Science 10

National Curriculum

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Chemical Reactions 5

Different types of chemical reactions are used to produce a range of products and can occur at different rates (ACSSU187).

- ★ Investigate how chemistry can be used to produce a range of useful substances such as fuels, metals and pharmaceuticals.
- ★ Predict the products of different types of simple chemical reactions.
- ★ Use word or symbol equations to represent chemical reactions.
- ★ Investigate the effect of a range of factors, such as temperature and catalysts, on the rate of chemical reactions.

A Task

Perfume is usually a mixture of plant oils and solvents. Fragrances of rose, lime, cedar, or spice can be achieved by mixing/grinding the fragrant sources with a solvent such as alcohol.

Make your own perfume.

A pharmacist and a doctor discussing a remedy (Illustration by H Brunschwig, 1505).

Pharmaceuticals have a very old history dating back to antiquity.

600 BC	The Indian surgical textbook 'Sushruta Samhita' describes hundreds of medicines that can be made from plants, minerals, and animals. The book suggested the use of a mix of wine and cannabis as an anaesthetic.
600 AD	Japanese pharmacists were considered superior to all other Japanese health specialists.
1200 AD	Pharmacies began to appear throughout Europe. Pharmacists were aware of arsenious oxide, silicic acid, and many carbonates. They were also aware that lead and copper compounds were poisonous.

5.1 Chemical Equations

Chemical Reaction

A **chemical reaction** is a process in which one or more substances, **the reactants**, are transformed into one or more different substances, **the products**.

The **reactants** are the starting substances.

The **products** are the result of the chemical reaction.

A chemical reaction rearranges the atoms of **the reactants** to create different substances in **the products**.

Chemical Equation

A chemical equation describes what happens in a chemical reaction. The equation shows the **reactants** on the left hand side, the **products** on the right hand side, and the chemical formulas of the substances.

A **chemical formula** uses chemical symbols to show which atoms and how many atoms are in a substance.

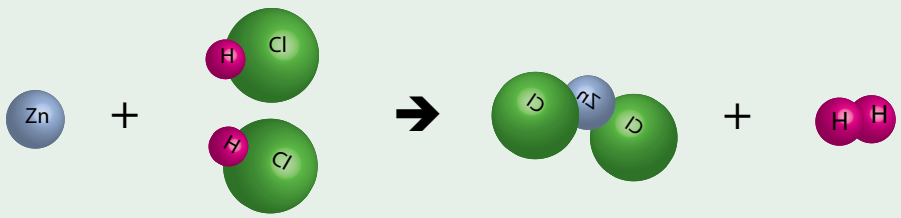
For example, the chemical formula for water is H_2O. A water molecule has two hydrogen atoms and one oxygen atom.

Example: Zinc and hydrochloric acid

Word equation

Zinc + Hydrochloric acid ➔ Zinc chloride + Hydrogen

Atomic equation



Symbolic equation

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

Exercise

1 What is a chemical reaction?

2 What is a chemical equation?

3 In the chemical reaction X + Y ➔ XY, which are the reactants and which are the products?

4 What is the chemical formula for hydrochloric acid?

Exercise

5 What is the formula for zinc chloride?

6 How many atoms of hydrogen and how many atoms of chlorine are in a molecule of hydrochloric acid?

7 How many atoms of zinc and how many atoms of chlorine are in a molecule of zinc chloride?

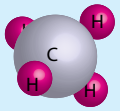
8 Is the number of hydrogen atoms in the reactants the same as the number of hydrogen atoms in the products?

Example

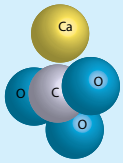
Write the chemical formula for each of the following molecules:

1 

Answer = HCl

2 

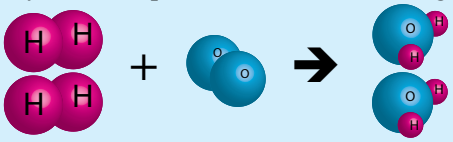
Answer = CH_4

3 

Answer = $CaCO_3$

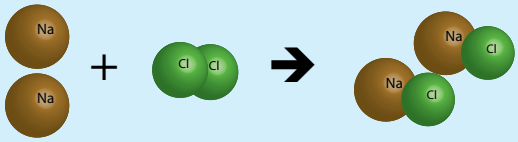
Example

Write symbolic equations for the following:

4 

$2H_2$ + O_2 → $2H_2O$

hydrogen + oxygen → water

5 

2Na + Cl_2 → 2NaCl

Example

Count the number of atoms of each element in the reactants and in the products:

6 $2Na + Cl_2 \rightarrow 2NaCl$

Na = 2	Na = 2
Cl = 2	Cl = 2

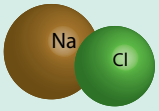
7 $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

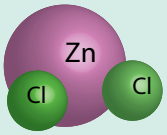
3×2=6 4×1=4 gives a total of 10 oxygen atoms

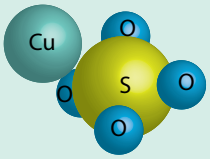
C = 3	C = 3
H = 8	H = 8
O = 10 (5×2=10)	O = 10

Exercise

1 Write the chemical formula for each of the following molecules:

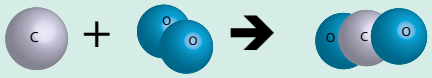
a) 

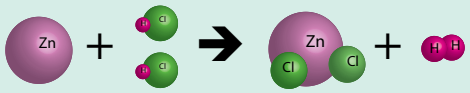
b) 

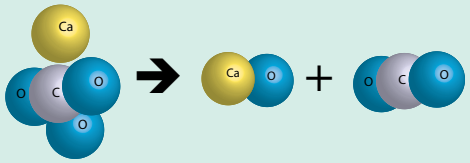
c) 

Exercise

2 Write symbolic equations:

a) 

b) 

c) 

Exercise

3 Count the number of atoms of each element in the reactants and in the products:

a) $C + O_2 \rightarrow CO_2$

b) $H_2 + Cl_2 \rightarrow 2HCl$

c) $CaCO_3 \rightarrow CaO + CO_2$

d) $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

e) $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

f) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

g) $C_{12}H_{22}O_{11} + 12O_2 \rightarrow 12CO_2 + 11H_2O$

5.2 Balancing Equations

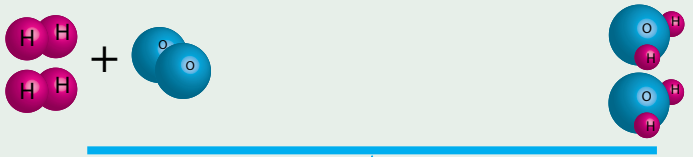
Balancing

Balancing chemical equationst means making sure that the number of atoms of each element in the reactants **is the same as** the number of atoms of each element in the products.

Balancing equations is important because a balanced equation will allow accurate calculations of the amounts of reactants and the amounts of products. These calculations are vital considering the thousands and thousands of chemical reactions that occur in our modern lives.

4 atoms of H
2 atoms of O

4 atoms of H
2 atoms of O



$2H_2 + O_2 \rightarrow 2H_2O$

$2H_2O$ = 4 atoms H, 2 atoms O

Example

Which of the following chemical equations are balanced?

1 $N_2 + H_2 \rightarrow 2NH_3$

N = 2	N = 2
H = 2	H = 6 Not balanced for H

2 $C_2H_6 + 5O_2 \rightarrow 2CO_2 + 3H_2O$

C = 2	C = 2
H = 6	H = 6
O = 10	O = 7 Not balanced for O

3 $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

C = 4	C = 4
H = 4	H = 4
O = 10	O = 10 Balanced equation

4 $FeCl_3 + NH_4OH \rightarrow Fe(OH)_3 + 3NH_4Cl$

Fe = 1	Fe = 1
Cl = 3	Cl = 3
N = 1	N = 3 Not balanced for N
O = 1	O = 3 Not balanced for O
H = 5	H = 15 Not balanced for H

Exercise

Which of the following chemical equations are balanced?

1 $Zn + HCl \rightarrow ZnCl_2 + H_2$

2 $N_2 + 3H_2 \rightarrow 2NH_3$

3 $Al + Br_2 \rightarrow AlBr_3$

4 $H_2 + O_2 \rightarrow H_2O$

5 $2S + 3O_2 \rightarrow SO_2$

6 $C_2H_6 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

7 $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

8 $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

9 $C_{12}H_{22}O_{11} + 12O_2 \rightarrow 12CO_2 + 11H_2O$

10 $CO_2 + 2H_2O \rightarrow 3O_2 + C_6H_{12}O_6$

11 $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

12 $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

13 $K_2CO_3 + BaCl_2 \rightarrow KCl + BaCO_3$

14 $Fe_2O_3 + 3C \rightarrow 3CO + 2Fe$

15 $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

16 $Mg(OH)_2 + H_2SO_4 \rightarrow MgSO_4 + 2H_2O$

How to Balance

In a balanced equation, the number of atoms in the reactants must be the same as the number of atoms in the products.

Balancing is about writing numbers at the front of each formula (coefficients) until the equation balances.

1. Draw a box around each formula.
2. Count the atoms of each element in the reactants and in the products.
3. Write coefficients until the equation balances (the numbers at the front).

Example

Balance each of the following chemical equations:

1 $\boxed{Al} + \boxed{O_2} \rightarrow \boxed{Al_2O_3}$

Al = 1 Al = 2 ×
O = 2 O = 3 ×

$\boxed{Al} + \boxed{O_2} \rightarrow 2\boxed{Al_2O_3}$

Al = 1 Al = 4 ×
O = 2 O = 6 ×

$4\boxed{Al} + 3\boxed{O_2} \rightarrow 2\boxed{Al_2O_3}$

Al = 4 Al = 4 ✓
O = 6 O = 6 ✓

The balanced equation is: $4Al + 3O_2 \rightarrow 2Al_2O_3$

2 $\boxed{CO_2} + \boxed{H_2O} \rightarrow \boxed{O_2} + \boxed{C_6H_{12}O_6}$

C = 1 C = 6 ×
O = 3 O = 8 ×
H = 2 H = 12 ×

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

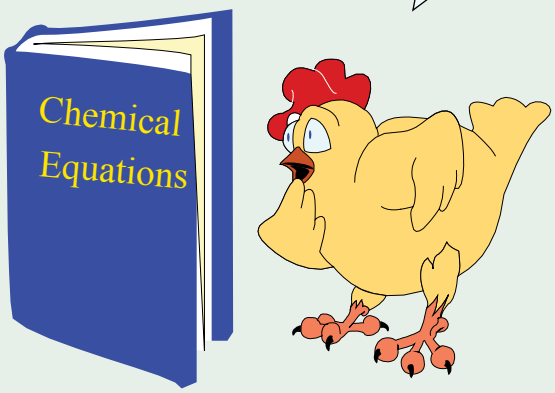
C = 6 C = 6 ✓
O = 18 O = 8 ×
H = 12 H = 12 ✓

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

C = 6 C = 6 ✓
O = 18 O = 18 ✓
H = 12 H = 12 ✓

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

Change **only** the numbers at the front - the coefficients.
Leave the inside numbers alone.



