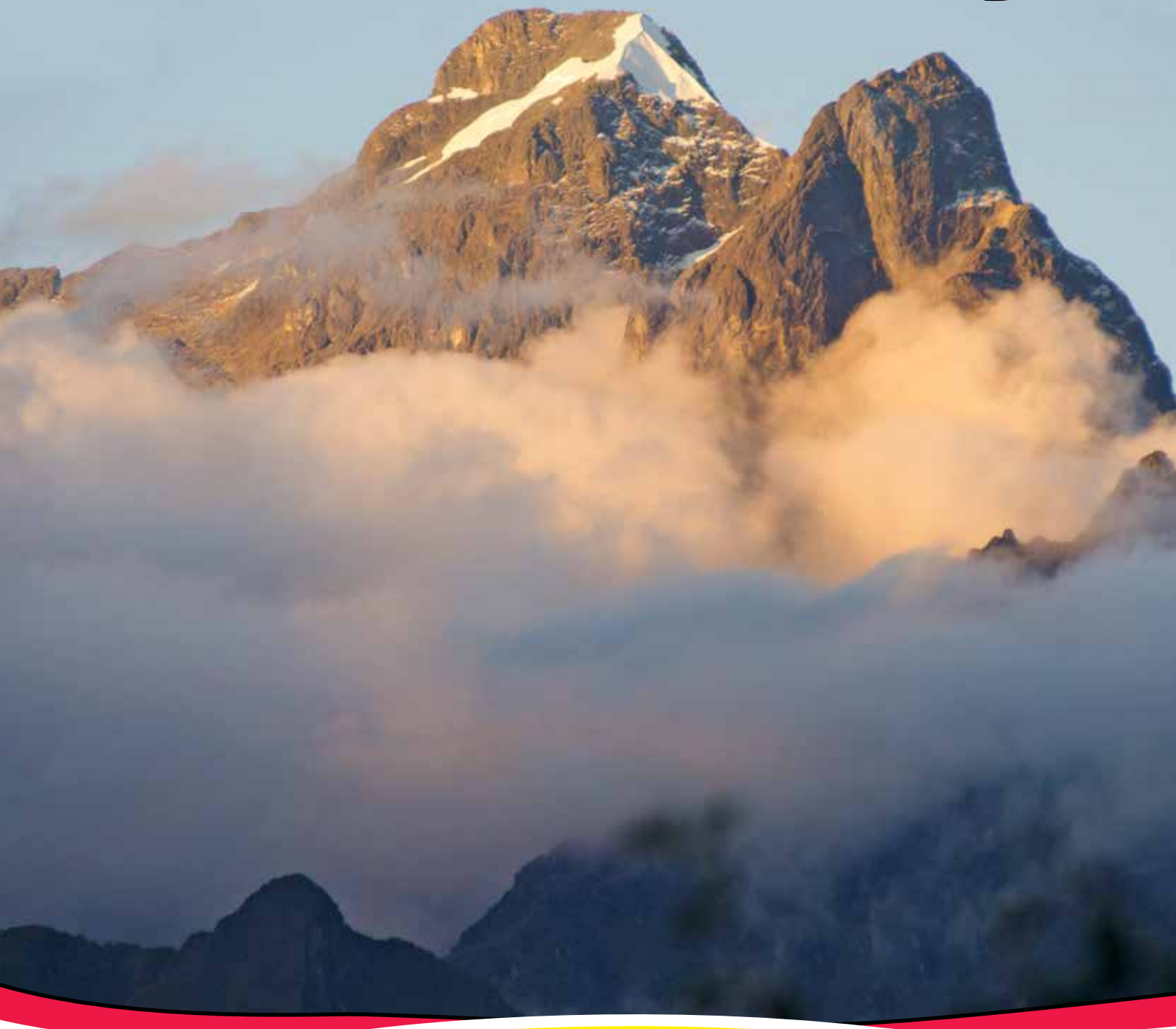
Science 9



National Curriculum

Dr Terry Dwyer

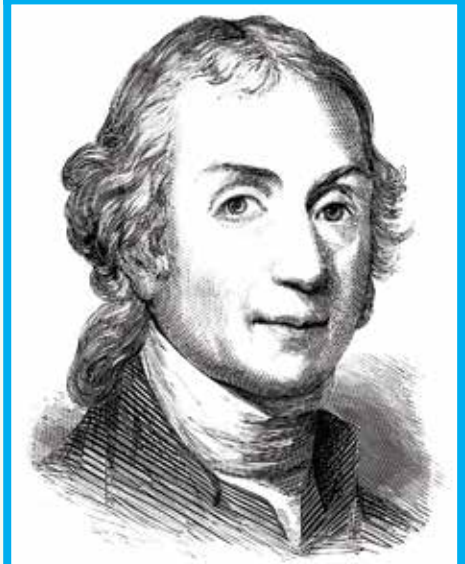
Chemical Reactions II

6

Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (ACSSU179).

- ★ Investigate reactions of acids with metals, bases, and carbonates.
- ★ Investigate a range of different reactions to classify them as exothermic or endothermic.
- ★ Recognise the role of oxygen in combustion reactions and compare combustion with other oxidation reactions.
- ★ Compare respiration and photosynthesis and their role in biological processes.
- ★ Describe how the products of combustion reactions affect the environment.

Carbon monoxide, a product of incomplete combustion, kills. Carbon monoxide is colourless, odourless, tasteless.



Joseph Priestley is credited with the discovery of oxygen (O_2), carbon monoxide (CO), soda water (CO_2 in water), and many other discoveries.

A Task

Acids and bases in the home

a) Make red cabbage indicator (Directions can be found on the internet).

b) Identify household substances as acidic, basic, or neutral by adding very small amounts of each substance to about 2 tablespoons of red cabbage indicator.

Acidic - red cabbage indicator turns pinkish.
Basic - red cabbage indicator turns green.
Neutral - red cabbage indicator remains blue.

Carbon monoxide (CO)

Carbon monoxide is a toxic gas responsible for many deaths. Carbon monoxide is typically produced by incomplete combustion where there isn't enough oxygen to produce carbon dioxide (CO_2).

Aristotle (384-322 BC) noted that burning coals produced toxic fumes. Locking a person in a closed room with burning coals has been used through the ages to kill people.

Priestley (1733-1804) is generally given credit for differentiating between carbon dioxide (CO_2) and carbon monoxide (CO).

6.1 Naming Compounds

Nomenclature

A chemical **nomenclature** is a set of rules for naming chemical compounds. This avoids the confusing use of common names such as saltpetre (Saltpetre can be either potassium nitrate - KNO_3 or sodium nitrate - $NaNO_3$).

There are millions of different compounds, and each of them need a unique name.

These two pages concentrate on the naming of basic compounds. More complicated naming of chemical compounds will be left until later.

Simple compounds with just two elements are named with two words:

Example:

CO_2

The second word usually ends in **ide**

monocarbon (one carbon atom) *dioxide* (two oxygen atoms)

CARBON DIOXIDE

Mono on the first word is usually dropped

Memorise the prefixes for up to 5 atoms:

1 atom	Mono-
2 atoms	Di-
3 atoms	Tri-
4 atoms	Tetra-
5 atoms	Penta-

These prefixes are added to indicate the number of atoms.

A prefix is the first part of a word.

Examples

Name the following compounds:

1 SO_2 (S - sulphur, O - oxygen)

First word: One sulphur → monosulphur (drop the mono on the first word) → **Sulphur**

Second word (end in *ide*): Two oxygen atoms → **dioxide**

Sulphur dioxide

2 N_2O_3 (N - nitrogen, O - oxygen)

First word: Two nitrogen → **Dinitrogen**

Second word (end in *ide*): Three oxygen atoms → **trioxide**

Dinitrogen trioxide

3 CCl_4 (C - carbon, Cl - chlorine)

First word: One carbon → monocarbon (drop the mono on the first word) → **Carbon**

Second word (end in *ide*): Four chlorine atoms → **tetrachloride**

Carbon tetrachloride

4 NaBr (Na - sodium, Br - bromium)

First word: One sodium → monosodium (drop the mono on the first word) → **Sodium**

Second word (end in *ide*): One bromium atom → **monobromide**

Sodium monobromide

Exercise

Name each of the following compounds:

1 SiO_2 (Si - silicon, O - oxygen)

3 SO_3 (S - sulphur, O - oxygen)

4 NO_2 (N - nitrogen, O - oxygen)

5 NI_3 (N - nitrogen, I - iodine)

6 PCl_3 (P - phosphorous, O - chlorine)

7 SO_3 (S - sulphur, O - oxygen)

8 CO (C - carbon, O - oxygen)

9 H_2O (H - hydrogen, O - oxygen)

10 CsCl (Cs - caesium, Cl - chlorine)

11 PBr_5 (P - phosphorous, Br - bromine)

12 As_2O_5 (As - arsenic, O - oxygen)

Simple polyatomic compounds are named by combining two words:

Example:

$MgNO_3$

MAGNESIUM NITRATE

A **polyatomic** molecule is made up of two or more atoms.

These atoms tend to stay together as a group.

Example:

NO_3 This group of atoms tend to stay together and has been given the name **nitrate**.

You need to memorise the names of polyatomic groups.

Some of the more common polyatomic groups are below.

First word	Formula
Ammonium	NH_4
Aluminium	Al
Calcium	Ca
Copper	Cu
Hydrogen	H
Iron	Fe
Magnesium	Mg
Potassium	K
Sodium	Na
Silver	Ag
Zinc	Zinc

Second word	Formula
Hydrogen carbonate	HCO_3
Hydroxide	OH
Nitrate	NO_3
Permanganate	MnO_4
Phosphate	PO_4
Carbonate	CO_3
Sulfate	SO_4
Sulfite	SO_3

Examples

Name the following compounds:

1 $CaCO_3$ → Calcium carbonate

2 $NaHCO_3$ → Sodium hydrogen carbonate

3 $Mg(OH)_2$ → Magnesium hydroxide

4 $NaNO_3$ → Sodium nitrate

5 $KMnO_4$ → Potassium permanganate

6 $Al(MnO_4)_3$ → Aluminium permanganate

7 $FePO_4$ → Iron phosphate

Exercise

Name the following compounds:

1	$NaOH$	**2**	$SnSO_4$
3	Na_2CO_3	**4**	$NaNO_3$
5	Na_3PO_4	**6**	$CuSO_4$
7	$(NH_4)_3PO_4$	**8**	$AgNO_3$
9	$FeSO_4$	**10**	$Ca(HCO_3)_2$
11	$FeSO_3$	**12**	K_2SO_4
13	KNO_3	**14**	K_2CO_3
15	$Zn(OH)_2$	**16**	$ZnSO_4$
17	$Zn_3(PO_4)_2$	**18**	$(NH_4)_2SO_4$

6.2 Ions

Ions

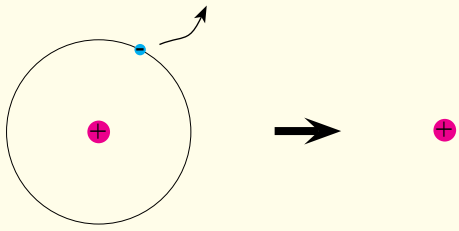
An **ion** is an atom or molecule that has lost or gained an electron. An electron has a negative charge.

When an atom or molecule loses an electron it becomes **positively charged**.

Example
The hydrogen atom can lose an electron and become positive. The symbol is H^+

When an atom or molecule gains an electron it becomes **negatively charged**.

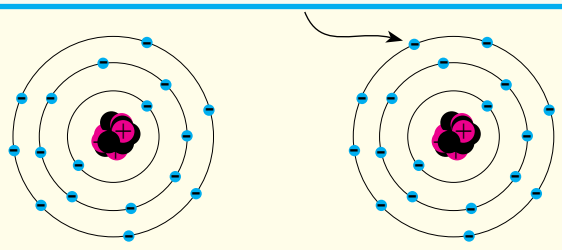
Example
The chlorine atom can gain an electron and become negative. The symbol is Cl^-



Hydrogen atom
1 proton (+)
1 electron (-) } neutral

Hydrogen ion
1 proton (+) } positive

The hydrogen atom (H) **can lose an electron to become a** positively charged **hydrogen ion** (H^+).



Chlorine atom
17 protons (+)
17 electrons (-) } neutral

Chlorine ion
17 protons (+)
18 electrons (-) } negative

The chlorine atom (Cl) **can gain an electron to become a** negatively charged **chlorine ion** (Cl^-).

Examples

Describe the ion formed:

1 Hydrogen (H) loses an electron.
When an atom or molecule loses an electron it becomes **positively charged**.

Hydrogen ion (H^+)

2 Chlorine (Cl) gains an electron.
When an atom or molecule gains an electron it becomes **negatively charged**.

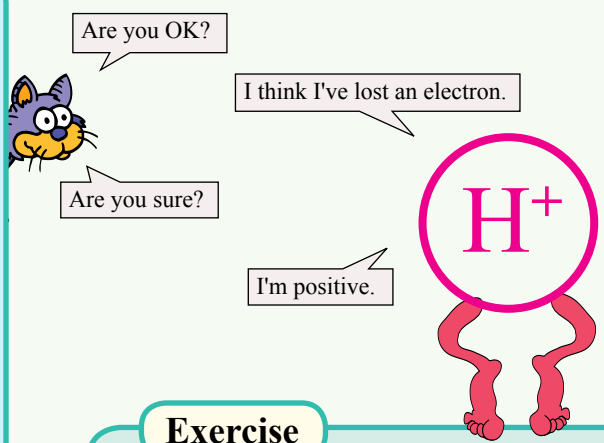
Chloride ion (Cl^-)

3 Nitrate (NO_3) gains an electron.
When an atom or molecule gains an electron it becomes **negatively charged**.

Nitrate ion (NO_3^-)

4 Ammonium (NH_4) loses an electron.
When an atom or molecule loses an electron it becomes **positively charged**.

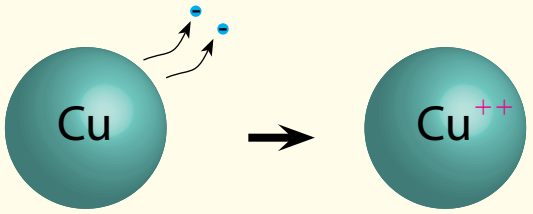
Ammonium ion (NH_4^+)



Exercise

Describe the ion formed?

