these are *spectator* ions and can be left out of the equation.

Activity 15D: Ionic equations Ans p.203

Use your answers for Activity 15C to write *ionic* equations for the following reactions. An example follows.

Mix of solutions	Balanced ionic equation
$Ca(NO_3)_2$ and NaOH	$Ca^{2+} + 2OH^- \longrightarrow Ca(OH)_2(s)$

Uses of precipitation reactions

Precipitation reactions are very useful for removing unwanted ions from solutions, particularly from domestic and industrial water supplies.

Activity 15E: Precipitation reactions Ans p.203

1. Describe in your own words what happens in an exchange reaction.

2. Explain what is meant by the following.

a. A precipitate.

b. A soluble substance.

c. An insoluble substance.

d. A spectator ion.

Use the solubility rules to help you answer questions **3**–**7**.

3. a. Name three soluble metal nitrates.

b. Name one insoluble metal chloride.

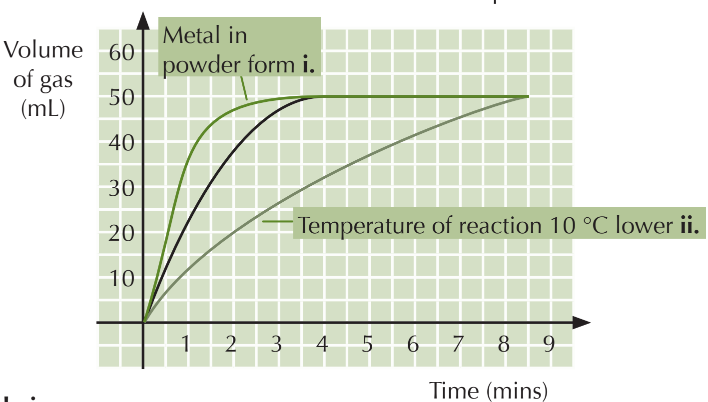
3. a. $2Li + S \longrightarrow Li_2S$
   b. $2Na + Cl_2 \longrightarrow 2NaCl$
   c. $4Al + 3O_2 \longrightarrow 2Al_2O_3$
   d. $Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$
   e. $Mg + 2HCl \longrightarrow MgCl_2 + H_2$
4. a. $2Mg + O_2 \longrightarrow 2MgO$
   b. $4Na + O_2 \longrightarrow 2Na_2O$
   c. $2Na + 2H_2O \longrightarrow 2NaOH + H_2$
   d. $Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$
   e. $Zn + H_2O(g) \longrightarrow ZnO + H_2$
   f. $Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$
   g. $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

Activity 4D: Describing reactions using names of particles (page 44)

1. Lithium *atoms* and oxygen *molecules* react to form lithium *ions* and oxide *ions*.
2. Sodium *atoms* and water *molecules* react to form sodium *ions* and hydroxide *ions* and hydrogen *molecules*.
3. Zinc *atoms* react with sulfuric acid (hydrogen *ions* and sulfate *ions*) to form zinc *ions*, sulfate *ions*, and hydrogen *molecules*.

Activity 5A: Rates of reaction (page 48)

1. • Surface area of solid – reactions result from collisions between reacting particles; powders have a greater surface area than a single lump, so more collisions are likely to occur between reactants.
   • Concentration of reactant – reactions result from collisions between reacting particles; high concentration of reactant means more particles in a given volume and therefore more collisions possible.
   • Temperature of the reactants – reactions result from collisions between reacting particles; changing the temperature changes the energy of the particles; particles with high energy move faster, creating more collisions in a given time; the energy involved in the collision between particles is greater, which makes a reaction more likely.
2. a. One or both of the chemicals have been used up.
   b.



   c. b. i.

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