Balancing Chemical Equations

Try some of the online 'balance chemical equation' applications and videos.

Exercise

Balance each of the following chemical equations:

1 $Cu + O_2 \rightarrow CuO$

2 $H_2 + O_2 \rightarrow H_2O$

3 $H_2O \rightarrow H_2 + O_2$

4 $Fe + S_8 \rightarrow FeS$

5 $Fe + Cl_2 \rightarrow FeCl_3$

6 $NaCl \rightarrow Na + Cl_2$

7 $Ca + N_2 \rightarrow Ca_3N_2$

8 $H_2 + Br_2 \rightarrow HBr$

9 $Al + O_2 \rightarrow Al_2O_3$

10 $Fe_2O_3 + H_2 \rightarrow Fe + H_2O$

11 $AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + Ag$

12 $NH_3 + O_2 \rightarrow N_2 + H_2O$

13 $Fe_2O_3 + C \rightarrow CO + Fe$

14 $Fe_2O_3 + CO \rightarrow CO_2 + Fe$

15 $CH_4 + O_2 \rightarrow CO_2 + H_2O$

16 $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

5.3 Types of Reactions

Types of Reactions

A **chemical reaction** (reactants → products) is usually accompanied by one or more of the following:

- colour changes
- changes in heat (an exothermic reaction produces heat, an endothermic reaction absorbs heat).
- production of gas
- formation of a precipitate

There are many different **types and classification of chemical reactions**. Some of the more basic types and classifications of chemical reactions are:

- Synthesis reactions
  (A + B → AB)
- Decomposition reactions
  (AB → A + B)
- Single replacement
  (AB + C → AC + B)
- Double replacement
  (AB + CD → AD + CB)
- Precipitation
  solution A + solution B → insoluble product
- Combustion
  (A + O_2 → oxides + other products)
- Acid-base reactions
  (acid + base → salt + water)

Types of Chemical Reactions

Watch online videos demonstrating 'types of chemical reactions'.

Examples

Synthesis: Two or more compounds combine to form a more complex compound.

$2H_2 + O_2 \rightarrow 2H_2O$

Decomposition: A complex compound is broken down into simpler compounds.

$C_{12}H_{22}O_{11} \rightarrow 12C + 11H_2O$

Single replacement: An element in a compound is replaced by another element.

$H_2SO_4 + Zn \rightarrow ZnSO_4 + H_2$

Double replacement: Two compounds swap elements to produce two new compounds.

$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

Acid-base: Double replacement reactions in which an acid and a base react to produce a salt and water (also known as neutralisation reactions).

$NaOH + HCl \rightarrow NaCl + H_2O$

Combustion: Oxygen combines with another compound to produce water and carbon dioxide.

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

Exercise

State the type of reaction and balance each of the following reactions:

a) $H_2O \rightarrow O_2 + H_2$

b) $H_2 + C_2H_2 \rightarrow C_2H_6$

c) $H_2SO_4 + Mg(OH)_2 \rightarrow MgSO_4 + H_2O$

d) $Na + FeCl_3 \rightarrow NaCl + Fe$

e) $H_2 + N_2 \rightarrow NH_3$

f) $Sn + PbO \rightarrow SnO_2 + Pb$

g) $NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

h) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

i) $CaCO_3 \rightarrow CaO + O_2$

j) $C_2H_2 + O_2 \rightarrow CO_2 + H_2O$

k) $Ca + Cu(OH)_2 \rightarrow Ca(OH)_2 + Cu$

l) $HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + H_2O$

Synthesis

Synthesis reactions, or combination reactions, happen when two or more substances combine chemically to produce a single new substance.

Examples:

Two elements combining to form a compound:

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

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$
iron + oxygen → iron oxide

$H_2 + Cl_2 \rightarrow 2HCl$
hydrogen + chlorine → hydrochloric acid

Two compounds combining to form a more complex compound:

$CaO + CO_2 \rightarrow CaCO_3$
calcium oxide + carbon dioxide → calcium carbonate

$SO_3 + H_2O \rightarrow H_2SO_4$
sulphur trioxide + water → sulphuric acid

A compound and an element combining to form a new compound:

$2CO + O_2 \rightarrow 2CO_2$
carbon monoxide + oxygen → carbon dioxide

Symbols in brackets in chemical equations show the physical state of the chemical at the reaction temperature.

(s)	solid
(l)	liquid
(g)	gas
(aq)	dissolved in water

Challenge

Haber Process

The Haber process is an efficient way of synthesising hydrogen (H_2) and nitrogen (N_2) to produce ammonia (NH_3).

Find ten uses of ammonia.

Oxidation of metals

Most metals chemically combine with oxygen in the air to form oxides.

Some metals will oxidise more readily than other metals:

Metal	Symbol	an oxide
Potassium	K	K_2O
Sodium	Na	Na_2O
Calcium	Ca	CaO
Magnesium	Mg	MgO
Aluminium	Al	Al_2O_3
Zinc	Zn	ZnO
Iron	Fe	Fe_2O_3
Tin	Sn	SnO
Lead	Pb	PbO
Copper	Cu	CuO
Silver	Ag	Ag_2O
Platinum	Pt	PtO
Gold	Au	Au_2O_3

Exercise

1 What is a synthesis reaction?

2 In the synthesis reaction: X + Y → XY, which are the reactants and which are the products?

3 Which of the following are synthesis reactions?

a) $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$

b) $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

c) $2CH_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{(g)} + 4H_2O_{(g)}$

d) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

e) $3H_{2(g)} + N_{2(g)} \rightarrow 2NH_{3(g)}$

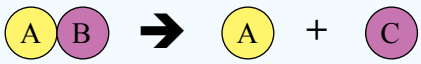
4 Which metal is more easily oxidised; lead, silver, or gold?

5 Nitrogen (N_2) in the atmosphere can be synthesised with hydrogen gas (H_2) to produce ammonia gas (NH_3). Write a symbolic balanced equation for producing ammonia gas.

6 Aluminium (Al) will chemically combine with oxygen in the air (O_2) to form aluminium oxide (Al_2O_3). Write a symbolic balanced equation for the oxidation of aluminium.

Decomposition

Decomposition reactions occur when a single substance breaks down to form two or more new simpler substances.



Examples:

Electrolysis of water:

$2H_2O \rightarrow 2H_2 + O_2$

water → hydrogen + oxygen

Heating sugar (or using sulphuric acid as a catalyst):

$C_{12}H_{22}O_{11} \rightarrow 12C + 11H_2O$

sugar → carbon + water

Heating ammonium carbonate:

$(NH_4)_2CO_3 \rightarrow 2NH_3 + CO_2 + H_2O$

Ammonium carbonate → ammonia + carbon dioxide + water

Heating metal carbonates to produce the metal oxide and carbon dioxide:

$CuCO_3 \rightarrow CuO + CO_2$

copper carbonate → copper oxide + carbon dioxide

$MgCO_3 \rightarrow MgO + CO_2$

magnesium carbonate → magnesium oxide + carbon dioxide

$CaCO_3 \rightarrow CaO + CO_2$

calcium carbonate → calcium oxide + carbon dioxide

Decomposition of Sugar

Watch online videos demonstrating 'decomposition of sugar'.

Decomposition of Hydrogen Peroxide

Watch online videos demonstrating 'decomposition of hydrogen peroxide'.

Activity

Decomposition of metal carbonates

Materials: Metal carbonates, limewater ($Ca(OH)_2$), test tubes, test tube stoppers with delivery tube, retort stands, bossheads with clamps, bunsen burner, tongs, gloves, safety glasses.

Method:

a) Place a small amount of metal carbonate in a test tube and set up the apparatus as shown.

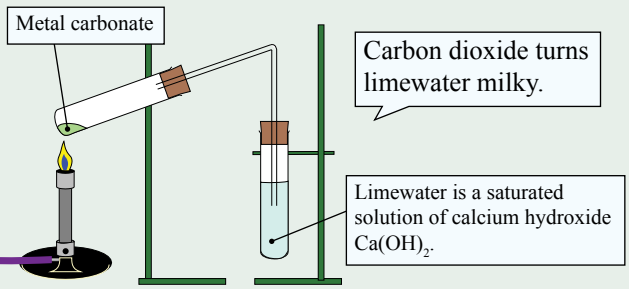
b) Gently heat the test tube and gradually increase the heat (**keep applying some heat while the delivery tube is in the limewater to prevent suckback**).

c) Repeat with other carbonates.

1 Predict what would happen if limewater was sucked back onto the hot metal carbonate.

2 Record your observations.

3 Write word and symbolic equations for the decomposition of metal carbonates.



Exercise

1 What is a decomposition reaction?

2 In the chemical reaction: $XY \rightarrow X + Y$, which are the reactants and which are the products?

3 What are the products, in words, produced by heating the following metal carbonates?

a) calcium carbonate
b) magnesium carbonate
c) zinc carbonate
d) iron carbonate
e) copper carbonate

4 Hydrogen peroxide (H_2O_2) will decompose into hydrogen (H_2) and oxygen (O_2). Write a symbolic balanced equation for the decomposition of hydrogen peroxide.

Single Replacement

Single replacement, or displacement, reactions happen when an element in a compound is replaced by another element.

The B in AB has been replaced by C.
C can be considered to be more reactive than B.

Examples:

Acids and metals. A metal can replace the hydrogen in an acid:

$$2HCl_{(aq)} + Fe_{(s)} \rightarrow FeCl_{2(aq)} + H_{2(g)}$$
hydrochloric acid + iron → iron chloride + hydrogen

$$H_2SO_{4(aq)} + Zn_{(s)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$$
sulphuric acid + zinc → zinc sulphate + hydrogen

More reactive metals can replace other metals in metal compounds

Copper is more reactive than silver thus:

$$2AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2Ag$$
silver nitrate + copper → copper nitrate + silver

Iron is more reactive than copper thus:

$$CuSO_{4(aq)} + Fe_{(s)} \rightarrow FeSO_{4(aq)} + Cu(s)$$
copper sulphate + iron → iron sulphate + copper

Metal Reactivity

Also called the metal reactivity series

Metal	Symbol
Potassium	K
Sodium	Na
Calcium	Ca
Magnesium	Mg
Aluminium	Al
Zinc	Zn
Iron	Fe
Tin	Sn
Lead	Pb
Copper	Cu
Silver	Ag
Platinum	Pt
Gold	Au

More reactive

Single Replacement Reactions

Watch online videos demonstrating 'single replacement reactions'.