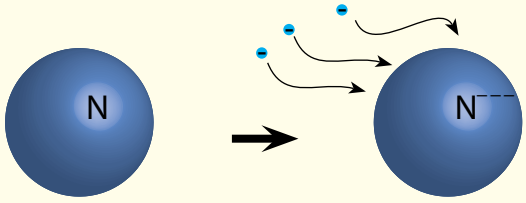
1 Sodium (Na) loses an electron.
2 Iodine (I) gains an electron.
3 Lithium (Li) loses an electron.
4 Fluorine (F) gains an electron.
5 Potassium (K) loses an electron.
6 Permanganate (MnO_4) gains an electron.
7 Nitrite (NO_2) gains an electron.
8 Hydroxide (OH) gains an electron.



Copper atom
29 protons (+)
29 electrons (-)
} neutral

Hydrogen ion
29 protons (+)
27 electrons (-)
} positive

The copper atom (Cu) **can lose two electrons to become a** positively charged **copper ion** (Cu^{++} or Cu^{2+}).



Nitrogen atom
7 protons (+)
7 electrons (-)
} neutral

Nitride ion
7 protons (+)
10 electrons (-)
} negative

The nitrogen atom (N) **can gain three electrons to become** a negatively charged **nitride ion** (N^{---} or N^{3-}).

What did one charged atom say to the other?
I've got my ion you.

I have this extra electron that I don't want.
Don't be negative.

Great day rates.
Even better NO_3's.

A bit of trivia

- Sodium and potassium ions are vital for all living cells. These ions also form the basis of nerve impulses.
- Calcium ions combine with carbonate ions to form calcium carbonate - the shells of countless marine organisms.
- Calcium ions are critically vital to the existence of multicellular organisms.

Examples

Describe the ion formed:

1 Zinc (Zn) loses two electrons.

When an atom or molecule loses an electron it becomes **positively charged**.

Zinc ion (Zn^{++} or Zn^{2+})

2 Sulphate (SO_4) gains two electrons.

When an atom or molecule gains an electron it becomes **negatively charged**.

Sulphate ion (SO_4^{--} or SO_4^{2-})

3 Iron (Fe) loses three electrons.

When an atom or molecule loses an electron it becomes **positively charged**.

Iron ion (Fe^{+++} or Fe^{3+})

4 Iron (Fe) loses two electrons.

When an atom or molecule loses an electron it becomes **positively charged**.

Iron ion (Fe^{++} or Fe^{2+})

Exercise

1 What is the difference between a copper atom and a copper ion?

2 A copper ion is written as Cu^{2+}. What does the 2+ indicate?

3 A nitride ion is written as N^{3-}. What does the 3– indicate?

4 Describe the ion formed?

a) Calcium (Ca) loses two electrons.

b) Oxygen (O) gains two electron.

c) Phosphide (P) gains three electrons.

d) Sulphide (S) gains two electrons.

e) Aluminium (Al) loses three electrons.

f) Tin (Sn) loses two electrons.

g) Tin (Sn) loses four electrons.

6.3 Ionic Compounds

Ionic Formulae

Many chemical compounds are ionic compounds. Calcium carbonate is an ionic compound because it contains Ca^{2+} ions and CO_3^{2-} ions.

The formulae of ionic compounds are written so that **the number of positive charges is equal to the number of negative charges**. The formula for calcium carbonate is $CaCO_3$.

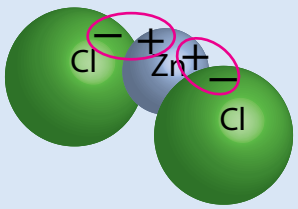
When writing the formula for ionic compounds:

- The positive ion is written first.
- No charges are shown in the formula.
- The number of positive charges must equal the number of negative charges.

What is the formula for zinc chloride?

Zinc ion		*Chloride ion*
Zn^{2+}		Cl^-
2 positives	*must equal*	*2 negatives*
1 zinc		*2 chlorides*

$ZnCl_2$



Examples

What is the formula for:

1 Sodium (Na^+) chloride (Cl^-)?

1 positive equals 1 negative
1 sodium ion with 1 chloride ion

$NaCl$ = sodium chloride

2 Sodium (Na^+) carbonate (CO_3^{2-})?

2 positive equals 2 negative
2 sodium ions with 1 carbonate ion

Na_2CO_3 = sodium carbonate

3 Magnesium (Mg^{2+}) chloride (Cl^-)?

2 positive equals 2 negative
1 magnesium ion with 2 chloride ions

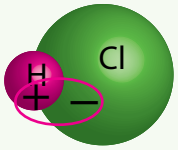
$MgCl_2$ = magnesium chloride

4 Ammonium (NH_4^+) sulphate (SO_4^{2-})?

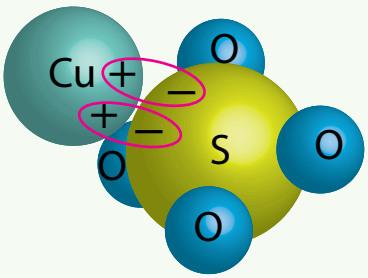
2 positive equals 2 negative
2 Ammonium ions with 1 sulphate ion

$(NH_4)_2SO_4$ = ammonium sulphate

H^+ Cl^- → HCl



Cu^{2+} SO_4^{2-} → $CuSO_4$



Exercise

What is the formula for:

1 Potassium (K^+) chloride (Cl^-)?
2 Potassium (K^+) hydroxide (OH^-)?
3 Magnesium (Mg^{2+}) oxide (O^{2-})?
4 Copper (Cu^{2+}) carbonate (CO_3^{2-})?
5 Sodium (Na^+) chromate (CrO_4^{2-})?
6 Silver (Ag^+) sulphate (SO_4^{2-})?
7 Copper (Cu^{2+}) nitrate (NO_3^-)?
8 Zinc (Zn^{2+}) chloride (Cl^-)?

Some metals can form ions with different charges. Some common examples are:

iron (II)	Fe^{2+}
iron (III)	Fe^{3+}
copper (II)	Cu^{2+}
copper (III)	Cu^{3+}
tin (II)	Sn^{2+}
tin (IV)	Sn^{4+}

A bit of trivia

- Ferrous oxide and ferric oxide. The endings -ous, and -ic are still used to represent ions with lesser and greater charge respectively.
- Ferrous is iron (II) Fe^{2+}
- Ferric is iron (III) Fe^{3+}
- Stannous is tin (II) Sn^{2+}
- Stannic is tin (IV) Sn^{4+}

Writing Formulas with Ions

Watch a couple of online videos about 'writing formulas with ions'.

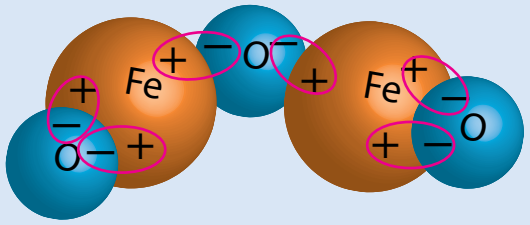
What is the formula for iron (III) oxide?

iron(III) ion Fe^{3+} — *oxide ion* O^{2-}

6 positives must equal 6 negatives

2 iron — *3 oxides*

Fe_2O_3



Activity

Periodic table of ions

Construct a large chart of the 'Periodic Table of Ions' for the classroom wall.

Challenge

Copper (III) nitrate is $Cu(NO_3)_3$

Can you make a model to demonstrate that the formula for copper (III) nitrate is $Cu(NO_3)_3$?

Examples

What is the formula for:

1 Copper (II) (Cu^{2+}) oxide (O^{2-})?

2 positive equals 2 negative
1 copper (II) ion with 1 oxide ion

CuO = copper (II) oxide

2 Copper (III) (Cu^{3+}) oxide (O^{2-})?

6 positive equals 6 negative
2 copper (III) ions with 3 oxide ions

Cu_2O_3 = copper (III) oxide

3 Iron (III) (Fe^{3+}) sulphate (SO_4^{2-})?

6 positive equals 6 negative
2 iron (III) ions with 3 sulphate ions

$Fe_2(SO_4)_3$ = iron (III) sulphate

4 Tin (IV) (Sn^{4+}) nitrate (NO_3^-)?

4 positive equals 4 negative
1 tin ion with 4 nitrate ions

$Sn(NO_3)_4$ = tin (IV) nitrate

Exercise

What is the formula for:

1 Sodium (Na^+) hydroxide (OH^-)?
2 Hydrogen (H^+) chloride (Cl^-)?
3 Copper (II) (Cu^{2+}) chloride (Cl^-)?
4 Copper (III) (Cu^{3+}) carbonate (CO_3^{2-})?
5 Potassium (K^+) oxide (O^{2-})?
6 Nickel (III) (Ni^{3+}) sulphite (SO_3^{2-})?
7 Sodium (Na^+) permanganate (MnO_4^-)?
8 Silver (Ag^+) sulphate (SO_4^{2-})?
9 Iron (II) (Fe^{2+}) oxide (O^{2-})?
10 Iron (III) (Fe^{3+}) bromide (Br^-)?
11 Tin (IV) (Sn^{4+}) hydroxide (OH^-)?
12 Iron (III) (Fe^{3+}) nitrate (NO_3^-)?
13 Lead (IV) (Pb^{4+}) chromate (CrO_4^{2-})?

6.4 Acids

Acids

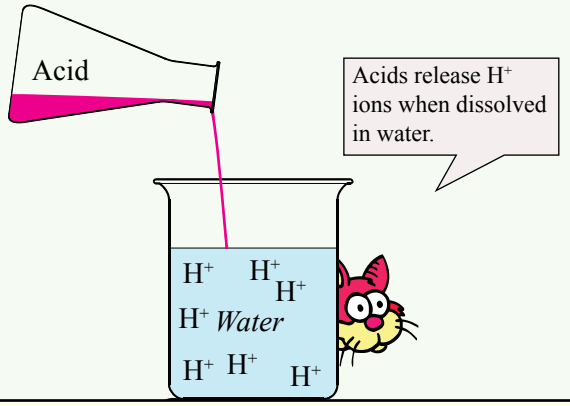
Acids are defined as substances that release hydrogen ions (H^+) when dissolved in water.

When hydrochloric acid (HCl) is dissolved in water it can break up into its ions H^+ and Cl^-. Hydrochloric acid is considered a **strong acid** because it can release a relatively large number of H^+ ions when dissolved in water.

$$HCl \rightarrow H^+ + Cl^-$$

Acetic acid is considered a **weak acid** because it releases few H^+ ions when dissolved in water.

$$CH_3COOH \rightarrow CH_3COO^- + H^+$$



Common acids

Acetic acid, CH_3COOH or $C_2H_4O_2$, is described as a weak acid. The pungent smell and sour tast of vinegar is due to the 5% acetic acid.

Citric acid, $C_6H_8O_7$, is also described as a weak acid. Citric acid is responsible for the sour sharp taste in citrus fruits.

Lactic acid, $C_3H_6O_3$, is also described as a weak acid. Lactic acid was first isolated from milk in 1780. Lactic acid is also found in human muscles after heavy exercise.

Sulphuric acid, H_2SO_4, is described as a strong acid. Sulphuric acid will quickly corrode skin, flesh, and metals.

Nitric acid, HNO_3, is also described as a strong acid. Nitric acid is dangerously highly corrosive and also reacts with other substances to produce dangerous gases.

Acids:

- *release H^+ ions in water.*
- *have a sour sharp taste (similar to the taste of lemon juice or vinegar).*
- *turn litmus paper red.*
- *are corrosive and will dissolve some metals.*
- *neutralise bases to produce water and a salt.*
- *conduct electricity.*
- *have a PH below 7.*

Some household acids. Acetic acid (vinegar), citric acid (lemon juice), lactic acid (milk), ascorbic acid (Vitamin C), carbonic acid (soft drink).

Exercise

1 What is the definition of an acid?

2 Can you name four acids?

3 When HF is dissolved in water it tends to release the following ions:

$$HF \rightarrow H^+ + F^-$$

Is HF an acid?

4 When NaOH is dissolved in water it tends to release the following ions:

$$NaOH \rightarrow Na^+ + OH^-$$

Is NaOH an acid?

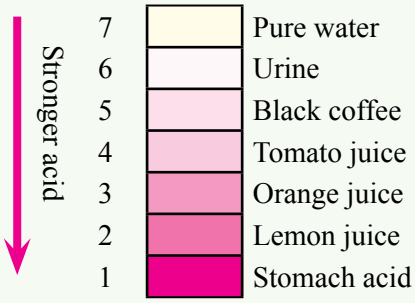
Acid Strength

The strength of an acid depends on the number of H^+ ions in an aqueous solution. An **aqueous solution** is a solution in which water is the solvent.