Activity

Acids and Metals.

Materials: Various metals such as Zn, Al, Fe, Cu, Mg, 1M hydrochloric acid, test tubes, holder, rack, bunsen burner, sand paper, gloves, safety glasses.

Method:

a) Add 5 cm of hydrochloric acid to five test tubes.

b) Sand the outside of each metal to remove the outer layer of oxide. Then carefully place each metal into one of the test tubes.

c) Arrange the test tubes in order of reactivity. (For the test tubes with no activity, gently warm the test tubes and observe any reactivity).

1 Record your observations and list the metals from low to high reactivity with hydrochloric acid.

2 Did your order of metal reactivity agree with the metal reactivity table below?

Exercise

1 What is a single replacement reaction?

2 In the chemical reaction:
$XY + Z \rightarrow XZ + Y$, which are the reactants and which are the products?

3 Which of the following are single replacement reactions?
a) $Cl_2 + 2NaBr \rightarrow Br_2 + 2NaCl$
b) $2AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2Ag$
c) $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
d) $FeCO_3 \rightarrow FeO + CO_2$
e) metal + acid → metal salt + hydrogen

4 Use the metal reactivity table above to decide which of the following single replacement reactions are possible:
a) $2AgNO_3 + Sn \rightarrow Sn(NO_3)_2 + 2Ag$
b) $CuSO_4 + Au \rightarrow AuSO_4 + Cu$
c) $ZnSO_4 + Mg \rightarrow MgSO_4 + Zn$
d) $CaCO_3 + Fe \rightarrow FeCO_3 + Ca$

Double Replacement

Double replacement reactions occur when two compounds swap molecules to form two or more new compounds.

B and D have replaced each other.

Examples:

Neutralisation (Acid + Base)

acid + *base* → *salt* + *water*

$HCl_{(aq)}$ + $NaOH_{(aq)}$ → $NaCl_{(aq)}$ + $H_2O_{(l)}$
hydrochloric acid + sodium hydroxide → sodium chloride + water

$H_2SO_{4(aq)}$ + $2NH_4OH_{(aq)}$ → $(NH_4)_2SO_{4(aq)}$ + $2H_2O_{(l)}$
sulphuric acid + ammonium hydroxide → ammonium sulphate + water

$H_2CO_{3(aq)}$ + $2NaOH_{(aq)}$ → $Na_2CO_{3(aq)}$ + $2H_2O_{(l)}$
carbonic acid + sodium hydroxide → sodium carbonate + water

Precipitation reactions

Precipitation reactions happen when two soluble reactants combine to produce an **insoluble solid** (the precipitate).

$MgCl_{2(aq)}$ + $2NaOH_{(aq)}$ → $2NaCl_{(aq)}$ + $Mg(OH)_{2(s)}$
magnesium chloride + sodium hydroxide → sodium chloride + magnesium hydroxide

It is possible to predict if a precipitate will form when two solutions are mixed.

The (s) indicates the precipitate.

$2KI_{(aq)}$ + $Pb(NO_3)_{2(aq)}$ → $2KNO_{3(aq)}$ + $PbI_{2(s)}$
potassium iodide + lead nitrate → potassium nitrate + lead iodide

Precipitate - the solid deposit from a solution.

Precipitation can be used to test for the presence of metals in water

ACID
(Turns blue litmus red)
(pH less than 7)

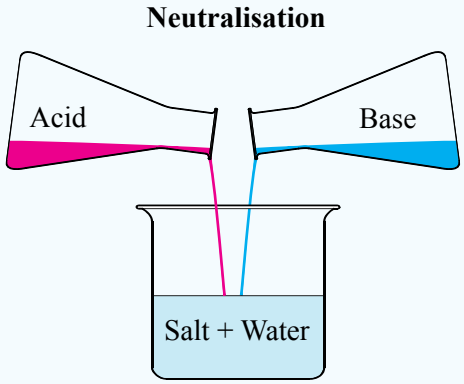
Examples:

Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulphuric acid	H_2SO_4

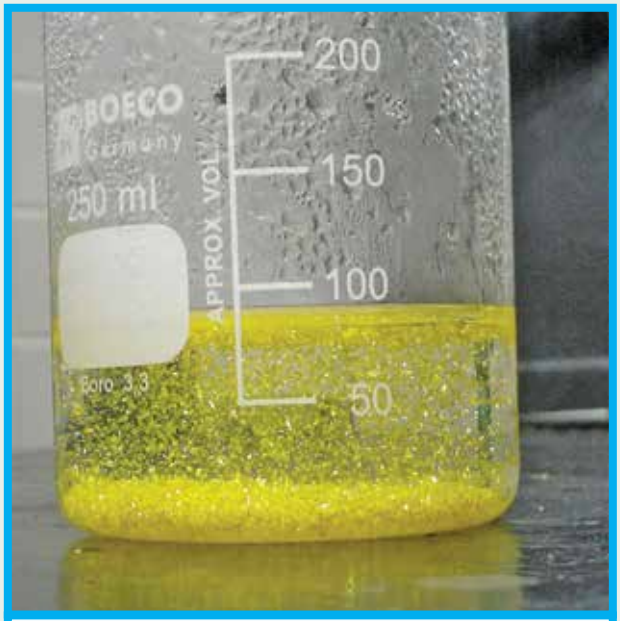
BASE
(Turns red litmus blue)
(pH greater than 7)

Examples:

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



In chemistry, neutralisation is a chemical reaction in which an acid and a base react to produce a salt and water.



A golden precipitate of lead iodide as a result of mixing lead nitrate and potassium iodide (Courtesy Der Kreole, Wikimedia Commons).

Lead Iodide - Golden Snow

Watch online videos demonstrating 'Lead iodide the golden snow'.

Precipitation

It is possible to predict whether a precipitate is produced when two solutions are mixed (A precipitate is insoluble - doesn't dissolve in water).

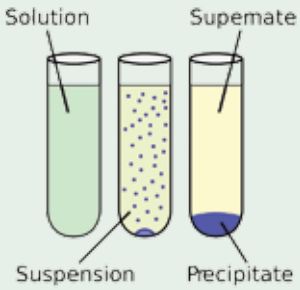
The solubility table on the right indicates which compounds are soluble.

Example:
NaCl is **soluble** in water.
$PbCl_2$ is **not soluble** in water.

$Mg(OH)_2$ is **not soluble** in water.
NaOH is **soluble** in water.

Precipitation reactions
Precipitation reactions happen when two soluble reactants combine to produce an **insoluble solid** (the precipitate).

Solubility Table		
Ion	**Solubility**	**Exceptions**
NO_3^-	soluble	none
Cl^-	soluble	Ag^+, Hg^{2+}, Pb^{2+}
I^-	soluble	Ag^+, Hg^{2+}, Pb^{2+}
SO_4^{2-}	soluble	Ca^{2+}, Ba^{2+}, Sr^{2+}, Ag^+, Hg^{2+}, Pb^{2+}
CO_3^{2-}	insoluble	Li^+, Na^+, K^+, Rb^+, NH_4^+
PO_4^{3-}	insoluble	Li^+, Na^+, K^+, Rb^+, NH_4^+
OH^-	insoluble	Ca^{2+}, Ba^{2+}, Sr^{2+}, Li^+, Na^+, K^+, Rb^+
S^{2-}	insoluble	Li^+, Na^+, K^+, Rb^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}
Na^+	soluble	none
NH_4^+	soluble	none
K^+	soluble	none



Precipitation - the creation of a solid substance from a solution. The solid may be suspended or fall to the bottom of the solution.

Example

Will a precipitate be formed when a solution of magnesium nitrate $Mg(NO_3)_2$ and a solution of sodium hydroxide NaOH are mixed?

Step 1 Complete the double replacement reaction.

$Mg(NO_3)_{2(aq)} + 2NaOH_{(aq)} \rightarrow Mg(OH)_2 + 2NaNO_3$

Step 2 Use the solubility table to find if the reactants are soluble or insoluble.

(a) $Mg(OH)_2$ is **not soluble** in water

(b) $Na(NO_3)$ is **soluble** in water.

Answer: A precipitate of magnesium hydroxide will be formed.

Example

Will a precipitate be formed when a solution of silver nitrate $AgNO_3$ and a solution of potassium chloride KCl are mixed?

Step 1 Complete the double replacement reaction.

$AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl + KNO_3$

Step 2 Use the solubility table to find if the reactants are soluble or insoluble.

(a) AgCl is **not soluble** in water

(b) KNO_3 is **soluble** in water.

Answer: A precipitate of silver chloride will be formed.

Exercise

1 What is a double replacement reaction?

2 In the double replacement reaction:
AB + CD ➔ AD + CB, which are the reactants and which are the products?

3 Copy and complete the following double replacement reaction in words:

HCl + NaOH ➔
hydrochloric acid + sodium hydroxide ➔

4 Will a precipitate be formed when a solution of magnesium chloride $MgCl_2$ and a solution of sodium hydroxide NaOH are mixed?

5 Will a precipitate be formed when a solution of cobolt chloride $CoCl_2$ and a solution of sodium sulphate Na_2SO_4 are mixed?

5.4 Rate of Reaction

Rates of Reactions

The rate of a chemical reaction is the speed at which a chemical reaction happens.

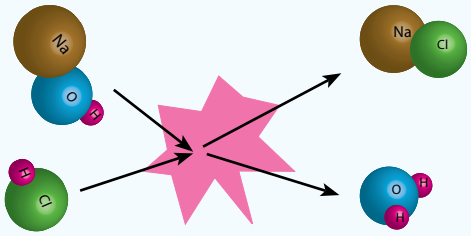
Some chemical reactions proceed slowly, at a **low rate**. Examples of low rate chemical reactions are rusting (iron combining with oxygen $4Fe + 3O_2 \rightarrow 2Fe_2O_3$).

Some chemical reactions happen quickly, at a **high rate**. Examples of high rate chemical reactions are fire (burning of methane gas $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$), precipitation (combining solutions of silver nitrate and sodium chloride to produce a precipitate of silver chloride),

Collision theory

The collison theory is used to explain why factors affect the reaction rate. It suggests that a chemical reaction occurs when the reactant particles collide with each other with enough energy to produce a reaction.

The rate of reaction increases when the number of successful collisons per second increases.



$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

Factors affecting reaction rates

It is possibe to speed up or slow down the rate of chemical reactions by changing

a) Temperature
b) Concentration of reactants.
c) Particle size, and by using
d) catalysts.

Fire is a fast exothermic, releasing heat, chemical reaction between oxygen and a combustible material.

$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)}$

wood + oxygen → carbon dioxide + water

Rust is the product of a slow chemical reaction between oxygen and iron. The reaction can be summarised by:

$4Fe_{(s)} + 3O_{2(g)} + 2H_2O_{(l)} \rightarrow 2Fe_2O_3.H_2O_{(s)}$

iron + oxygen + water → hydrated iron oxide

Exercise

1 An example of a fast chemical reaction is the 'squeaky pop' when hydrogen in a test tube is lit. Give another example of a fast reaction.

2 An example of a slow chemical reaction is the rusting of iron. Give another example of a slow chemical reaction.

3 What is meant by the rate of a reaction?

4 What is the 'collision theory'?

5 Indicate four factors that affect the rate of chemical reactions.

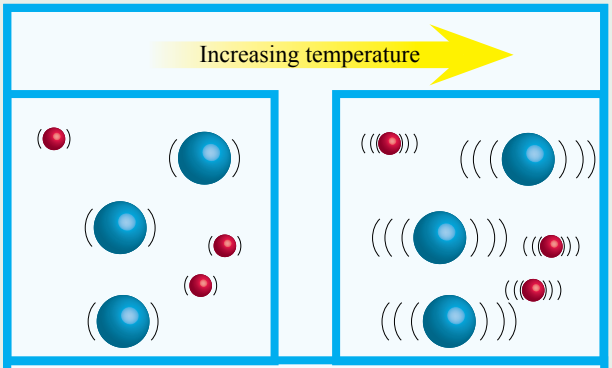
6 Suggest five ways of slowing down the rusting process.

$4Fe_{(s)} + 3O_{2(g)} + 2H_2O_{(l)} \rightarrow 2Fe_2O_3.6H_2O_{(s)}$

iron + oxygen + water → hydrated iron oxide

Temperature

Increasing or decreasing the **temperature** can speed up or slow down the rate of a chemical reaction. For example, bread dough rises more quickly when warmed.



Increasing the temperature increases the kinetic energy of the particles. Increased kinetic energy will increase the number of collisions per second, and increase the rate of reaction.

There are numerous examples of **temperature affecting the rate of chemical reactions**:

- Put a lightstick in hot water and it will glow more intensely.
- A lightstick will last longer when it is colder.
- Cold-blooded animals are slower when the weather is colder (A poikilotherm is an organism whose internal temperature varies considerably).
- Concrete sets faster when it is warmer.

Lightstick, or glowstick, trails. Lightsticks are the result of a chemical reaction between phenyl oxalate and hydrogen peroxide producing light, chemiluminescence.

Temperature and Reaction Rate

Watch online videos demonstrating 'Temperature and reaction rate'.

Activity

Temperature and Rate of Reaction

Materials: Effervescent tablets, beakers, thermometer, stopwatch.

Method:

a) Add 200 mL of hot water to a beaker and measure its temperature. Then measure the time taken for a tablet to fully dissolve.

b) Repeat with normal tap water.

c) Repeat with cold water.

1 Graph your results (Time to dissolve vs water temperature).

2 Write a conclusion.

The independent variable, the variable that is changed, is plotted on the x-axis. The dependent variable, the variable that is measured, is plotted on the y-axis.

Old chemists never die, they just stop reacting

Why are chemists great at solving problems?

They have all the solutions.

Exercise

1 What is the effect of temperature on chemical reaction rate?

2 Use collison theory to explain why increasing temperature increases the chemical reaction rate.

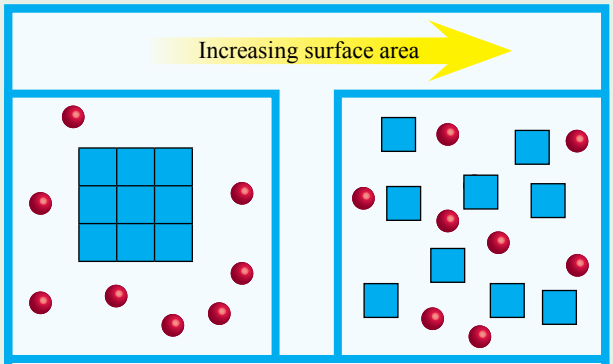
3 Explain, in terms of chemical reaction rates, why food is stored in refrigerators.

4 Give three examples of temperature affecting the rate of a chemical reaction.

5 Increasing the temperature doesn't always increase the reaction rate. Explain why increasing the temperature above 54°C, when making yogurt, actually stops the reaction.

Surface Area

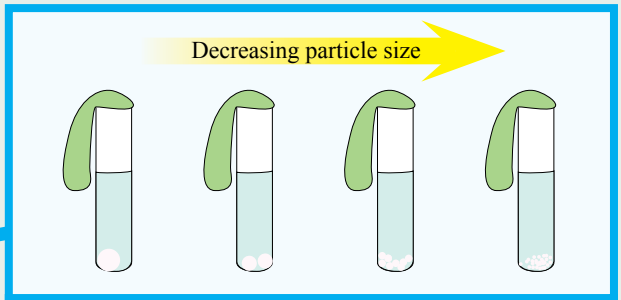
Increasing or decreasing the **surface area** of a reactant can speed up or slow down the rate of a chemical reaction. For example, steel wool will easily burn while a piece of steel won't burn.



Breaking a reactant into smaller pieces increases the surface area of the reactant. This increases the number of collisions per second, and thus the rate of reaction is increased.

The result of a sugar dust explosion at a sugar refinery (Courtesy Wikimedia Commons).

Dust explosions can happen when combustible materials have a very small size and provide a large surface area to atmospheric oxygen. Examples are explosions from dust clouds of coal, grain, sugar, flour, and even powdered metals.



If decreasing the particle size can speed up the rate of reaction **then** decreasing the size of marble chips in a marble chip/hydrochloric acid reaction will increase the rate at which a balloon will collect CO_2.

Activity

Particle Size and Rate of Reaction

Materials: Marble chips, dilute hydrochloric acid, test tubes, test tube rack, balloons, gloves, safety glasses.

Method:

b) Break the marble chips into four different sizes (Powder to chips). Place 2 g of each size into a test tube.

a) Add 5 mL of dilute hydrochloric acid (HCl) to each of four balloons. Attach each balloon to the top of each test tube without letting the HCl into the test tube.

c) At the same time, tip the HCl into the test tube.

1 Record your observations. Provide an explanation for your observations.

2 Balance the following chemical equation:

$$\underset{\text{marble chips}}{CaCO_3} + HCl \rightarrow CaCl_2 + H_2O + CO_2\uparrow$$

Exercise

1 How does increasing the surface area of a reactant increase the rate of a chemical reaction?

2 Use collison theory to explain why increasing the surface area of a reactant increases the chemical reaction rate.

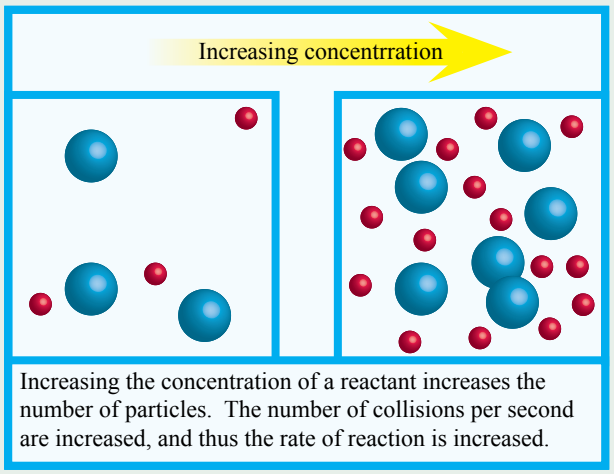
3 Give three examples of the surface area of a reactant affecting the rate of a chemical reaction.

4 Use collison theory to explain why clouds of dust of combustible material such as coal are extremely dangerous?

5 Suggest some ways in which the danger of clouds of grain dust in grain silos might be reduced.

Concentration

Increasing or decreasing the **concentration** of reactants can speed up or slow down the rate of a chemical reaction. For example, liquid oxygen is highly concentrated oxygen. Burning with liquid oxygen happens at a much higher rate than burning with atmospheric oxygen.



Increasing the concentration of a reactant increases the number of particles. The number of collisions per second are increased, and thus the rate of reaction is increased.

Liquid oxygen and kerosene powering a Saturn V rocket. Liquid oxygen is a concentrated form of oxygen and changes to a gas at −183°C (Courtesy NASA).

Activity

Concentration and Rate of Reaction

Materials: Antacid tablets, hydrochloric acid (4M, 2M, 1M), 200 mL beakers, tongs, stopwatch, gloves, safety glasses.

Method:

a) Carefully, with safety equipment, place 100 mL of 1M HCl in a beaker.

b) Gently, using tongs, lower an antacid tablet into the beaker. Use the stopwatch to measure the time taken for the antacid tablet to completely dissolve.

c) Repeat with other concentrations of HCl.

1 Graph your results (Time to dissolve vs concentration of HCl).

2 Write word and symbolic equations for the reaction of HCl with the active ingredient in the antacid tablet.

3 Write a conclusion.

Burning with Liquid Oxygen

Watch online videos demonstrating 'Burning liquid oxygen'.

Exercise

1 How does increasing the concentration of reactants increase the rate of a chemical reaction?

2 Use collison theory to explain why increasing the concentration of a reactant increases the chemical reaction rate.

3 Give three examples of the concentration of a reactant affecting the rate of a chemical reaction.

Catalysts

A **catalyst** is a substance that increases the rate of a chemical reaction, but is not consumed or changed by the reaction.

The presence of the catalyst makes it easier for the reactants to collide and produce the products.

An **example** is the catalytic converter in a car's exhaust system. Normally, poisonous carbon monoxide in the exhaust reacts too slowly with oxygen to produce carbon dioxide.