The pH, **p**ower of **H**ydrogen, is a measure of the acidity of an aqueous solution.

- The pH scale ranges from 0 to 14.
- Water has a pH of 7.
- Acids have a pH less than 7.
- The lower the pH number, the stronger the acid.

The pH paper is placed in the solution and then colour matched with the pH scale.



Activity

pH of household solutions

Materials: Samples of household solutions suspected of being acids, watch glass, pH paper (also called pH litmus paper).

Method:

a) Place a small amount of a solution on the watch glass.

b) Put one end of a pH paper in the solution and record your result.

c) Clean the watch glass and repeat for each solution.

1 Is the water that you used to clean the watch glass neutral (pH = 7)?

2 Estimate the error of the pH paper? (± 0.5, ± 0.1, ± 1.5, ± 2.0)?

Measuring pH

Watch a couple of online videos about 'Measuring pH'.

Challenge

Is your soil acidic?

Devise a method of using pH paper to measure the pH of soil (Remember that H^+ ions are released in an aqueous solution).

Exercise

1 Write a definition of an acid.

2 What is an aqueous solution?

3 What is pH?

4 What is the pH of pure water?

5 A solution returns a pH of 3. Is the solution an acid?

6 A solution returns a pH of 8. Is the solution an acid?

7 A sample of milk returned a pH of just under 7 and a sample of a softdrink returned a pH of 3? Which sample has the higher concentration of H^+ ions?

8 A variety of soils were measured for pH:

Soil A pH = 5.5
Soil B pH = 4.0
Soil C pH = 6.5

a) Which soil is the least acidic?
b) Which soil is the most acidic?

6.5 Acids & Bases

Bases

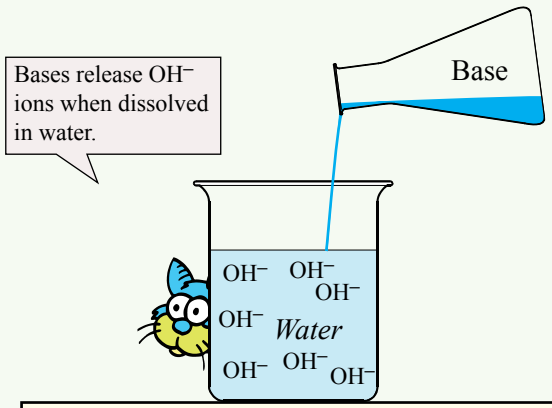
Bases are defined as substances that release hydroxide ions (OH^-) when dissolved in water.

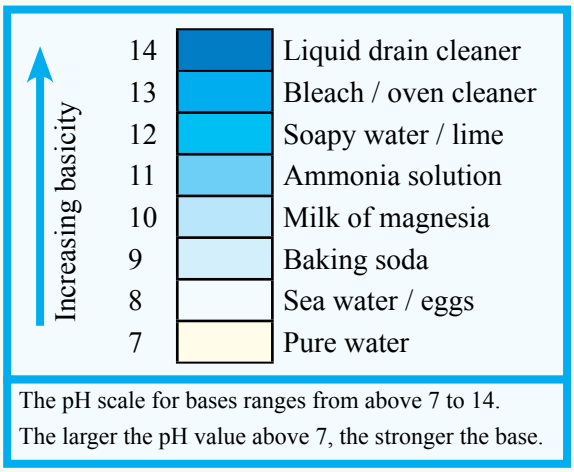
When sodium hydroxide (NaOH) is dissolved in water it can break up into its ions Na^+ and OH^-. Sodium hydroxide, or caustic soda, is considered a **strong base** because it can release a relatively large number of OH^- ions when dissolved in water.

$$NaOH \rightarrow Na^+ + OH^-$$

Bases:

- *release OH^- ions in water.*
- *feel slippery or soapy.*
- *turn litmus paper blue.*
- *are caustic and will eat away skin.*
- *neutralise acids to produce water and a salt.*
- *conduct electricity.*
- *have a PH above 7.*





The pH scale for bases ranges from above 7 to 14.
The larger the pH value above 7, the stronger the base.

Common bases

Sodium hydroxide, NaOH, also known as caustic soda, is described as a strong base. The dissolving of sodium hydroxide in water is a highly exothermic reaction (Care needs to be taken to avoid splashing).

Calcium hydroxide, CaOH, also known as slaked lime, is also described as a strong base. Calcium has many uses including the production of sodium hydroxide.

Household ammonia, NH_4OH, is dilute ammonium hydroxide. Dilute ammonium hydroxide is used in many cleaning agents.

Sodium carbonate, Na_2CO_3, is considered a base even though it doesn't release OH^- ions when dissolved in water. Sodium carbonate is considered a base because it can neutralise acids.

Exercise

1 What is the definition of a base?

2 Can you name four bases?

3 According to the above pH scale, which is the stronger base, oven cleaner or liquid drain cleaner?

4 When ammonium hydroxide is dissolved in water it tends to release the following ions:

$$NH_4OH \rightarrow NH_4^+ + OH^-$$

Is NH_4OH a base?

5 When H_3PO_4 is dissolved in water it tends to release the following ions:

$$H_3PO_4 \rightarrow H^+ + H_2PO_4^-$$

Is H_3PO_4 a base or an acid?

Bases neutralise acids to produce a salt and water

Acid + Base ➔ Salt + Water

ACID
(Turns blue litmus red)

Examples:

Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulphuric acid	H_2SO_4

BASE
(Turns red litmus blue)

Examples:

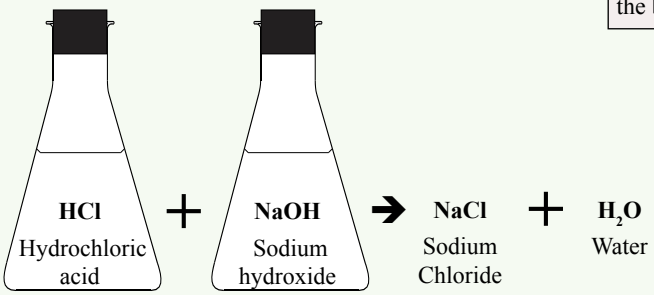
Calcium hydroxide	$Ca(OH)_2$
Magnesium hydroxide	$Mg(OH)_2$
Sodium hydroxide	NaOH

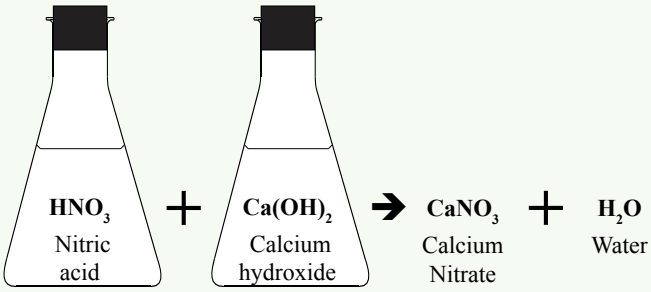
SALT
A chemical salt is the result of a neutralisation reaction between an acid and a base.

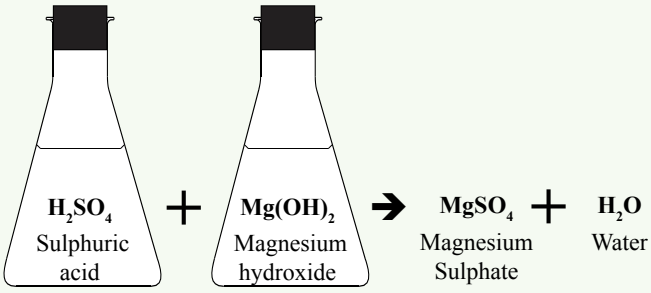
Examples:

Sodium chloride	NaCl
Calcium nitrate	$CaNO_3$
Magnesium sulphate	$MgSO_4$

+ **WATER** H_2O







Activity

Neutralisation of softdrink

Materials: A clear softdrink, clear dilute vinegar in a dropper, test tubes, universal pH paper, phenolphthalein.

Method:

a) Use the pH paper to confirm that the soft drink is a base and that vinegar is an acid.

b) Half-fill a test tube with the clear soft drink and add 2-3 drops of phenolphthalein.

c) Slowly add one drop at a time of dilute vinegar until the pink/red phenolphthalein becomes a very light pink.

> Phenolphthalein is red/pink in a base.
> Phenolphthalein is colourless in an acid.

d) Test the neutralised solution with pH paper to confirm that the pH is 7.

> Neutralisation happens because the base absorbs the H^+ from the acid.

> Neutralisation turns the acid, and the base, neutral (pH = 7).

Exercise

1 Copy and complete the neutralisation equation: Acid + Base ➔ +

2 What is neutralisation?

3 Copy and complete the following neutralisation reaction:

HCl + NaOH ➔ +

4 Given the following acids and bases:

Acid	Base
HCl	NaOH
HNO_3	$Ca(OH)_2$
H_2SO_4	$Mg(OH)_2$

Which acid and which base would you mix together to produce the following salts?

a) $MgCl_2$ Magnesium chloride

b) $NaNO_3$ Sodium nitrate

c) $CaSO_4$ Calcium sulphate

6.6 Acids & Metals

When an acid reacts with a metal, a salt and hydrogen gas is produced.

Acid + Metal → Salt + Hydrogen

ACID
(Turns blue litmus red)

Examples:

Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulphuric acid	H_2SO_4

Metal
(Hard, opaque, shiny, conductive)

Examples:

Magnesium	Mg
Zinc	Zn
Iron	Fe

SALT
A chemical salt is the result of a reaction between an acid and a metal.

Examples:

Magnesium chloride	$MgCl_2$
Zinc nitrate	$Zn(NO_3)_2$
Iron sulphate	$FeSO_4$

+ **HYDROGEN** H_2

Should you make jokes about sodium and hydrogen?

NaH

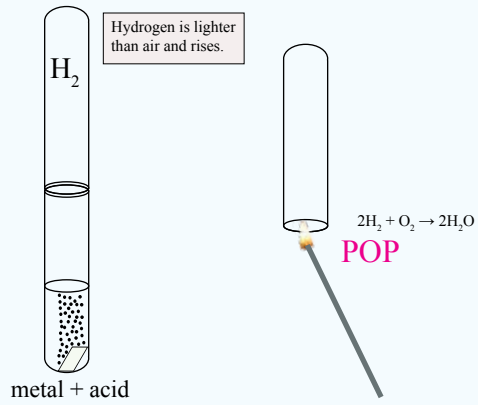
Acids and Metals

Watch a couple of online videos about 'Acids and Metals'.

Test for Hydrogen

Watch a couple of online videos about 'Test for Hydrogen'.

Test for hydrogen



A lit splint placed near the mouth of a test tube will give a 'pop' sound if hydrogen is in the test tube.

The 'pop' sound is a small explosion as hydrogen combines with oxygen. $2H_2 + O_2 \rightarrow 2H_2O$

Activity

Acids and metals

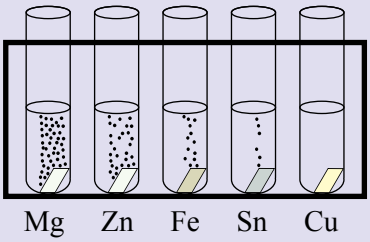
Materials: Test tubes, test tube rack, dilute hydrochloric acid, dilute sulphuric acid, various metals (magnesium, zinc, iron, tin, copper).

Method:

a) One-third fill test tubes with dilute hydrochloric acid and put them in the test tube rack.

b) Use sand paper to clean each metal, add each metal to a test tube (add the metals in the order of the metal activity list).

c) Repeat with dilute sulphuric acid.



1 Why clean each metal with sand paper?

2 Did your observations relate to the metal activity series?

3 Are the reactions endothermic or exothermic?

More reactive

Metal	Symbol	with Acid	Example
Potassium	K	React violently	$2K + 2HCl \rightarrow 2KCl + H_2$ (potassium + hydrochloric acid → potassium chloride + hydrogen)
Sodium	Na	React violently	$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2$ (sodium + sulphuric acid → sodium sulphate + hydrogen)
Calcium	Ca	React violently	$Ca + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2$ (calcium + nitric acid → calcium nitrate + hydrogen)
Magnesium	Mg	Reacts rapidly	$Mg + 2HCl \rightarrow MgCl_2 + H_2$ (magnesium + hydrochloric acid → magnesium chloride + hydrogen)
Aluminium	Al	Reacts rapidly	$4Al + 6H_2SO_4 \rightarrow 2Al_2(SO_4)_3 + 3H_2$ (aluminium + sulphuric acid → aluminium sulphate + hydrogen)
Zinc	Zn	Reacts quickly	$Zn + 2HNO_3 \rightarrow Zn(NO_3)_2 + H_2$ (zinc + nitric acid → zinc nitrate + hydrogen)
Iron	Fe	Reacts slowly	$2Fe + 6HCl \rightarrow 2FeCl_3 + 3H_2$ (iron (III) + hydrochloric acid → iron (III) chloride + hydrogen)
Tin	Sn	Reacts slowly	$Sn + 2HNO_3 \rightarrow Sn(NO_3)_2 + H_2$ (tin (II) + nitric acid → tin (II) nitrate + hydrogen)
Lead	Pb	No reaction	
Copper	Cu	No reaction	
Silver	Ag	No reaction	

Dilute nitric acid will react with magnesium and zinc to produce a salt and hydrogen.