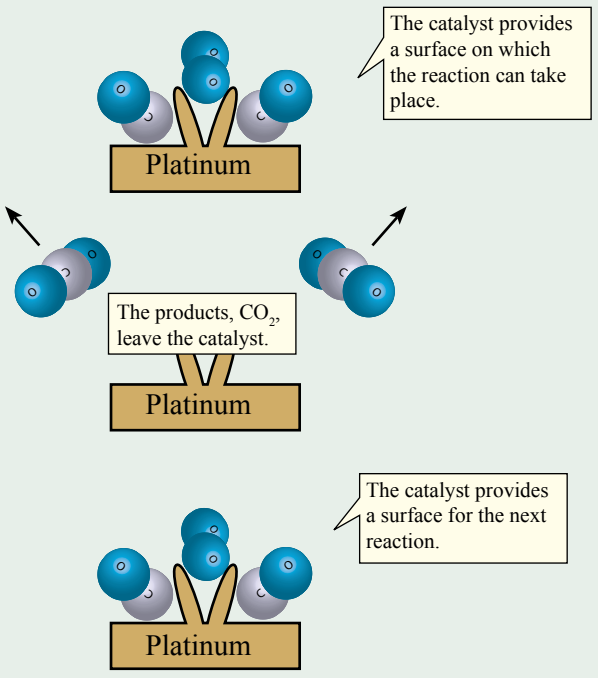
The catalyst is written above the arrow.

The presence of a catalyst speeds up the reaction.

$$2CO + O_2 \xrightarrow{\text{platinum}} 2CO_2$$

carbon monoxide + oxygen → carbon dioxide

Metal catalysts such as platinum provide a surface on which the reaction between carbon monoxide and oxygen can take place at a much faster rate than without the catalyst. The products leave the surface and the platinum can be repeatedly used for more reactions.



A three way catalytic converter in a car's exhaust system. The catalytic converter speeds up the chemical reactions changing toxic gases to less toxic gases.

The three chemical reactions are:

- nitrous oxides → oxygen + nitrogen
- carbon monoxide + oxygen → carbon dioxide
- hydrocarbons + oxygen → carbon dioxide + water

A variety of metals are used as the catalysts.

Nitrous oxides are greenhouse gases many times more potent than carbon dioxide. Nitrous oxides deplete the ozone layer more than any other gas. Nitrous oxides also form acid rain: $2NO_2 + H_2O \rightarrow \underset{\text{nitrous acid}}{HNO_2} + \underset{\text{nitric acid}}{HNO_3}$

Reactions involving catalysts are common. Catalysts are often written above the arrow.

Examples

Photosynthesis - chlorophyll is a catalyst:

$$6CO_2 + 6H_2O + \text{sunlight} \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

Amylase in saliva acts as a catalyst to digest **starches to sugars** in the mouth:

$$C_6H_{10}O_5 + H_2O \xrightarrow{\text{amylase}} C_6H_{12}O_6$$

A catalyst is used to **make ammonia**.

$$N_2 + 3H_2 \xrightarrow{\text{osmium}} 2NH_3$$

Catalysts and Reactions

Watch online videos demonstrating 'catalyst and reactions'.

Enzymes

Enzymes are proteins that speed up the rate of chemical reactions in organisms. Enzymes are biological catalysts used in thousands of chemical reactions to support life.

The human digestive system has many enzymes that act as catalysts in breaking down food into nutrients that can be used by cells of the body.

Examples:

fat $\xrightarrow{\text{bile}}$ emulsified fat

sucrose $\xrightarrow{\text{sucrase}}$ glucose + fructose

peptides $\xrightarrow{\text{peptidases}}$ amino acids

Human enzymes each work for just one particular reaction and work best at optimal conditions such as a temperature of 37°C and a pH of 2 for stomach enzymes.

Enzymes are biological catalysts used in thousands of chemical reactions. As an example, enzymes are used to break down food into nutrients that can be used in cells.

Activity

Catalyst and Rate of Reaction

Materials: Measuring cylinder, hydrogen peroxide (H_2O_2), detergent solution (1 liquid detergent to 4 water), yeast, spatula, dropper, gloves, safety glasses.

Method:

a) Add 10 mL of hydrogen peroxide (H_2O_2) to the measuring cylinder and then add a drop of detergent solution (The detergent is used to show bubbles if a gas is produced). Observe the rate of breakdown of H_2O_2.

$2H_2O_2 \rightarrow O_2 + 2H_2O$

b) Add a small amount of yeast. Observe the rate of breakdown of H_2O_2.

1 Record your observations. Is the breakdown of H_2O_2 an endothermic or exothermic reaction?

2 Write the equation for the breakdown of H_2O_2 and include the catalyst.

3 Name the gas in the bubbles.

Exercise

1 What is a catalyst?

2 What is an enzyne?

3 Explain how a catalyst can increase the rate of a chemical reaction.

4 Give three examples of catalysts increasing the rate of a chemical reaction.

5 In the following symbolic equation for making epoxyethane, a sterilising and fumigant gas, name the catalyst?

$$\underset{\text{ethene}}{2CH_2CH_2} + \underset{+\text{ oxygen}}{O_2} \xrightarrow{\text{silver}} \underset{\text{epoxyethane}}{2CH_2CH_2O}$$

6 Manganese dioxide (MnO_2) is an effective catalyst in the decomposition of hydrogen peroxide (H_2O_2) into oxygen and water. Write a balanced symbolic equation for the decomposition of hydrogen peroxide.

5.5 Chemical Industry

Chemical Industry

Chemistry is used to make thousands upon thousands of useful substances and is vital to the World's economy.

The immense variety of chemically produced products range from perfumes and soaps to plastics and sulphuric acid. Some of the immense number of products is listed in the table below.

Product	Examples
petroleum	petrol, diesel, oil, grease
petrochemicals	ethylene, propylene, benzene
polymers	polyethylene, polyester
elastomers	polyurethane, neoprene
pharmaceuticals	antibiotics, analgesics, tranquilisers, stimulants
inorganic	ammonia, sodium hydroxide, sulphuric acid, nitric acid
organic	phenol, urea, acrylonitrile
agrochemicals	fertilisers, herbicides, insecticides
flavours and fragrances	vanillan, coumarin, benzyl benzoate
gases	nitrogen, oxygen, acetylene
explosives	nitroglycerin, ammonium nitrate
oleochemicals	soybean oil, coconut oil,
metals	copper, lead, zinc, iron, gold
foods	food additives, fermentation, cooking, sugar processing
other	paints, adhesives, welding, paper, glass,

A railway tanker containing chemically produced chlorine. Chlorine is used to make antiseptics, papers, plastics, medicines, paints, solvents, insecticides, textiles.

Chlorine is produced through the electrolysis of salt solution and can be summarised as:

$$\underset{\text{salt}}{2NaCl} + \underset{\text{water}}{2H_2O} \rightarrow \underset{\text{chlorine}}{Cl_2} + \underset{\text{hydrogen}}{H_2} + \underset{\text{sodium hydroxide}}{2NaOH}$$

Pigments are used to colour paints, plastic, cloth, foods, and many other materials (Courtesy Dan Brady, Wikimedia Commons). Many pigments are metal compounds such as red - cobalt nitrate ($Co(NO_3)_2$), blue- copper sulphate ($CuSO_4$), yellow - potassium chromate (K_2CrO_4).

A MIG (metal inert gas) welder uses a shield of inert gas over the weld to prevent the weld chemically mixing with atmospheric gases.

Pharmaceuticals

A **pharmaceutical drug** is a chemical substance used to treat, cure, or prevent disease.

Examples:

- **Analgesics** are painkillers.
- **Stimulants** are used to improve alertness.
- **Tranquilisers** are used to calm people.
- **Antibiotics** are used to kill bacteria.
- **Antiseptics** are used to prevent infections.
- **Statins** are used to lower high cholesterol levels in the blood.
- **Anticoagulants** are used to prevent clotting of the blood.
- **Antidepressants** are used to help reduce moderate or severe depression.
- **Decongestants** are used to reduce congestion in the upper respiratory tract.

Drug development is expensive because it can take twenty years to discover, isolate, chemically produce, trial, patent, and market.

Activity

Stimulants and Heart Rate

Materials: Daphnia culture, caffeine, .

Method:

a) Count the heart rates of 'control' Daphnia.

b) Count the heart rates of 'experimental' daphnia after the addition of a droplet of diluted stimulant (eg., caffeine, Claritin).

1 Record your observations and write a conclusion.

Daphnia Cultures

Watch online videos demonstrating 'How to grow and observe Daphnia cultures'.

Daphnia Cultures and Ethical Issues

Consider the ethical issues of experimenting with Daphnia cultures.

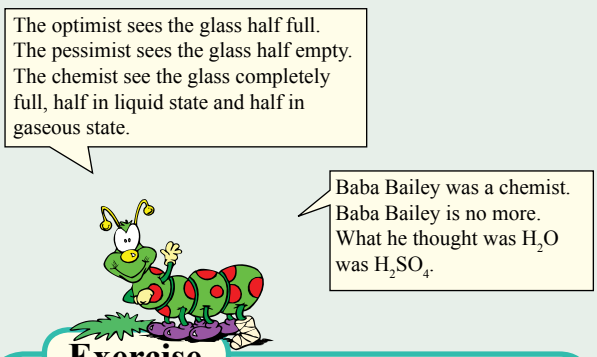
A small sample of the thousands of pharmaceutical drugs.

Pain is a warning to the body.

Pain caused by an infection may be treated with **antibiotics**. The antibiotics may remove the infection and thus the pain.

Analgesics may relieve nociceptive pain. Nociceptive pain is caused by damage to body tissue and is usually felt as throbbing, sharp, or aching pain.

Neuropathic pain, described as burning or searing pain, is caused by damage to nerves. Depending upon diagnosis, a variety of drugs may be used to treat neuropathic pain. Analgesics are generally not as effective in treating neuropathic pain.



Exercise

1 What is a pharmaceutical drug?

2 Why is drug development so expensive?

3 What is the difference between nociceptive pain and neuropathic pain?

Plastics

Plastics are made of polymers, long chains of carbon molecules.

Polymerisation is the process by which a polymer is made by joining up monomers. A monomer is a large carbon molecule produced by cracking crude oil or derived from natural materials.

Many different plastics can be made by combining many different monomers in many different ways.

'poly' = many, 'mono' = one

Polymer means many monomers. Monomer means one large molecule.

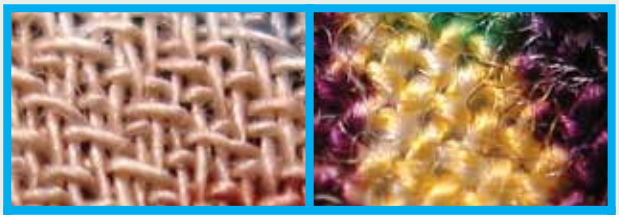
Plastic is everywhere. Cups, carpets, food wrap, bulletproof vests, furniture, boat hulls, and just about everything can be made of plastic.

Rayon

Rayon is derived from natural cellulose (Cellulose, $C_6H_{10}O_5$, forms the cell walls of plants).

Rayon is similar to the feel and texture of silk, wool, and cotton.

Rayon, similar to other fibres, is twisted into yarn, then woven into fabric, and then made into clothes. Rayon is also used to make carpets and surgical materials.



A close-up of a skirt and a blouse made from different rayon textures.

How to make Rayon

Watch online videos demonstrating 'How to make rayon'.

Activity

Make some Rayon Thread

Materials: 10cm square piece of tissue paper, copper carbonate ($CuCO_3$), 50% ammonia solution, dilute sulphuric acid (2M), 250 mL beakers, stirring rod, small syringe, tweezers, paper towel, safety glasses, gloves.

Method:

a) Tear the tissue paper into small pieces and put in a beaker. Add 4 g of $CuCO_3$ and 30 mL of NH_4OH. Avoiding the fumes, stir until a thick blue solution with no lumps is formed (10 mins).

b) Put 50 mL of the dilute H_2SO_4 in a beaker. Use the syringe to slowly squirt the thick dark blue solution from **a)** under the surface of the H_2SO_4.

c) Use tweezers to remove the rayon thread. Wash the rayon thread under cold water and then dry the rayon thread with the paper towel.

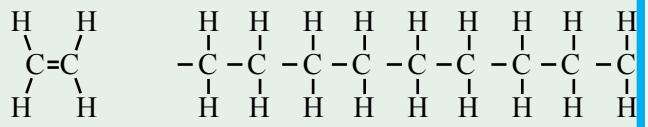
1 Record your observations and describe the properties of the rayon thread.

2 How might the properties of the rayon thread be changed?

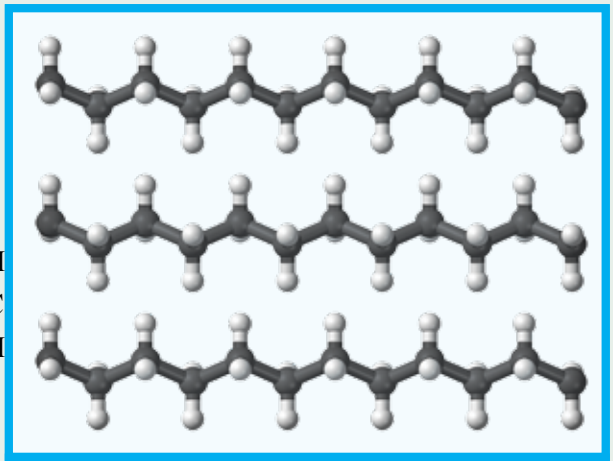
3 Tissue paper was used as the source of cellulose to make the rayon. What other materials could have been used to make the rayon?

Polyethylene is made from the polymerisation of ethylene, C_2H_4, molecules.

Polyethylene is used in wraps, bottles, disposable gloves, garbage bags, and to insulate electrical wires.



ethylene polyethylene

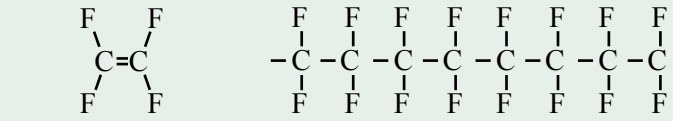


Polyethylene, $(C_2H_4)_n$, is made up of long chains of ethylene, C_2H_4.
The monomer, ethylene, is polymerised into the polymer polyethylene.

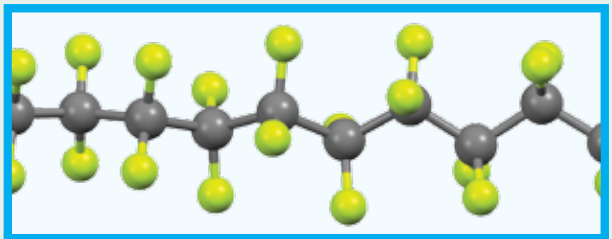
Polytetrafluoroethylene, also known as **Teflon**, is made by the polymerisation of tetrafluoroethylene, C_2F_4, molecules.

Teflon is strong, heat-resistant, and has a nearly frictionless surface.

Teflon is used in cookware, waterproofing, plumbing tape, tubing, and bearings.



tetrafluoroethylene polytetrafluoroethylene



Polytetrafluoroethylene, $(C_2F_4)_n$, is made up of long chains of tetrafluoroethylene, C_2F_4.

Polystyrene, also known as **styrofoam**, is made by the polymerisation of styrene, C_8H_8, molecules.

Styrofoam is a hard plastic used for furniture, and mant household items. The light, foamy styrofoam is formed by heating and blowing air through polystyrene.

Make a Bouncing Polymer Ball

Watch online videos demonstrating how to 'make a bouncing polymer ball'.

Challenge

Make a Bouncing Polymer Ball.

Exercise

1. What are plastics made of?
2. What is a polymer?
3. What is a monomer?
4. Name the monomer that is polymerised to form the polymer polyethylene.
5. Name the monomer that is polymerised to form the polymer polyethene.
6. Name the polymer that is formed from monomers of chloroethene, C_2H_3Cl.
7. Name the polymer that is formed from monomers of tetrafluoroethylene, C_2F_4.
8. The chemical formula of ethylene is C_2H_4. What is meant by $(C_2H_4)_n$?

Fuels

Fuels are materials that are able to release energy in the form of heat energy.

Example:

Solid fuels such as wood and coal store their energy as chemical energy. Combustion can be used to convert their energy to heat energy.

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

coal + oxygen → carbon dioxide + heat

Liquid fuels such as petrol, diesel, kerosene, and LPG are easier to transport than solid fuels.

Combustion can be used to convert their energy to heat energy.

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

petrol + oxygen → carbon dioxide + water + heat

Gaseous fuels such as natural gas, propane, hydrogen, and coal gas are also easier to transport than solid fuels.

Combustion can be used to convert their energy to heat energy.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + \text{heat}$$

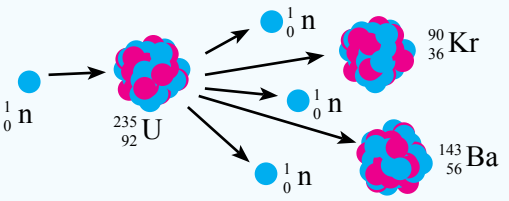
propane + oxygen → carbon dioxide + water + heat

Nuclear fuels such as uranium-235 and plutonium-239 store their energy as nuclear energy.

Bombarding the nucleus of nuclear fuels with neutrons can be used to convert their energy to heat energy.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{36}Kr + {}^{143}_{56}Ba + 3{}^{1}_{0}n + \text{heat}$$

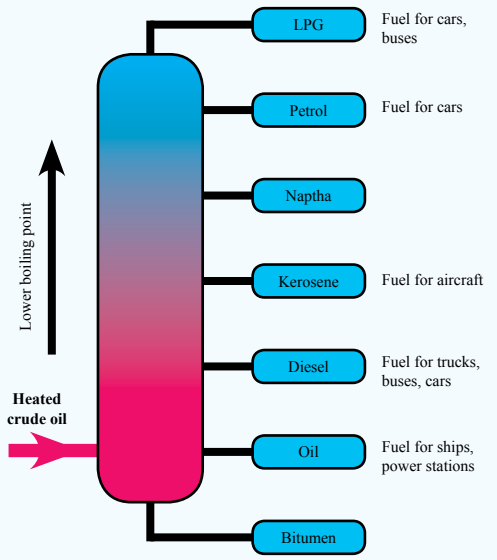
uranium + neutron → krypton + barium + neutron + heat



The combustion of fossil fuels produces carbon dioxide, water vapour, particles of carbon such as smoke and soot, carbon monoxide, sulphur dioxide, and nitrogen oxides.

The combustion of compressed natural gas produces less particles and a lower proportion of carbon dioxide. The combustion of ultra-low-sulphur diesel produces less particles and less sulphur dioxide.

The majority of liquid fuels such as petrol, diesel, kerosene, and LPG are produced from crude oil. Crude oil can vary in colour from pale yellow, to red, green, and black. The above crude oils are from, left to right, Caucasus, the Middle East, Arabia, and France (Courtesy Glasbruch2007, Wikimedia Commons).



Crude oil is separated into different fuels by fractional distillation. Fuels with high boiling points condense at the bottom of the fractional distillation tower. Fuels with low boiling ponts condense at the top of the tower.

An oil rig off the coast of Brazil. At full capacity the platform produces 180 thousand barrels of crude oil and 6 million cubic metres of gas per day (Courtesy Agencia Brasil, Wikimedia Commons).

Most liquid fuels are produced from crude oil. It is generally accepted that crude oil begins with the remains of dead plants and animals. Crude oil is formed as organic material is changed by heat and pressure in the Earth's crust.

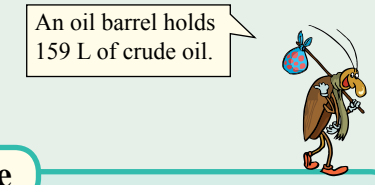
Word Bank

Add the following words to your word bank by writing the word, a definition of the word, and a sentence or phrase using the word:

Word	Definition	A sentence
Chemical reactions		
Chemical equations		
Combination reactions	Two or more substances combine chemically to produce one product.	A combination reaction is also known as a synthesis reaction.
Decomposition reactions		
Single replacement reactions		
Double replacement reactions		
Precipitation reactions		
Rates of reaction		
Catalysts		
Enzymes		

Learning Power

Can you spend about 30 seconds looking at a word, and then write down the word and its definition without looking?



Exercise

1. What is a fuel?
2. Give two examples of a solid fuel.
3. Write a symbolic balanced equation for the burning of coal.
4. Give two examples of a liquid fuel.
5. Write a symbolic balanced equation for the combustion of petrol (summarised as C_8H_{18}).
6. Give two examples of a gaseous fuel.
7. Give two examples of a nuclear fuel.
8. What are some of the products of the combustion of fossil fuels other than carbon dioxide and water vapour?
9. How are the many different fuels extracted from crude oil?

5.6 Science Knowledge

Agrochemicals

Agrochemicals, or agricultural chemicals, are essential to the massive agricultural industry. There are a great variety of agrochemicals.

Fertilisers, both natural and synthetic, provide plants with nutrients that are essential to their healthy growth. Chemical and biological knowledge is used in the production and application of most fertilisers. For example, phosphate rock is converted to water soluble phosphate salts by the treatment of sulphuric acid, nitric acid, or phosphoric acids.

An infestation of aphids on a rose stem. Aphids feed on the sap in the plant's phloem vessels. Aphids also spread plant viruses among plants. For this plant to be healthy and productive, the number of aphids will somehow need to be reduced.

Insecticides are substances used to kill insects. Vast quantities of insecticides are used in the large scale production of food. Chemical knowledge and biological knowledge is essential in developing, producing, and applying insecticides.