However, nitric acid will tend to produce dangerous nitrogen oxide gases in reactions with other metals.

A bit of trivia

- The acid that is used in car batteries is sulphuric acid. Acid battery is concentrated and very dangerous.
- The acid in our stomach is hydrochloric acid. This acid allows us to digest the proteins in food such as meat.
- The main use of nitric acid is in the production of fertilisers.

A railway tanker of concentrated sulphuric acid (H_2SO_4).

Exercise

1 Copy and complete the acid-metal equation:
Acid + Metal → +

2 What is the test for hydrogen gas?

3 Copy and complete the following acid-metal word equations:

a) hydrochloric acid + magnesium → +

b) sulphuric acid + zinc → +

c) nitric acid + calcium → +

d) sulphuric acid + tin (II) → +

e) hydrochloric acid + iron (III) → +

4 Given the following acids and metals:

Acid	Metal
HCl	Na
HNO_3	Mg
H_2SO_4	Zn

Which acid and which base would you mix together to produce the following salts?

a) $MgCl_2$ Magnesium chloride

b) $NaNO_3$ Sodium nitrate

c) $ZnSO_4$ Zinc sulphate

6.7 Acids & Carbonates

When an acid reacts with a carbonate, a salt, water and carbon dioxide gas is produced.

acid + carbonate → salt + water + carbon dioxide

ACID
(Turns blue litmus red)

Examples:

Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulphuric acid	H_2SO_4

Carbonate

Examples:

Calcium carbonate	$CaCO_3$
Sodium carbonate	Na_2CO_3
Copper carbonate	$CuCO_3$

SALT
A chemical salt is the result of a reaction between an acid and a carbonate (or metal or base).

Examples:

Magnesium chloride	$MgCl_2$
Zinc nitrate	$Zn(NO_3)_2$
Iron sulphate	$FeSO_4$

+ **Carbon Dioxide** CO_2

+ **Water** H_2O

Carbon dioxide is heavier than air.

hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

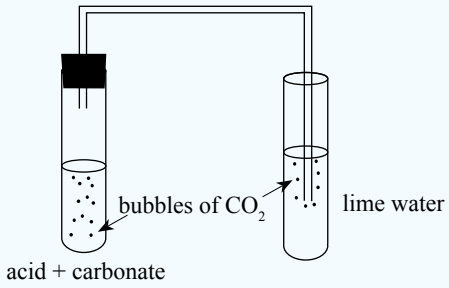
Acids and Carbonates

Watch a couple of online videos about 'Acids and Carbonates'.

Tests for Carbon Dioxide

Watch a couple of online videos about 'Tests for Carbon Dioxide'.

Test for carbon dioxide



Lime water turns milky in the presence of carbon dioxide (CO_2). Lime water is a saturated solution of calcium hydroxide ($Ca(OH)_2$).

Activity

Acids and carbonates

Materials: Test tubes, test tube rack, test tube stopper with tubing as shown, dilute hydrochloric acid, dilute sulphuric acid, various carbonates (calcium carbonate - marble chips, copper carbonate, sodium carbonate, sodium hydrogen carbonate).

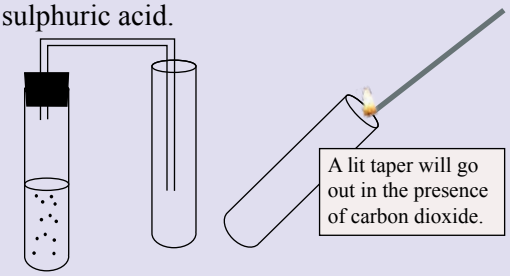
Method:

a) Place a couple of calcium carbonate chips in a test tube.

b) Add about 2 cm of dilute hydrochloric acid to the test tube.

c) Pass the gas through lime water, or collect the gas in a test tube and test as shown.

d) Repeat with other carbonates and dilute sulphuric acid.



1 Attempt to write equations (word or symbolic) for each of the reactions.

2 Are the reactions endothermic or exothermic?

Acid + Carbonate

Acid	Salt formed	Examples
Hydrochloric acid	Chloride	$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$ hydrochloric acid + sodium carbonate → sodium chloride + water + carbon dioxide $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$ hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide $2HCl + FeCO_3 \rightarrow FeCl_2 + H_2O + CO_2$ hydrochloric acid + iron (II) carbonate → iron (II) chloride + water + carbon dioxide
Sulphuric acid	Sulphate	$H_2SO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + H_2O + CO_2$ sulphuric acid + sodium carbonate → sodium sulphate + water + carbon dioxide $H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$ sulphuric acid + calcium carbonate → calcium sulphate + water + carbon dioxide $H_2SO_4 + K_2CO_3 \rightarrow K_2SO_4 + H_2O + CO_2$ sulphuric acid + potassium carbonate → potassium sulphate + water + carbon dioxide
Nitric acid	Nitrate	$2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$ nitric acid + sodium carbonate → sodium nitrate + water + carbon dioxide $2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$ nitric acid + calcium carbonate → calcium nitrate + water + carbon dioxide $HNO_3 + NaHCO_3 \rightarrow NaNO_3 + H_2O + CO_2$ nitric acid + sodium hydrogen carbonate → sodium nitrate + water + carbon dioxide

Rose-red rhodochrosite crystals set in a matrix of chalcopyrite and quartz crystals (Rob Lavinsky - WikimediaCommons). Rhodochrosite is manganese carbonate ($MnCO_3$).

A bit of trivia

- Baking soda reacts with acids in foods to produce carbon dioxide bubbles and cause cakes and bread dough to rise.
- Baking soda is sodium hydrogen carbonate ($NaHCO_3$) or sodium bicarbonate.
- Sodium hydrogen carbonate is also used as an antacid - to neutralise the hydrochloric acid causing symptoms of heartburn and upset stomach.

Bee stings are acidic. They can be neutralised using baking powder, which contains sodium hydrogen carbonate ($NaHCO_3$).

Sodium hydrogen carbonate ($NaHCO_3$) is commonly used in soaps and mouthwashes. It neutralises acid formation in the mouth and prevents teeth and gum decay.

Exercise

1 Copy and complete the acid-carbonate equation: acid + carbonate → + +

2 What is the test for carbon dioxide gas?

3 Copy and complete the following acid-carbonate equations:

a) hydrochloric acid + magnesium carbonate →

b) sulphuric acid + zinc carbonate →

c) nitric acid + calcium carbonate →

d) sulphuric acid + tin (II) carbonate →

e) hydrochloric acid + iron (III) carbonate →

f) hydrochloric acid + → magnesium chloride +

g) sulphuric acid + → potassium sulphate +

h) nitric acid + → tin (II) nitrate +

4 Given the following acids and carbonates:

Acid	Carbonate
HCl	Na_2CO_3
HNO_3	$MgCO_3$
H_2SO_4	$ZnCO_3$

Which acid and which base would you mix together to produce the following salts?

a) $MgCl_2$ Magnesium chloride

b) $NaNO_3$ Sodium nitrate

c) $ZnSO_4$ Calcium sulphate

6.8 Oxidation

Oxidation

Oxidation was originally used to describe a reaction in which oxygen combines with other elements or compounds to form an **oxide**. An **oxide** is a compound that contains at least one oxygen atom. Examples of **oxides** are water (H_2O - hydrogen oxide), rust (Fe_2O_3 - iron (III) oxide, carbon dioxide (CO_2)).

Oxygen is the most abundant element in the Earth's crust and is found in **oxides** such as silicon dioxide (SiO_2). Quartz is silicon dioxide.

21% of the volume of the air in our atmosphere is oxygen. Oxygen is also dissolved in water.

Oxygen (O_2) is a colourless, odourless, tasteless gas vital for life on Earth. Oxygen is slightly heavier than air and is slightly soluble in water.

When an element burns in oxygen the product is called an **oxide**.

$C + O_2 \rightarrow CO_2$
carbon + oxygen → carbon dioxide

$S + O_2 \rightarrow SO_2$
sulphur + oxygen → sulphur dioxide

$4P + 5O_2 \rightarrow 2P_2O_5$
phosphorus + oxygen → phosphorus pentoxide

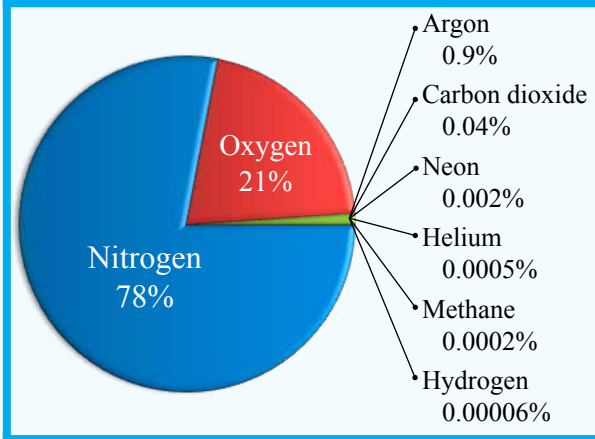
$4Na + O_2 \rightarrow 2Na_2O$
sodium + oxygen → sodium oxide

$4K + O_2 \rightarrow 2K_2O$
potassium + oxygen → potassium oxide

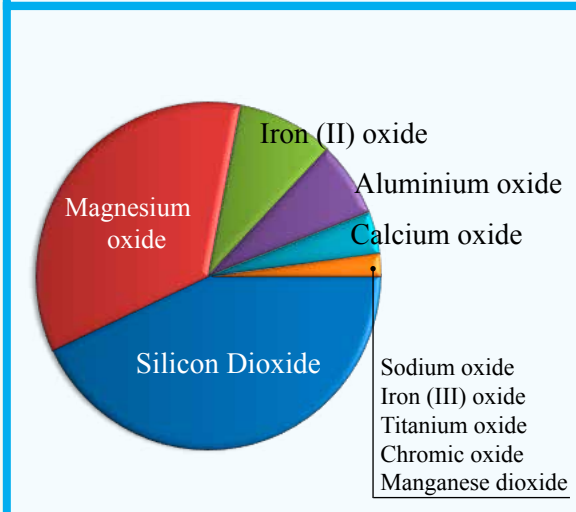
$2Ca + O_2 \rightarrow 2CaO$
calcium + oxygen → calcium oxide

$2Mg + O_2 \rightarrow 2MgO$
magnesium + oxygen → magnesium oxide

Our atmosphere extends up to 300 km above the Earth. Our atmosphere, of mainly nitrogen and oxygen, is held in place by gravity. Three-quarters of the atmosphere is within 11 km of the surface of the Earth.



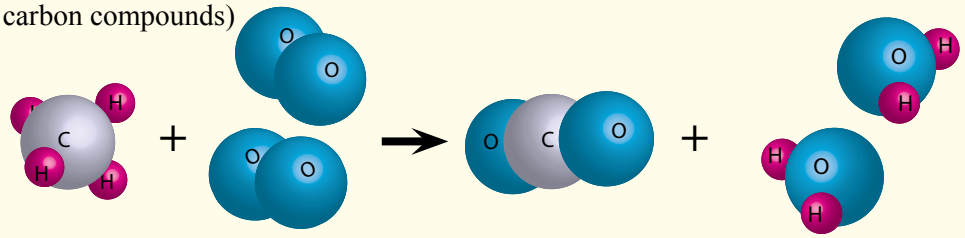
The gases in our atmosphere.



The Earth's crust is composed almost entirely of oxides.

Important examples of oxidation

Burning (Oxidation of carbon compounds)

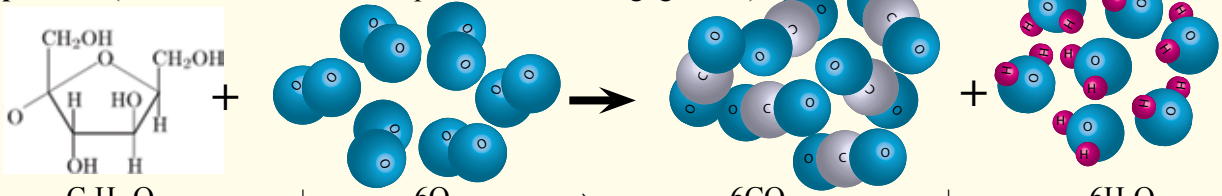


Natural gas

CH_4 + $2O_2$ → CO_2 + $2H_2O$

Methane + oxygen → carbon dioxide + water vapour

Respiration (Oxidation of carbon compounds in foods, eg. glucose)



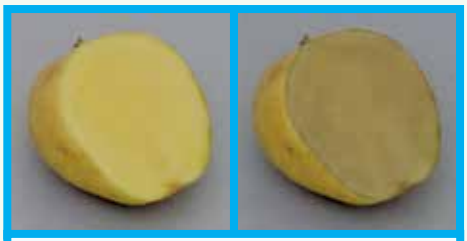
$C_6H_{12}O_6$ + $6O_2$ → $6CO_2$ + $6H_2O$

organic food compounds + oxygen → carbon dioxide + water vapour

Rusting (Oxidation of iron in air and moisture)

4Fe + $3O_2$ + $2H_2O$ → $2Fe_2O_3.H_2O$

iron + oxygen + moisture → iron (III) oxide combined with water



Oxidative browning on a cut potato.

Challenge

How to reduce oxidative browning?

Can you think of 5 ways of reducing the oxidative browning of fruit ie, prevent oxygen from reaching the surface of cut fruit?

Challenge

Burning candle wax

Balance the equation for the burning of candle wax: $C_{25}H_{52} + O_2 \rightarrow CO_2 + H_2O$

Exercise

1 What is oxidation?

2 What is an oxide? Give an example of an oxide.

3 Which of the following are oxides?

a) CaO **b)** MgO

c) NaCl **d)** Fe_2O_3

4 Complete the following word equations:

a) C + O_2 → CO_2

carbon + oxygen →

b) 2Ca + O_2 → 2CaO

calcium + oxygen →

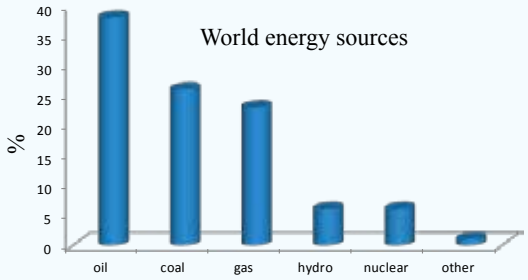
5 Give three important everyday examples of oxidation.

6 Why is that when water is the product of an oxidation reaction, it is often as a vapour?

6.9 Combustion

Combustion

Combustion is the burning of a fuel with oxygen to produce heat. Combustion is our major source of energy.



Combustion of petrol:

$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ + energy

heptane + oxygen → carbon dioxide + water + energy

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ + energy

octane + oxygen → carbon dioxide + water + energy

$C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$ + energy

nonane + oxygen → carbon dioxide + water + energy

Combustion of diesel:

$2C_{10}H_{22} + 31O_2 \rightarrow 20CO_2 + 22H_2O$ + energy

decane + oxygen → carbon dioxide + water + energy

$C_{15}H_{32} + 23O_2 \rightarrow 15CO_2 + 16H_2O$ + energy

pentadecane + oxygen → carbon dioxide + water + energy

Combustion of coal:

$C + O_2 \rightarrow CO_2$ + energy

coal + oxygen → carbon dioxide + energy

Combustion of natural gas:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + energy

methane + oxygen → carbon dioxide + water + energy

Combustion of wood:

$C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 5H_2O$ + energy

cellulose + oxygen → carbon dioxide + water + energy

Combustion is almost always incomplete. Fires produce all kinds of products such as carbon dioxide, water vapour, ash (carbon), carbon monoxide, and nitrogen oxides.

Smoke is a product of combustion and is a mix of solids, liquids, and gases

Petrol is made up of a variety of hydrocarbons with between 4 and 12 carbon atoms per molecule. Diesel typically contains between 8 and 21 carbon atoms per molecule.

Natural gas is mainly methane (CH_4).

Combustion

Combustion, or burning, is an exothermic chemical reaction involving a fuel and an oxidant.

Oxygen is an obvious oxidant. Combustion in the absence of oxygen can happen with compounds that contain oxygen.

Examples of oxidants, containing chemically bound oxygen, are potassium permanganate $KMnO_4$, hydrogen peroxide H_2O_2, and nitric acid HNO_3.

A Proton-K rocket being powered by the combustion of a fuel (hydrazine N_2H_4) and an oxidant (dinitrogen tetroxide N_2O_4).

Challenge

Hydrazine and dinitrogen tetroxide

Balance the following combustion equation:

$N_2H_4 + N_2O_4 \rightarrow N_2 + H_2O$

A coal power station in Victoria. The combustion of carbon produces considerable heat to produce steam to turn turbines to produce electricity. $C + O_2 \rightarrow CO_2 + \text{heat}$

Exercise

1 What is a combustion reaction?

2 Which two reactants are always needed in a combustion reaction?

3 Is combustion an exothermic reaction or an endothermic reaction?

4 Which of the following forms of energy are likely to be produced in the combustion of wood?

a) kinetic energy **b)** light energy
c) sound energy **d)** nuclear energy
e) electric energy **f)** heat energy

5 Write the word equation and the symbolic equation for the combustion of coal.

6 Complete the following word equation:

methane + oxygen →

7 Is the following equation balanced (the combustion of cellulose in wood)?

$C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 7H_2O + \text{energy}$

8 Attempt to write the word equation and the symbolic equation for the combustion of heptane (C_7H_{16}). Heptane is one of the fuels in petrol.

Acidification

The **combustion** of petrol, diesel, coal, gas, and wood releases large quantities of carbon dioxide (CO_2) into the atmosphere.

Carbon dioxide dissolves in water to produce carbonic acid:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

carbon dioxide + water → carbonic acid

Carbonic acid is considered a weak acid because it releases few H^+ ions when dissolved in water.

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

It is suggested that 40% of the carbon dioxide produced by human activity is absorbed by the oceans, rivers, and lakes. It is also suggested that the acidification of the oceans is having negative effects on marine life.

Carbon dioxide dissolves into the oceans, rivers, and lakes and forms carbonic acid. It has been suggested that the increased combustion of fossil fuels has increased the acidity of the oceans.

Warming

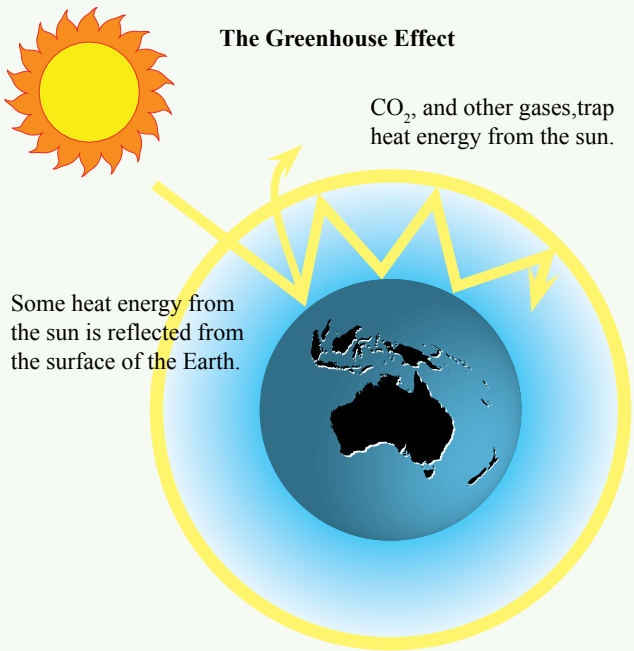
The **combustion** of petrol, diesel, coal, gas, and wood releases large quantities of carbon dioxide (CO_2) into the atmosphere.

It has been estimated that human activity over the last two hundred years has increased the amount of atmospheric carbon dioxide by around 40%.

Carbon dioxide is considered a greenhouse gas because it traps heat energy from the sun in the Earth's atmosphere. Other greenhouse gases are water vapour, methane, nitrous oxide, and ozone.

It is suggested that the increasing amount of carbon dioxide in the atmosphere will gradually increase the Earth's surface temperature and have negative effects on organisms.

The Greenhouse Effect



Exercise

1. Does carbon dioxide dissolve in the oceans, rivers, and lakes?
2. Complete the following word equation:

   $CO_2 + H_2O \rightarrow H_2CO_3$

   carbon dioxide + water →
3. Explain why it is thought that the acidity of the oceans is increasing.
4. What is a greenhouse gas?
5. Name three greenhouse gases.
6. Explain why it is thought that the Earth's surface temperature will increase.

Incomplete

Incomplete combustion generally happens when there isn't enough oxygen for all of the fuel to burn completely to produce carbon dioxide and water.

Incomplete combustion tends to produce toxic products such as carbon particles (soot) and carbon monoxide (CO).

Airborne particles of carbon are believed to be responsible for many respiratory problems and premature deaths.

Carbon monoxide (CO) is colourless, odourless, tasteless, and a very poisonous gas.

Activity

Incomplete combustion

Materials: Bunsen burner.

Method:

a) Light a bunsen burner and adjust the air valve to produce the types of flame shown.

A B C D

Bunsen burner flames from A J Fijałkowski (Wikipedia).

1 Which flame uses the least oxygen (less air through the air hole)?

2 Which flame would likely produce the most carbon (soot)?

Carbon monoxide, CO, the silent killer is responsible for many fatal air poisonings. Low levels of odourless, colourless carbon monoxide gas will kill.

Carbon monoxide takes the place of oxygen in red blood cells and stops oxygen from getting to the cells of the body. The person dies from lack of oxygen.

Complete combustion of natural gas:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

methane + oxygen → carbon dioxide + water

Incomplete combustion of natural gas:

$$3CH_4 + 4O_2 \rightarrow C + 2CO + 6H_2O$$

methane + oxygen → carbon + carbon monoxide + water

A steam train puffing sooty smoke - an indication of incomplete combustion.

Exercise

1 What is meant by incomplete combustion?

2 Complete combustion of methane (CH_4) produces carbon dioxide and water vapour. What are the products of incomplete combustion of methane?

3 What are the toxic effects of incomplete combustion?

4 The temperature of the flame of a bunsen burner can vary from 900°C to 1600°C depending whether the air valve is open or closed.
Which temperature most likely represents complete combustion?

Incomplete combustion

Watch online videos demonstrating incomplete combustion.

6.10 Respiration

Respiration

Cellular **respiration** is the process in which the chemical energy in food is released. This energy is used for cell growth and repair.

Respiration happens in plant cells and animal cells.

Carbohydrates, fats, sugars, and proteins are used as fuel in **respiration**.

Essentially, cellular **respiration** is a combustion reaction in which fuel is burned with oxygen to produce energy. Other products are carbon dioxide and water.

An average person breathes in around 11,000 litres of air every day.

21% of the air we breathe is oxygen.

The higher the amount of carbon dioxide in our blood, the faster we breathe.

My gills extract oxygen from the water.

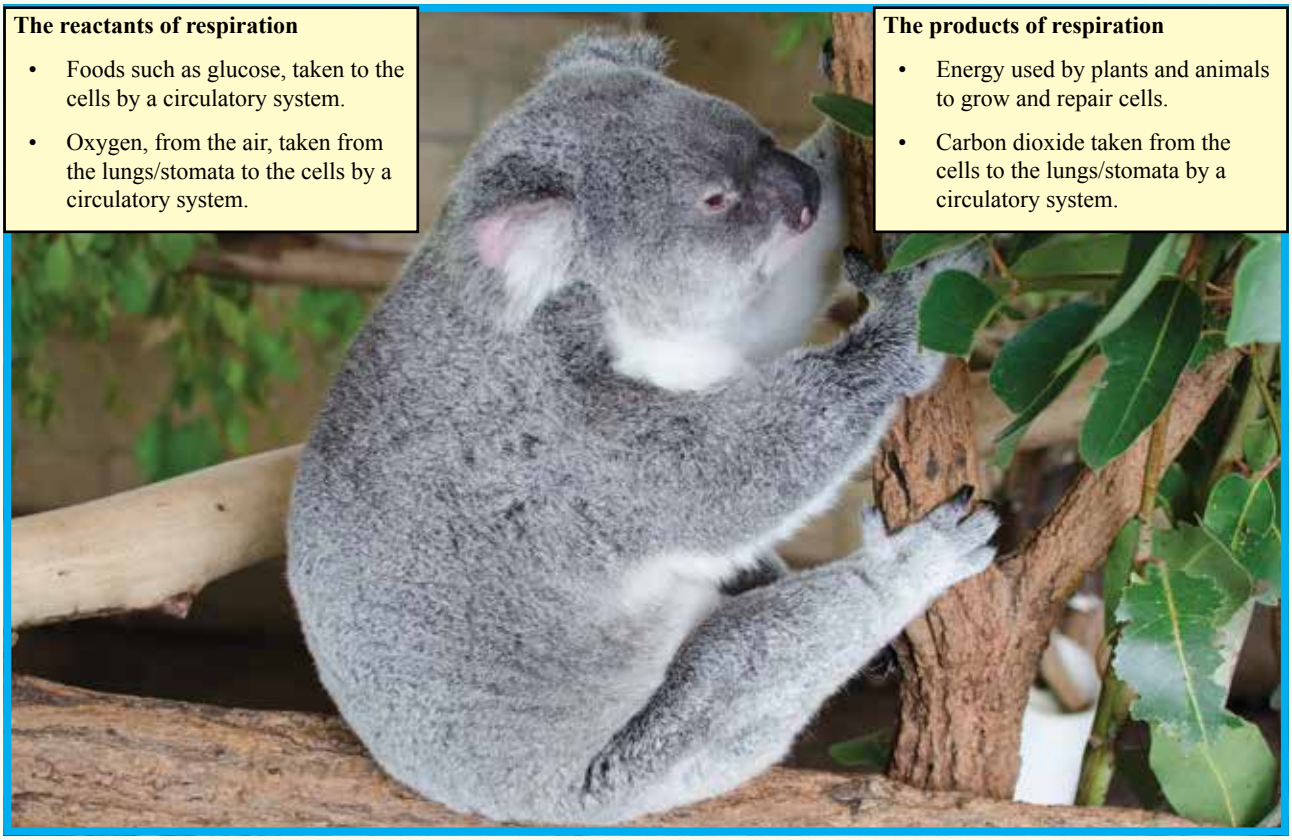
I can drown if there isn't enough oxygen in the water.

The reactants of respiration

- Foods such as glucose, taken to the cells by a circulatory system.
- Oxygen, from the air, taken from the lungs/stomata to the cells by a circulatory system.

The products of respiration

- Energy used by plants and animals to grow and repair cells.
- Carbon dioxide taken from the cells to the lungs/stomata by a circulatory system.