Challenge

How would you reduce the number of aphids? There are 360 rose bushes, each with varying numbers of aphid infestation.

Part of a large field of sunflowers. The sunflowers will be used to produce sunflower oil. A variety of agrochemicals are used to produce a quality productive crop.

Other examples of agrochemicals are:

- Herbicides - are substances used to kill weeds.
- Fungicides - are substances used to kill fungus.
- Nematicides - are substances used to kill nematodes that feed on plants. Nematodes are roundworms.
- Plant hormones - are substances used to control the growth of plants and the ripening of fruit.
- Growth agents such as rhizobacteria promote the growth of plants (Rhizobacteria can make more nitrogen available to plants).

Exercise

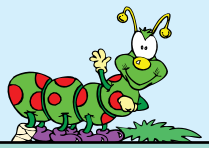
1 What are agrochemicals?
2 Name four different examples of agrochemicals?
3 Briefly describe the use of fertilisers in agriculture.
4 Briefly describe the use of insecticides in agriculture.

Oleochemicals

Oleochemicals are chemical compounds derived from plant oils and animal fats. As the price of chemicals derived from crude oil has risen in price, more interest has been shown in chemicals derived from plant and animal oils.

Fats tend to be solids at room temperature and **oils** tend to be liquids at room temperature.

Petrochemicals are derived from crude oil or natural gas.



Plant oils and animal fats

↓

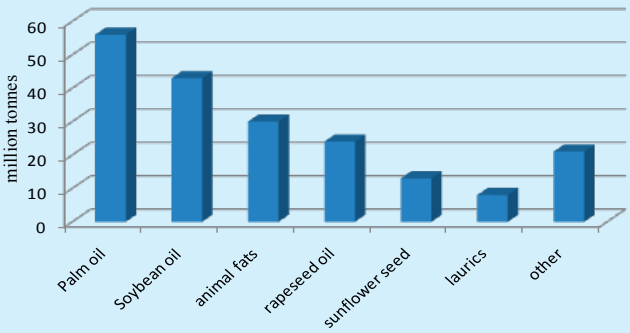
Hardened oils, fatty acids, glycerin, alcohols, fatty esters, methyl esters

↓

Biofuels, detergents, soaps, lubricants, plastics, toothpaste, shampoo, paints, inks, rubber, pharmaceuticals, cosmetics, candles, etc.

The massive growth of palm oil plantations is linked to the issue of deforestation.

A palm tree plantation in Malaysia. Palm oil is extracted from the pulp of the fruit. Palm kernel oil is extracted from the seed of the fruit.



Exercise

1 What are oleochemicals?

2 What is a major difference between fats and oils?

3 What is the difference between oleochemicals and petrochemicals?

4 Name two sources of plant oil.

5 Name five uses of oleochemicals.

6 Which plant is the largest source of plant oils?

5.7 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.

Magnesium is highly reactive. A thin coating of magnesium oxide, MgO, reduces its reactivity.

Oxidation of metals

Most metals chemically combine with oxygen in the air to form oxides. This chemical reaction is called corrosion.

Some metals will oxidise more readily than other metals:

Metal	Symbol	an oxide
Potassium	K	K_2O
Sodium	Na	Na_2O
Calcium	Ca	CaO
Magnesium	Mg	MgO
Aluminium	Al	Al_2O_3
Zinc	Zn	ZnO
Iron	Fe	Fe_2O_3
Tin	Sn	SnO
Lead	Pb	PbO
Copper	Cu	CuO
Silver	Ag	Ag_2O
Platinum	Pt	PtO
Gold	Au	Au_2O_3

More easily oxidised

Activity

Conduct investigations to test each of the following hypotheses.

Questioning & Predicting

If increasing temperature increases the rate of chemical reactions **then** increasing the temperature will decrease the time for a piece of magnesium to dissolve in hydrochloric acid.

Questioning & Predicting

If metals that are more reactive than copper can replace the copper from copper sulphate **then** magnesium and zinc will replace the copper in copper sulphate.

Questioning & Predicting

If different metals have different oxidisation rates **then** different metals will oxidise at different rates when exposed to air..

Questioning & Predicting

If atoms are neither created nor destroyed in a chemical reaction **then** the mass of the reactants is equal to the mass of products when marble chips react with hydrochloric acid.

5.8 Chapter Review

A **chemical reaction** is a process in which one or more substances, **the reactants**, are transformed into one or more different substances, **the products**.

The **reactants** are the starting substances.

The **products** are the result of the chemical reaction.

A chemical reaction rearranges the atoms of **the reactants** to create different substances in **the products**.

Balancing is about writing numbers at the front of each formula (coefficients) until the equation balances.

1 Draw a box around each formula.
2 Count the atoms of each element in the reactants and in the products.
3 Write coefficients until the equation balances.

Example

Which of the following chemical equations are balanced?

1 $2H_2 + O_2 \rightarrow 2H_2O$

H = 4	H = 4 ✓
O = 2	O = 2 ✓

Balanced equation

2 $C_2H_6 + 5O_2 \rightarrow 2CO_2 + 3H_2O$

C = 2	C = 2 ✓
H = 6	H = 6 ✓
O = 10	O = 4 + 3 = 7 ×

Unbalanced equation

Example

Balance the following chemical equation:

4 $\boxed{CO_2} + \boxed{H_2O} \rightarrow \boxed{O_2} + \boxed{C_6H_{12}O_6}$

C = 1	C = 6 ×
O = 3	O = 8 ×
H = 2	H = 12 ✓

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

C = 6	C = 6 ✓
O = 18	O = 8 ×
H = 12	H = 12 ✓

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

C = 6	C = 6 ✓
O = 18	O = 18 ✓
H = 12	H = 12 ✓

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

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

Exercise

1 What is a chemical reaction?

2 What is a chemical equation?

3 In the chemical reaction $X + Y \rightarrow XY$, which are the reactants and which are the products?

4 Which of the following chemical equations are balanced?

a) $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

b) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

c) $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

Exercise

5 Balance each of the following chemical equations:

a) $C + O_2 \rightarrow CO_2$

b) $H_2 + Cl_2 \rightarrow 2HCl$

c) $CaCO_3 \rightarrow CaO + CO_2$

d) $Fe_2O_3 + C \rightarrow CO + Fe$

e) $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

f) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

g) $H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$

h) $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

i) $Mg(OH)_2 + H_2SO_4 \rightarrow MgSO_4 + H_2O$

j) $C_{12}H_{22}O_{11} + O_2 \rightarrow CO_2 + H_2O$

There are many different **types and classifications of chemical reactions**.

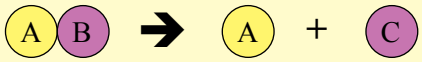
Synthesis reactions, or combination reactions, happen when two or more substances combine chemically to produce a single new substance.

Examples

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

$SO_3 + H_2O \rightarrow H_2SO_4$
sulphur trioxide + water → sulphuric acid

Decomposition reactions occur when a single substance breaks down to form two or more new simpler substances.



Examples

$C_{12}H_{22}O_{11} \rightarrow 12C + 11H_2O$
sugar → carbon + water

$(NH_4)_2CO_3 \rightarrow 2NH_3 + CO_2 + H_2O$
Ammonium carbonate → ammonia + carbon dioxide + water

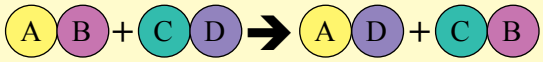
Single replacement, or displacement, reactions happen when an element in a compound is replaced by another element.

Examples

$2HCl_{(aq)} + Fe_{(s)} \rightarrow FeCl_{2(aq)} + H_{2(g)}$
hydrochloric acid + iron → iron chloride + hydrogen

$2AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2Ag$
silver nitrate + copper → copper nitrate + silver
(Copper is more reactive than silver and can replace silver in silver compounds)

Double replacement reactions occur when two compounds swap molecules to form two or more new compounds.



Examples

acid + *base* → *salt* + *water*

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$
hydrochloric acid + sodium hydroxide → sodium chloride + water

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

Exercise

1 State the type of reaction and balance each of the following reactions:

a) $Pb + O_2 \rightarrow PbO_2$

b) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

c) $H_2SO_4 + Cu(OH)_2 \rightarrow CuSO_4 + H_2O$

d) $Na + FeCl_3 \rightarrow NaCl + Fe$

e) $H_2 + N_2 \rightarrow NH_3$

f) $Na_2CO_3 \rightarrow Na_2O + CO_2$

g) $NH_4OH + HBr \rightarrow NH_4Br + H_2O$

h) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

i) $CaCO_3 \rightarrow CaO + O_2$

j) $C_2H_2 + O_2 \rightarrow CO_2 + H_2O$

k) $Na + Cu(OH)_2 \rightarrow NaOH + Cu$

l) $HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + H_2O$

m) $AgNO_3 + Sn \rightarrow Sn(NO_3)_2 + Ag$

Exercise

2 Which metal is more easily corroded; lead, silver, or gold?

Metals in order of decreasing reactivity are: K, Na, Ca, Mg, Al, Zn, Fe, Sn, Pb, Cu, Ag, Pt, Au

3 Nitrogen (N_2) in the atmosphere can be synthesised with hydrogen gas (H_2) to produce ammonia gas (NH_3). Write a symbolic balanced equation for producing ammonia gas.

4 Aluminium (Al) will chemically combine with oxygen in the air (O_2) to form aluminium oxide (Al_2O_3). Write a symbolic balanced equation for the oxidation of aluminium.

The rate of a chemical reaction is the speed at which a chemical reaction happens. **Collison theory** is used to explain why factors affect the reaction rate. It suggests that a chemical reaction occurs when the reactant particles collide with each other with enough energy to produce a reaction.

Increasing or decreasing the **temperature** can speed up or slow down the rate of a chemical reaction. For example, bread dough rises more quickly when warmed.

Increasing the temperature increases the kinetic energy of the particles. Increased kinetic energy will increase the number of collisions per second, and increase the rate of reaction.

Increasing or decreasing the **surface area** of a reactant can speed up or slow down the rate of a chemical reaction. For example, steel wool will easily burn while a piece of steel won't burn.

Increasing the surface area increases the number of collisions per second.

Increasing or decreasing the **concentration** of reactants can speed up or slow down the rate of a chemical reaction. For example, liquid oxygen is highly concentrated oxygen. Burning with liquid oxygen happens at a much higher rate than burning with atmospheric oxygen.

Increasing the concentration of a reactant increases the number of particles and thus the number of collisions per second are increased.

A **catalyst** is a substance that increases the rate of a chemical reaction, but is not consumed or changed by the reaction.