$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Glucose + Oxygen → Energy + Carbon dioxide + Water

Activity

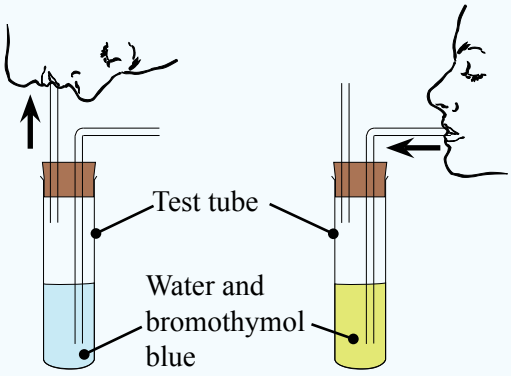
Gases in respiration

a) Set up apparatus, similar to the right, and add 2 or 3 drops of bromothymol blue solution.

b) Inhale through the test tube. Does the bromothymol blue change colour?

c) Exhale into the test tube.
Does the bromothymol blue change colour?

d) Which contains more carbon dioxide, inhaled air or exhaled air?



Carbon dioxide dissolved in water produces a weak acid (carbonic acid - H_2CO_3).
Bromothymol blue is blue in a basic or neutral solution.
Bromothymol blue turns green and then yellow in an acidic solution.

Activity

Gases in respiration

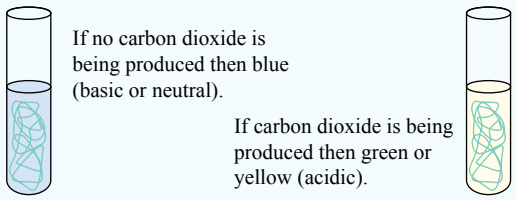
Materials: Pond weed, test tubes, bromothymol blue.

a) Add 2 or 3 drops of bromothymol blue solution to two test tubes two-thirds filled with water. Add some pond weed.

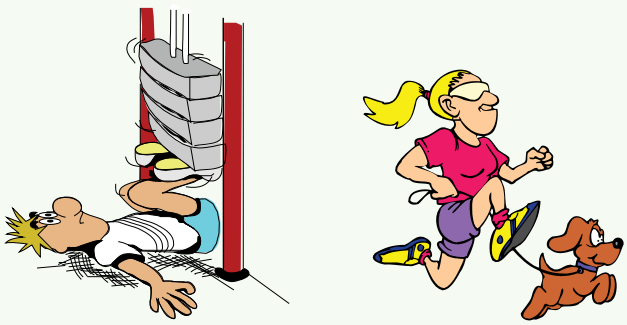
b) Leave one test tube in light and place the other test tube in a dark place (a cupboard?).

c) Record your results after one or two days.

1 Explain any differences in colour changes.



Pond weed in water with a few drops of bromothymol blue.



Anaerobic exercise versus aerobic exercise

Challenge

What is the difference between aerobic respiration and anaerobic respiration?

Exercise

1 What is meant by cellular respiration?

2 Write a word equation for cellular respiration (and a symbolic equation if possible).

3 What two ingredients are needed for respiration to occur?

4 Why is respiration so important for life on Earth?

5 Which of the following is an indication that respiration might be taking place?

a) oxygen is being produced.
b) oxygen is being reduced.
c) fuel is being produced.
d) fuel is being reduced.
e) carbon dioxide is being produced.
f) carbon dioxide is being reduced.

6.11 Photosynthesis

Photosynthesis

Photosynthesis is the process by which green plants make food using sunlight.

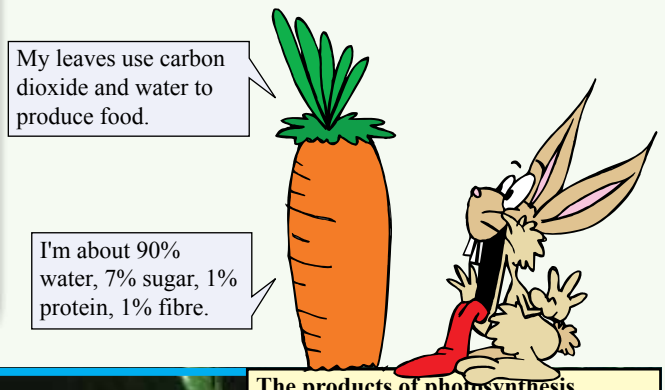
Plants and algae produce their own food using the energy from the sun to combine carbon dioxide and water to produce glucose and oxygen.

Chlorophyll, the green pigment in plants and algae, converts the sunlight energy to chemical energy.

Photosynthesis also produces the oxygen that plants and animals need for life.

Ocean phytoplankton, through photosynthesis, are credited with producing half of the world's oxygen.

The other half of the world's oxygen comes from photosynthesising trees, shrubs, grasses, and other plants.

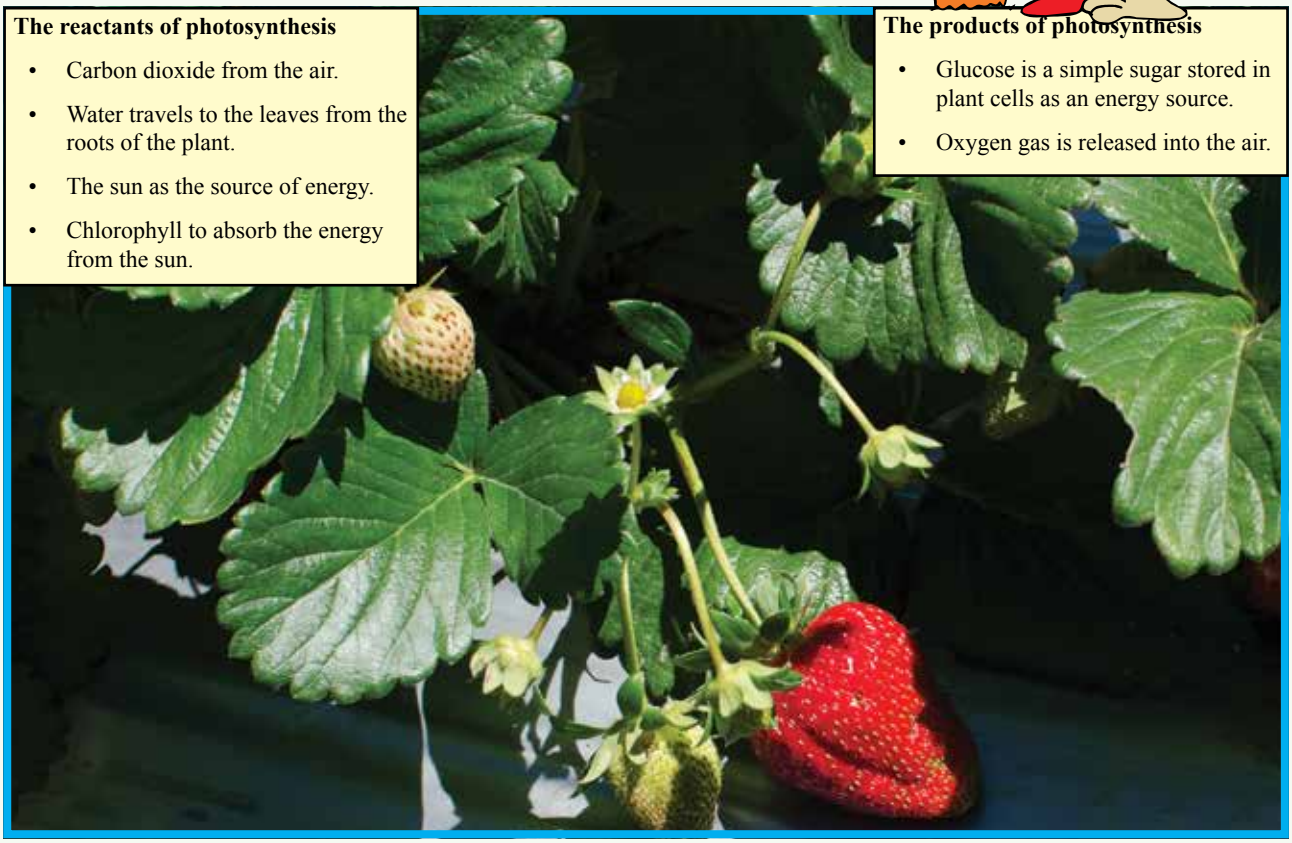


The reactants of photosynthesis

- Carbon dioxide from the air.
- Water travels to the leaves from the roots of the plant.
- The sun as the source of energy.
- Chlorophyll to absorb the energy from the sun.

The products of photosynthesis

- Glucose is a simple sugar stored in plant cells as an energy source.
- Oxygen gas is released into the air.



$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$$

Carbon dioxide + Water → Glucose + Oxygen

Activity

Gases in photosynthesis

1 Set up apparatus, similar to the set up on the right, to collect the gases produced by a pond weed.

2 Design experiments to test each of the following hypotheses:

Because photosyntesis uses sunlight, carbon dioxide and water to produce food and oxygen:

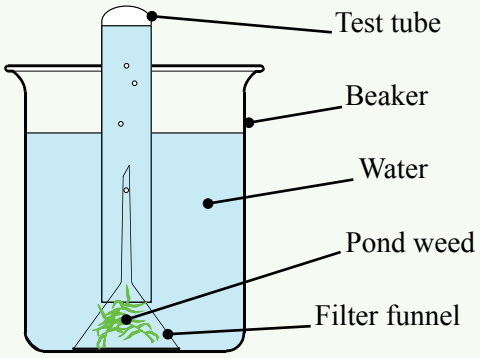
a) Pond weed will produce more gas with sunlight than without sunlight?

b) The gas collected when pond weed is in sunlight is oxygen.

c) Pond weed will absorb the carbon dioxide dissolved in the water when left in sunlight.

Because respiring plants use food and oxygen to produce energy, carbon dioxide, and water:

d) Pond weed, left in a dark cupboard, will increase the amount of carbon dioxide dissolved in the water.

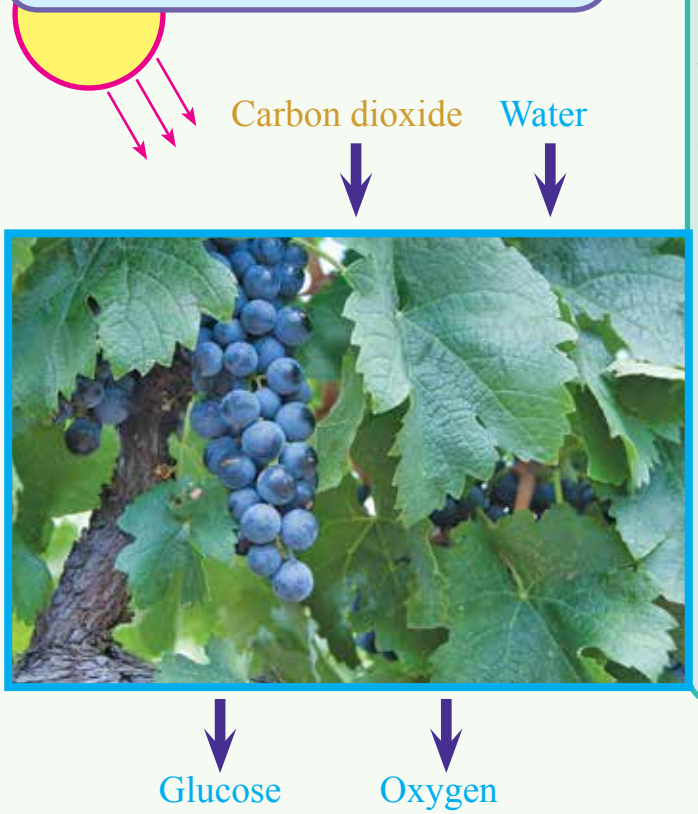


Adding bromothymol blue will help indicate the presence of carbon dioxide in the water (Carbon dioxide in water produces a weak acid which turns bromothymol blue green and then yellow as the acidity increases).

Adding sodium bicarbonate to the water increases the amount of carbon dioxide in the water.

A test for oxygen is that it will relight a glowing splint.

Tests for carbon dioxide gas is that it will put out a lit splint and turn limewater milky.



Exercise

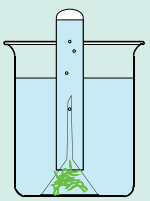
1 What is meant by photosynthesis?

2 Write a word equation for photosynthesis (and a symbolic equation if possible).

3 What four ingredients are needed for photosynthesis to occur?

4 Why is photosynthesis so important for life on Earth?

5 Pond weed is set up as shown and placed in sunlight:



a) Identify the gas that is likely to be collected in the test tube.

b) Is the amount of carbon dioxide, dissolved in the water, likely to be increased or decreased.

c) If bromothymol blue is added to the water, is it likely to remain blue or turn yellow or green?

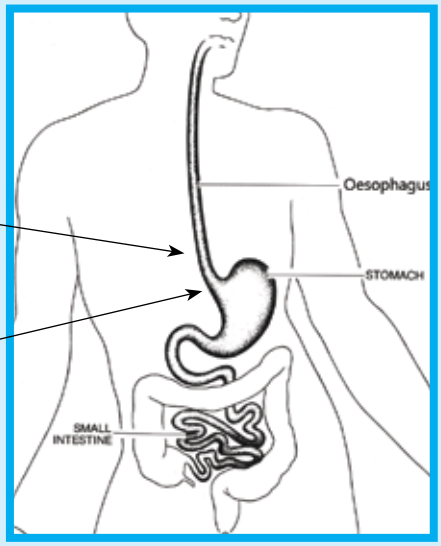
6.12 Science Knowledge

Reflux

Reflux is a common problem in which acidic stomach contents escape from the stomach and leak up into the 0esophagus.

The acidic stomach contents irritate the delicate wall of the oesophagus and can cause heartburn, nausea, a bitter taste in the mouth, chronic cough, hoarse voice, frequent throat clearing.

The escape of acidic stomach juices into the oesophagus is caused by a weakness in the sphincter, a circular band of muscle. The sphincter acts as a valve to stop stomach acid from getting into the esophagus.



Alcohol can increase the risk of reflux because alcohol can relax the esophageal sphincter and let acid into the esophagus.

Fatty foods increase the risk of acid reflux because fatty foods take longer to digest and the stomach stays full for longer.

An example of an antacid, calcium carbonate, $CaCO_3$, neutralising stomach acid:

$$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$$

hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

Antacids may also contain a gel to coat the walls of the esophagus and stomach.

Treatments for reflux include

a) Antacids such as alka-Seltzer $NaHCO_3$, Milk of Magnesia $Mg(OH)_2$, and Tums $CaCO_3$ may ease reflux by neutralising the acidity of the stomach.

Milk of Magnesia, $Mg(OH)_2$, works by neutralising stomach acid.

b) H2 blockers act to reduce the production of acid in the stomach.

c) Proton pump inhibitors prevent the production of stomach acid .

Exercise

1. What is reflux?
2. Heartburn affects many people. What, generally, is the cause of heartburn?
3. Is a home remedy of drinking a solution of baking soda, $NaHCO_3$, likely to reduce heartburn? Explain.
4. How might eating large amounts of cheese increase the risk of reflux?
5. Why would lying on your left side be more likely to reduce reflux than lying on your right side?

Acid rain

Rain is normally slightly acidic due to carbon dioxide dissolved in the raindrops. The pH of rain, due to carbonic acid, can range from just less than 7 to 5.7.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

carbon dioxide + water → carbonic acid

Carbonic acid is considered a weak acid because it releases few H^+ ions when dissolved in water.

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

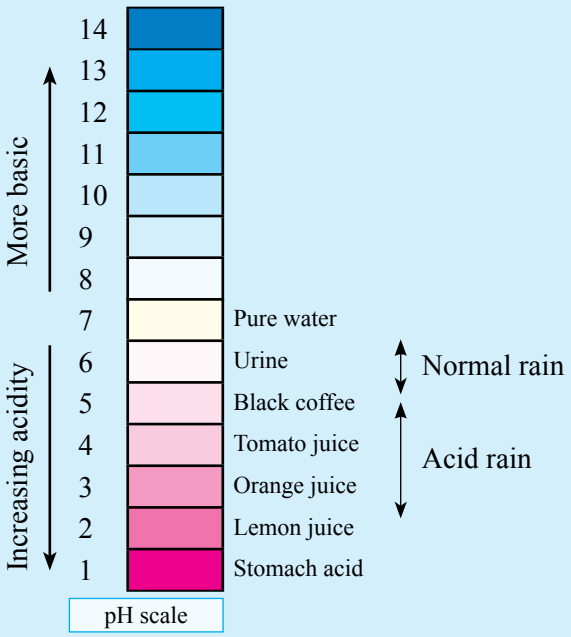
Emissions of sulphur dioxide and nitrogen oxides from power stations, industry, and motor vehicles can make rain more acidic than normal. A pH of below 2.4 has been recorded in industrialised areas.

$$SO_2 + H_2O \rightarrow H_2SO_3$$

sulphur dioxide + water → sulphurous acid

$$NO_2 + H_2O \rightarrow HNO_3 + NO$$

nitrogen dioxide + water → nitric acid + nitrogen oxide



The chemicals in acid rain can cause paint to peel, cause bridges and steel structures to corrode, cause statues to weather faster, stunt the growth of forests, kill aquatic animals, cause asthma, bronchitis, and heart problems in people.

Acid rain increases the natural weathering of marble statues. Marble is mainly calcium carbonate ($CaCO_3$).

Acid rain

Watch a couple of videos on 'acid rain'.

Exercise

1 Why is normal rain slightly acidic with a pH between 5.7 and 7?

2 Which two gas emissions are responsible for acid rain?

3 List three effects of acid rain.

4 Complete the following word equations for the formation of acid rain:

a) $SO_2 + H_2O \rightarrow H_2SO_3$

+ water →

b) $NO_2 + H_2O \rightarrow HNO_3 + NO$

+ water →

6.13 Science Inquiry

Science Inquiry

Science inquiry skills are important in science, and in any situation that requires critical thinking. The process of thinking in logical steps allows us to answer questions about the world around us.

Science inquiry skills include:

- questioning and predicting.
- planning and conducting.
- processing and analysing.
- evaluating.
- communicating.

Hypotheses

A **hypothesis** is an educated guess. A useful hypothesis is a statement which is testable, measurable, and may contain a prediction.

An example of a useful hypothesis is:

If electrolysis of water is represented by $2H_2O \rightarrow O_2 + 2H_2$ **then** the volume of hydrogen produced will be twice the volume of oxygen produced.

Variables

The **independent variable** is the variable that is changed. In graphs, the independent variable is plotted on the x-axis.

The **dependent variable** is the variable that is measured. In graphs, the dependent variable is plotted on the y-axis.

The **controlled variables** are all of the other variables that are to be kept constant.

Writing a science hypothesis

Watch a couple of 'writing a science hypothesis' videos.

Planning & Conducting

Explain the choice of variables to be controlled, changed, and measured in an investigation.

Planning an experiment is to describe in detail, the step-by-step procedures to follow.

Select and use appropriate equipment to accurately collect data.

Processing & Analysing

Summarise the data in the form of a graph or chart to help in understanding the data and to identify relationships.

Charts, graphs, and tables are also a great way of presenting investigation data to others.

The analysis of the data in a graph involves looking for trends, patterns and relationships in the graph.

Draw conclusions that are consistent with evidence.

Evaluating

Evaluate conclusions, identify sources of uncertainty, and describe ways to improve the quality of the data.

Communicating

Write a report using scientific ideas, information, and evidence-based arguments.

Present your report to your target audience using digital technology.

Examples of reports are shown in Chapter 1.

Science Investigations

Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem.

Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations.

Oxidative browning

Oxidative browning is a chemical process that produces a brown colour in foods.

When fruits are cut, the plant cells release enzymes. Certain enzymes, in the presence of oxygen, are converted to brown pigments known as melanins.

In this case, oxidative browning is described as enzymatic browning. Browning happens more rapidly at warm temperatures and when the pH is between 5 and 7.

Oxidative browning (Midori, Wikipedia).

Challenge

Consumers are reluctant to purchase browned fruit. How does the food industry prevent the browning of fruit and vegetables?

Activity

Conduct investigations to test each of the following hypotheses.

Questioning & Predicting

If the oxidative browning of a cut potato or apple is due to oxidation **then** covering the cut surface with cling wrap will stop the oxidative browning.

Questioning & Predicting

If the combustion of coal is represented by $C + O_2 \rightarrow CO_2$ **then** the burning of a lump of coal will reduce the mass of the coal to nil.

Questioning & Predicting

If carbon dioxide is heavier than air **then** carbon dioxide can be poured over a candle in a container to extinguish the flame.

Questioning & Predicting

If diet can change saliva pH **then** eating acidic foods such as berries, prunes, and grain will lower saliva pH.

6.14 Chapter Review

Simple compounds are named by combining two words:

Examples:

CO_2	Carbon dioxide
N_2O_3	Dinitrogen trioxide
CCl_4	Carbon tetrachloride
$MgNO_3$	Magnesium nitrate
$Mg(OH)_2$	Magnesium hydroxide
$Al(MnO_4)_3$	Aluminium permanganate

First word	Formula	Second word	Formula
Ammonium	NH_4	Hydrogen carbonate	HCO_3
Aluminium	Al	Hydroxide	OH
Calcium	Ca	Nitrate	NO_3
Copper	Cu	Permanganate	MnO_4
Hydrogen	H	Phosphate	PO_4
Iron	Fe	Carbonate	CO_3
Magnesium	Mg	Sulfate	SO_4
Potassium	K	Sulfite	SO_3
Sodium	Na		
Silver	Ag		
Zinc	Zinc		

An **ion** is an atom or molecule that has lost or gained an electron. When an atom or molecule loses an electron it becomes **positively charged**. When an atom or molecule gains an electron it becomes **negatively charged**.

Examples:

Zinc (Zn) loses two electrons and becomes a Zinc ion (Zn^{++} or Zn^{2+})

Sulphate (SO_4) gains two electrons and becomes a Sulphate ion (SO_4^{--} or SO_4^{2-})

The formula for:

Sodium (Na^+) chloride (Cl^-) is NaCl = sodium chloride

Magnesium (Mg^{2+}) chloride (Cl^-) is $MgCl_2$ = magnesium chloride

Iron (III) (Fe^{3+}) sulphate (SO_4^{2-}) is $Fe_2(SO_4)_3$ = iron (III) sulphate

When ready, cover the information above and answer the questions below.

Exercise

Name each of the following compounds:

1 SiO_2 (Si - silicon, O - oxygen)

2 NO_2 (N - nitrogen, O - oxygen)

3 SO_3 (S - sulphur, O - oxygen)

4 CO (C - carbon, O - oxygen)

5 H_2O (H - hydrogen, O - oxygen)

6 As_2O_5 (As - arsenic, O - oxygen)

7 NaOH (Na - sodium, OH - hydroxide)

8 $FeSO_4$ (Fe - iron, SO_4 - sulphate)

9 $Zn(OH)_2$ (Zn - zinc, OH - hydroxide)

10 $NaNO_3$ (Na - sodium, NO_3 - nitrate)

11 $Zn_3(PO_4)_2$ (Zn - zinc, PO_4 - posphate)

12 $Ca(HCO_3)_2$ (Ca - calcium, HCO_3 - hydrogen carbonate)

Exercise

13 Describe the ion formed?

- **a)** Sodium (Na) loses an electron.
- **b)** Iodine (I) gains an electron.
- **c)** Nitrite (NO_3) gains an electron.
- **d** Hydroxide (OH) gains an electron.
- **e)** Oxygen (O) gains two electron.
- **f)** Tin (Sn) loses two electrons.
- **g)** Tin (Sn) loses four electrons.

14 A copper ion is written as Cu^{2+}. What does the 2+ indicate?

15 A nitride ion is written as N^{3-}. What does the 3^- indicate?

16 What is the formula for:

- **a)** Potassium (K^+) chloride (Cl^-)?
- **b)** Magnesium (Mg^{2+}) oxide (O^{2-})?
- **c)** Sodium (Na^+) hydroxide (OH^-)?
- **d)** Copper (Cu^{2+}) nitrate (NO_3^-)?
- **e)** Iron (II) (Fe^{2+}) oxide (O^{2-})?
- **f)** Iron (III) (Fe^{3+}) oxide (O^{2-})?

Acids are defined as substances that release hydrogen ions (H^+) when dissolved in water.

Hydrochloric acid (HCl) is considered a **strong acid** because it can release a relatively large number of H^+ ions when dissolved in water.

$$HCl \rightarrow H^+ + Cl^-$$

Bases are defined as substances that release hydroxide ions (OH^-) when dissolved in water.

Sodium hydroxide, or caustic soda, is considered a **strong base** because it can release a relatively large number of OH^- ions when dissolved in water.

$$NaOH \rightarrow Na^+ + OH^-$$

The pH, **p**ower of **H**ydrogen, scale measures how acidic or basic a substance is. The pH scale ranges from 0 to 14.

- A pH of 7 is neutral.
- A pH less than 7 is acidic.
- A pH greater than 7 is basic.

Bases neutralise acids to produce a salt and water.

ACID (Turns blue litmus red)		**BASE** (Turns red litmus blue)	
Examples:		*Examples:*	
Hydrochloric acid	HCl	Calcium hydroxide	$Ca(OH)_2$
Nitric acid	HNO_3	Magnesium hydroxide	$Mg(OH)_2$
Sulphuric acid	H_2SO_4	Sodium hydroxide	NaOH

SALT

Examples:

Sodium chloride	NaCl
Calcium nitrate	$CaNO_3$
Magnesium sulphate	$MgSO_4$

+ **WATER** H_2O

Examples:

$$HCl + NaOH \rightarrow NaCl + H_2O$$
hydrochloric acid + sodium hydroxide → sodium chloride + water

Acids react with metals to produce a salt and hydrogen.

Examples:

$$2K + 2HCl \rightarrow 2KCl + H_2$$
potassium + hydrochloric acid → potassium chloride + hydrogen

$$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2$$
sodium + sulphuric acid → sodium sulphate + hydrogen

When ready, cover the information above and answer the questions below.

Exercise

1 What is the definition of an acid?

2 What is the definition of a base?

3 When HF is dissolved in water it tends to release the following ions:

$$HF \rightarrow H^+ + F^-$$

Is HF an acid or a base?

4 When ammonium hydroxide is dissolved in water it tends to release the following ions:

$$NH_4OH \rightarrow NH_4^+ + OH^-$$

Is NH_4OH an acid or a base?

5 What is pH?

6 A solution returns a pH of 3. Is the solution an acid or a base?

7 A solution returns a pH of 8. Is the solution an acid or a base?

8 A sample of milk returned a pH of just under 7 and a sample of a softdrink returned a pH of 3? Which sample has the higher concentration of H^+ ions?