The presence of the catalyst makes it easier for the reactants to collide and produce the products.

The catalytic converter in a car's exhaust system speeds up the conversion of carbon monoxide carbon dioxide.

$$2CO + O_2 \xrightarrow{\text{platinum}} 2CO_2$$

carbon monoxide + oxygen → carbon dioxide

Enzymes are proteins that speed up the rate of chemical reactions in organisms. Enzymes are biological catalysts used in thousands of chemical reactions to support life.

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

Exercise

1 What is meant by the rate of a reaction?
2 What is the 'collision theory'?
3 Indicate four factors that affect the rate of chemical reactions.
4 Use collison theory to explain why increasing temperature increases the chemical reaction rate.
5 Give three examples of temperature affecting the rate of a chemical reaction.
6 Use collison theory to explain why increasing the surface area of a reactant increases the chemical reaction rate.
7 Give three examples of the surface area of a reactant affecting the rate of a chemical reaction.

Exercise

8 How does increasing the concentration of reactants increase the rate of a chemical reaction?
9 Use collison theory to explain why increasing the surface area of a reactant increases the chemical reaction rate.
10 Give three examples of the concentration of a reactant affecting the rate of a chemical reaction.
11 What is a catalyst?
12 What is an enzyne?
13 Explain how a catalyst can increase the rate of a chemical reaction.
14 In the following symbolic equation for making epoxyethane, a sterilising and fumigant gas, name the catalyst?

$$2CH_2CH_2 + O_2 \xrightarrow{\text{silver}} 2CH_2CH_2O$$

ethene + oxygen → epoxyethane

A Sweet Trick

Marble and Straw Trick

Watch some online videos showing how to do this trick.

1 Put a marble, or round lolly, on the end of a straw.

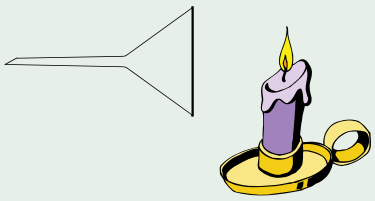
2 Bend the straw so that you can blow through it.

3 Lift the marble by blowing through the straw. The marble doesn't fall.

A Couple of Puzzles

1 Optical Illusion. Do the width of dashes on the right appear to be shorter than the dashes on the left?

2 Can you blow out a candle by blowing through a funnel? How can it be done?



22

25

22

20

23 22 23 21

3 Each differently coloured grub represents a number. The total of each row and each column is shown.

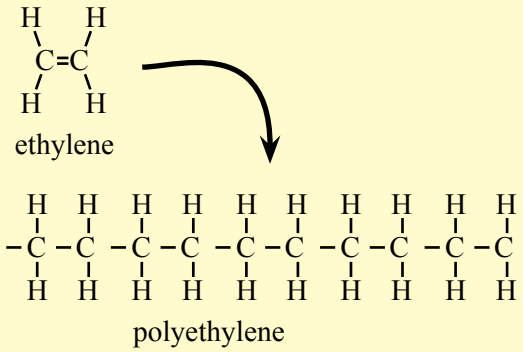
What number does each grub represent?

Plastics are made of polymers, long chains of carbon molecules.

Polymerisation is the process by which a polymer is made by joining up monomers. A **monomer** is a large carbon molecule produced by cracking crude oil or derived from natural materials.

Many different plastics can be made by combining many different monomers in many different ways.

The plastic **Polyethylene** is made from the polymerisation of ethylene, C_2H_4, molecules.



ethylene

polyethylene

Polyethylene is used in wraps, bottles, disposable gloves, garbage bags, and to insulate electrical wires.

A **pharmaceutical drug** is a chemical substance used to treat, cure, or prevent disease.

Examples:

- **Analgesics** are painkillers.
- **Antibiotics** are used to kill bacteria
- **Antiseptics** are used to prevent infections
- **Antidepressants** are used to help reduce moderate or severe depression.
- **Decongestants** are used to reduce congestion in the upper respiratory tract.

Drug development is expensive because it can take twenty years to discover, isolate, chemically produce, trial, patent, and market.

Fuels are materials that are able to release energy in the form of heat energy.

Fuels may be solid (wood and coal), liquid (petrol, diesel, kerosene, LPG), gas (natural gas, propane, hydrogen, coal gas), nuclear (uranium-235, plutonium-239).

Combustion can be used to convert their energy to heat energy.

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

petrol + oxygen → carbon dioxide + water + heat

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

Exercise

1 What are plastics made of?

2 What is a polymer?

3 What is a monomer?

4 Name the monomer that is polymerised to form the polymer polyethylene.

5 Name the monomer that is polymerised to form the polymer polyethene.

6 Name the polymer that is formed from monomers of chloroethene, C_2H_3Cl.

7 Name the polymer that is formed from monomers of tetrafluoroethylene, C_2F_4.

8 The chemical formula of ethylene is C_2H_4. What is meant by $(C_2H_4)_n$?

Exercise

9 What is a pharmaceutical drug?

10 Why is drug development so expensive?

11 What is a fuel?

12 Give two examples of a solid fuel.

13 Write a symbolic balanced equation for the burning of coal.

14 Give two examples of a liquid fuel.

15 Write a symbolic balanced equation for the combustion of petrol (summarised as C_8H_{18}).

16 Give two examples of a gaseous fuel.

17 Give two examples of a nuclear fuel.

18 What are some of the products of the combustion of fossil fuels other than carbon dioxide and water vapour?

Competition Questions

1 Oil usually refers to fats that are liquid at room temperature (25°C), while fats usually refers to fats that are solids at room temperature.
Which of the substances in the table may be described as oils because they are liquids at room temperature (25°C)?

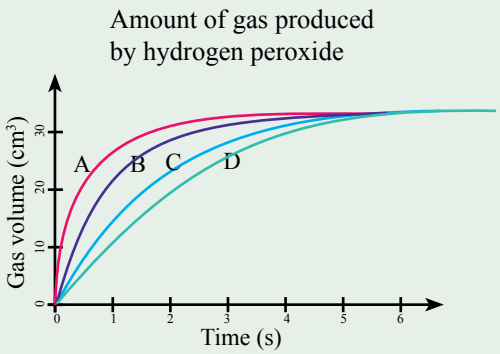
Oil/fat	Melting point
Mutton	42°C
Margarine	38°C
Olive	-6°C
Palm	35°C
Peanut	3°C
Sunflower	-17°C

a) Mutton, margarine, palm.
b) Olive, sunflower, palm.
c) Olive, sunflower, peanut.
d) Olive, palm, peanut, sunflower.

2 When testing hypotheses, 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).
Given the hypothesis: The breakdown of hydrogen peroxide into oxygen and water is increased when a catalyst is added.
Which variable is plotted on the x-axis?

a) Rate of reaction.
b) Amount of hydrogen peroxide.
c) Amount of oxygen.
d) Amount of catalyst.

The rate of a chemical reaction is the speed at which the chemical reaction happens. A reaction with a high rate of reaction will be completed before the same reaction with a low rate of reaction. The graph on the right shows the time taken for for a certain amount of hydrogen peroxide to decompose into oxygen and water. The volume of oxygen being used to indicate the progress of the reaction.



3 How much gas has been produced by reaction B after one second?

a) 10 cm^3
b) 15 cm^3
c) 20 cm^3
d) 25 cm^3

4 Which reaction has the highest rate of reaction?

a) A
b) B
c) C
d) D

Harder Test Questions

1 Classify each of the following chemical reactions as one of synthesis, decomposition, single replacement, or double replacement.

a) $2Na + Cu(OH)_2 \rightarrow 2NaOH + Cu$

b) $3H_2 + N_2 \rightarrow 2NH_3$

c) $2HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + 2H_2O$

d) $CaCO_3 \rightarrow CaO + O_2$

2 A popular way of cleaning bathrooms, sinks, etc. is to wet the area, sprinkle baking soda, and then wipe with a vinegar soaked sponge.

This involves an acid-base reaction and can be summarised as:

$NaHCO_3 + C_2H_4O_2 \rightarrow NaC_2H_3O_2 + CO_2 + H_2O$

sodium bicarbonate + acetic acid → sodium acetate + carbon dioxide + water

a) What are the reactants in this reaction?

b) What are the products in this reaction?

c) Would you expect this reaction to be an endothermic or exothermic reaction? Explain.

d) Why would this reaction be useful in cleaning surfaces?

e) Is the above equation balanced?

Pharmacologists discover, develop, and evaluate drugs for human and animal use.

- Relevant school subjects are Science, English, Mathematics.
- Courses generally involve an science or medical science degree at a university.

Solubility Table		
Ion	**Solubility**	**Exceptions**
NO_3^-	soluble	none
Cl^-	soluble	Ag^+, Hg^{2+}, Pb^{2+}
I^-	soluble	Ag^+, Hg^{2+}, Pb^{2+}
SO_4^{2-}	soluble	Ca^{2+}, Ba^{2+}, Sr^{2+}, Ag^+, Hg^{2+}, Pb^{2+}
CO_3^{2-}	insoluble	Li^+, Na^+, K^+, Rb^+, NH_4^+
PO_4^{3-}	insoluble	Li^+, Na^+, K^+, Rb^+, NH_4^+
OH^-	insoluble	Ca^{2+}, Ba^{2+}, Sr^{2+}, Li^+, Na^+, K^+, Rb^+
S^{2-}	insoluble	Li^+, Na^+, K^+, Rb^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}
Na^+	soluble	none
NH_4^+	soluble	none
K^+	soluble	none

3 Use the above solubility table to decide if a precipitate will be formed in each of the following double replacement reactions:

a) a solution of magnesium nitrate $Mg(NO_3)_2$ and a solution of sodium hydroxide NaOH is mixed together.

b) a solution of silver nitrate $AgNO_3$ and a solution of potassium chloride KCl is mixed together.

4 The active metals list will help predict whether a metal will react with a solution in single replacement reactions.

Metals with a higher reactivity (i.e. higher in the list) will replace a metal with lower reactivity.

Predict whether each of the following reactions will happen.

a) $Zn + CuCl_2 \rightarrow$

b) $Cu + AgNO_3 \rightarrow$

c) $Pb + ZnSO_4 \rightarrow$

d) $Zn + MgCO_3 \rightarrow$

e) $Ca + Sn(NO_3)_2 \rightarrow$

f) $Na + CaCO_3 \rightarrow$

Metal activity

Metal	**Symbol**
Sodium	Na
Calcium	Ca
Magnesium	Mg
Aluminium	Al
Zinc	Zn
Iron	Fe
Tin	Sn
Lead	Pb
Copper	Cu
Silver	Ag

More reactive