Exercise

9 Copy and complete the neutralisation equation: Acid + Base ➔ +

10 What is neutralisation?

11 Given the following acids and bases:

Acid	**Base**
HCl	NaOH
HNO_3	$Ca(OH)_2$
H_2SO_4	$Mg(OH)_2$

Which acid and which base would you mix together to produce the following salts?

a) $MgCl_2$ Magnesium chloride
b) $NaNO_3$ Sodium nitrate
c) $CaSO_4$ Calcium sulphate

12 Copy and complete the acid-metal equation: Acid + Metal → +

13 Copy and complete the following acid-metal equations:

a) hydrochloric acid + magnesium → +

b) sulphuric acid + zinc → +

Acids react with carbonates to produce a salt, water, and carbon dioxide

ACID
(Turns blue litmus red)

Examples:

Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulphuric acid	H_2SO_4

Carbonate

Examples:

Calcium carbonate	$CaCO_3$
Sodium carbonate	Na_2CO_3
Copper carbonate	$CuCO_3$

SALT

Examples:

Sodium chloride	$NaCl$
Zinc nitrate	$Zn(NO_3)_2$
Iron sulphate	$FeSO_4$

+ **WATER** H_2O

+ **Carbon Dioxide** CO_2

Examples:

$$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$$

hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

Oxidation was originally used to describe a reaction in which oxygen combines with other elements or compounds to form an **oxide**. An **oxide** is a compound that contains at least one oxygen atom. Examples of **oxides** are water (H_2O - hydrogen oxide), rust (Fe_2O_3 - iron (III) oxide, carbon dioxide (CO_2)).

Examples of oxidation:

Respiration - the oxidation of carbon compounds in foods such as sugars and fats.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

glucose + oxygen → carbon dioxide + water

Rusting - the oxidation of iron in air and moisture)

$$4Fe + 3O_2 + 2H_2O \rightarrow 2Fe_2O_3.H_2O$$

iron + oxygen + moisture → iron (III) oxide

Combustion is the burning of a fuel with oxygen to produce heat. Combustion is our major source of energy.

Combustion of coal:

$$C + O_2 \rightarrow CO_2 + \text{energy}$$

coal + oxygen → carbon dioxide + energy

Combustion of natural gas:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{energy}$$

methane + oxygen → carbon dioxide + water + energy

Combustion of petrol:

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O + \text{energy}$$

octane + oxygen → carbon dioxide + water + energy

When ready, cover the information above and answer the questions below.

Exercise

1 Copy and complete the acid-metal equation:
acid + carbonate → + +

2 What is the test for carbon dioxide gas?

3 Copy and complete the following acid-carbonate equations:

a) hydrochloric acid + magnesium carbonate →

b) sulphuric acid + zinc carbonate →

c) nitric acid + calcium carbonate →

4 Given the following acids and carbonates:

Acid	Carbonate
HCl	Na_2CO_3
HNO_3	$MgCO_3$
H_2SO_4	$ZnCO_3$

Which acid and which base would you mix together to produce the following salts?

a) $MgCl_2$ Magnesium chloride

b) $NaNO_3$ Sodium nitrate

c) $ZnSO_4$ Calcium sulphate

Exercise

5 What is oxidation?

6 Which of the following are oxides?

a) CaO **b)** MgO

c) $NaCl$ **d)** Fe_2O_3

7 Why is that when water is the product of an oxidation reaction, it is usually as a vapour?

8 What is a combustion reaction?

9 Which two reactants are always needed in a combustion reaction?

10 Is combustion an exothermic or endothermic reaction?

11 Which of the following forms of energy are likely to be produced in the combustion of wood?

a) kinetic energy **b)** light energy

c) sound energy **d)** nuclear energy

e) electric energy **f)** heat energy

12 Write the word equation and the symbolic equation for the combustion of coal.

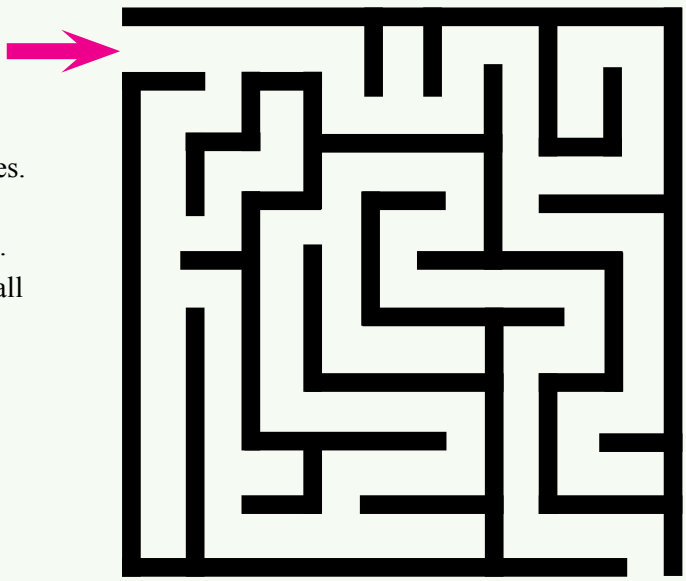
A Sweet Trick

1 Place four one dollar coins on a twenty dollar note on top of a bottle.

2 Your audience can keep the coins if they can remove the note without touching the bottle or the coin.

3 The trick - Use your finger, in a downwards motion, to quickly chop the note.

A Couple of Puzzles



1 There are a number of methods of solving mazes. One method is the 'right-hand rule'.

a) Put your right hand on the wall of the maze.

b) Keep your right hand in contact with the wall as you move through the maze.

Does the 'right-hand rule' work on this maze?

Would a 'left-hand rule' work on this maze?

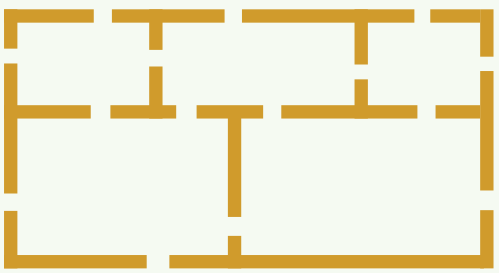
Would this method solve all mazes?

2 In which direction should a bottle be thrown from a moving train so as to reduce the chances that the bottle is broken when it hits the ground? Should the bottle be thrown forward at the same speed of the train or backwards?

3 Each door of the castle is to be locked.

A plan of the castle is shown.

To save time locking doors, can you find a way of moving through each of the fifteen doors once, and once only?



Cellular **respiration** is the process in which the chemical energy in food is released. This energy is used for cell growth and repair.

Respiration happens in plant cells and animal cells.

Carbohydrates, fats, sugars, and proteins are used as fuel in **respiration**.

Essentially, cellular **respiration** is a combustion reaction in which fuel is burned with oxygen to produce energy. Other products are carbon dioxide and water.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$
$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

Carbon dioxide dissolved in water produces a weak acid (carbonic acid - H_2CO_3).
Bromothymol blue is blue in a basis or neutral solution.
Bromothymol blue turns green and then yellow in an acidic solution.

Photosynthesis is the process by which green plants make food using sunlight.

Plants and algae produce their own food using the energy from the sun to combine carbon dioxide and water to produce glucose and oxygen.

Chlorophyll, the green pigment in plants and algae, converts the sunlight energy to chemical energy.

Photosynthesis also produces the oxygen that plants and animals need for life.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$
$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen}$$

The products of photosynthesis

- Glucose is a simple sugar stored in plant cells as an energy source.
- Oxygen gas is released into the air.

When ready, cover the information above and answer the questions below.

Exercise

1 What is meant by cellular respiration?

2 Write a word equation for cellular respiration (and a symbolic equation if possible).

3 What two ingredients are needed for respiration to occur?

4 Why is respiration so important for life on Earth?

5 Which of the following is an indication that respiration might be taking place?

a) oxygen is being produced.
b) oxygen is being reduced.
c) fuel is being produced.
d) fuel is being reduced.
e) carbon dioxide is being produced.
f) carbon dioxide is being reduced.

Exercise

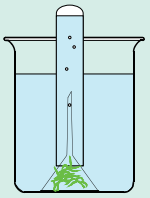
6 What is meant by photosynthesis?

7 Write a word equation for photosynthesis (and a symbolic equation if possible).

8 What four ingredients are needed for photosynthesis to occur?

9 Why is photosynthesis so important for life on Earth?

10 Pond weed is set up as shown and placed in sunlight:



a) Identify the gas that is likely to be collected in the test tube.

b) Is the amount of carbon dioxide, dissolved in the water, likely to be increased or decreased.

c) If bromothymol blue is added to the water, is it likely to remain blue or turn yellow or green?

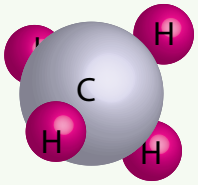
Competition Questions

Methane is the main gas in natural gas. The chemical equation for the combustion of methane is:

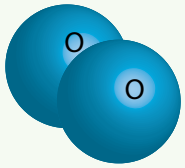
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

The equation shows that for every molecule of methane that is burned, two molecules of oxygen is burned, one molecule of carbon dioxide and 2 molecules of water are produced.

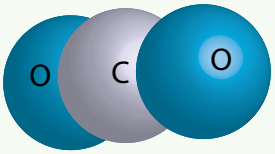
Using the atomic masses shown, this means that for every 16 grams of methane that is burned, $2 \times 32 = 64$ grams of oxygen is also burned.



Atomic mass of CH_4
$= 12 + 1 \times 4$
$= 16$



Atomic mass of O_2
$= 16 \times 2$
$= 32$



Atomic mass of CO_2
$= 12 + 16 \times 2$
$= 44$

1 For every 16 grams of methane that is burned, how many grams of carbon dioxide is produced?

a) 22
b) 44
c) 88
d) 176

2 Petrol is a mixture of many different hydrocarbons. The main hydrocarbon is octane. The chemical equation for the combustion of octane is:

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

The balanced equation shows that for every two molecules ($2 \times 114 = 228$ grams) of octane that are burned, how many grams of oxygen is also burned?

a) 25
b) 50
c) 400
d) 800

3 For every 228 grams of methane that is burned, how many grams of carbon dioxide is produced?

a) 44
b) 88
c) 704
d) 1100

4 The chemical equation for the combustion of coal is:

$C + O_2 \rightarrow CO_2$

For every gram of carbon that is burned, how many grams of carbon dioxide is produced?

a) 12
b) 16
c) 44
d) 88

A petrol station being refuelled by a petrol tanker.

Atomic mass of C_8H_{18}
$= 8 \times 12 + 18 \times 1$
$= 114$

Harder Test Questions

1 A variety of soils were measured for pH:

Soil A pH = 5.5
Soil B pH = 4.0
Soil C pH = 6.5

a) Which soil is the least acidic?
b) Which soild is the most acidic?

2 The burning of wood can be summarised by the following equation:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

a) In the above equation wood is assumed to consist of cellulose. What is the chemical formula of cellulose?
b) Is this an exothermic or endothermic reaction? Explain.
c) How many molecules of carbon dioxide are produced for every molecule of cellulose that is burned?

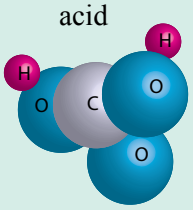
3 Which two chemicals would you mix together to produce:

a) a salt?
b) carbon dioxide?
c) hydrogen?

4 The diagram below shows a carbonic acid molecule.

a) Write the formula for carbonic acid.
b) Carbonic acid is considered a relatively weak acid because it releases few H^+ ions when dissolved in water. Attempt to complete the following ionic equation:

?	→	?	+	H^+
Carbonic acid	→	bicarbonate ion	+	hydrogen ion

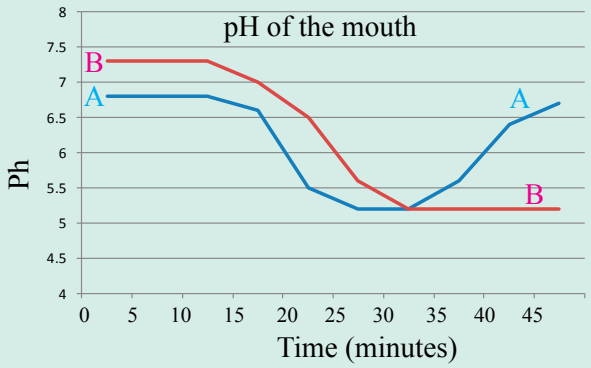


5 Which of the following best describes what is formed when methane reacts with oxygen?

a) an oxide
b) carbon dioxide + water
c) salt + hydrogen
d) salt + water + carbon dioxide

6 Lemon juice is an acid and bleach is an base. Which statement is FALSE?

a) red litmus turns blue in bleach
b) red litmus turns blue in lemon juice
c) blue litmus stays blue in bleach
d) blue litmus turns red in lemon juice



7 The pH of the mouth juices of two students is shown above. The pH was measured before and after they ate cakes. From the 12 minute mark to the 30 minute mark, each student ate cake. Student A brushed her teeth at the 35 minute mark.
Which statement is true?

a) Eating cake makes the mouth fluids weakly acidic for some time after eating.
b) B's mouth fluids were slightly acidic at the start of the pH measurements.
c) The pH of saliva is normally weakly acidic.
d) There is no evidence that saliva can be mildly basic.

Environmental engineers apply their engineering skills to pollution control and other environmental impacts.

- Relevant school subjects are Science, English, Mathematics.
- Courses generally involve a university engineering degree.