

Chemistry

made simple

An easy reader for AQA GCSE Combined Science: Trilogy (8464)

1. Atoms and the periodic table

2. Bonding and structure

3. Quantitative chemistry

4. Chemical changes

5. Energy changes

6. Rates and equilibrium

7. Organic chemistry

8. Chemical analysis

9. The atmosphere

10. Using resources

Name: _____

How to use this booklet

Read one small part at a time. Each part explains one idea in simple words. Then try the worked example yourself before you look at the answer.

Look out for these boxes:

Equation box

A key equation you need to know how to use.

Worked example

A calculation done step by step.

Top tip

A handy reminder or a common mistake to avoid.

Higher tier only

Text written in bold italics like this is only for the Higher paper. Foundation students can skip it.

At the end of each chapter there is a **Have a go** section. The answers are at the back of the booklet.

Remember: in every calculation, write the equation, put in the numbers, then write the answer with its unit.

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1

Atoms and the periodic table

What atoms are made of and how elements are sorted.

Elements, compounds and mixtures

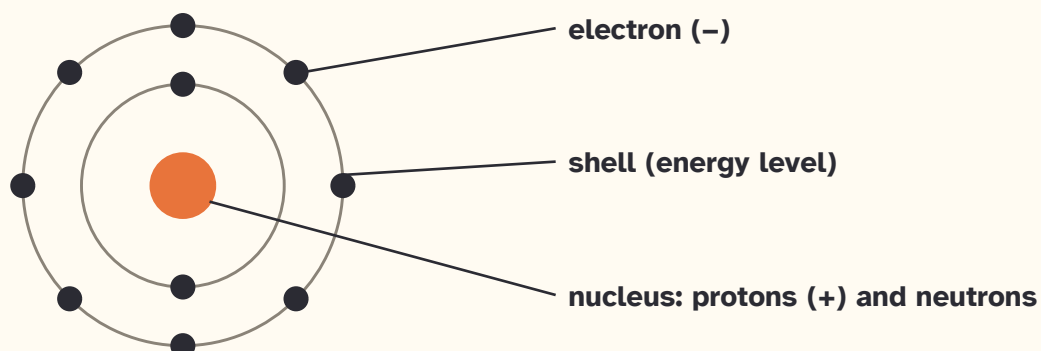
- An **element** is made of only one type of atom. There are about 100 elements. Each has a symbol, like O for oxygen or Na for sodium.
- A **compound** is two or more elements **chemically joined**. For example, water (H₂O) is hydrogen and oxygen joined together.
- A **mixture** is two or more things mixed but NOT chemically joined. Air and salty water are mixtures.

Mixtures can be separated without a chemical reaction:

Method	What it separates	Example
Filtration	An insoluble solid from a liquid	Sand from water
Crystallisation	A dissolved solid from a solution	Salt from salty water
Simple distillation	A liquid from a solution	Pure water from sea water
Fractional distillation	Liquids with different boiling points	Crude oil into fractions
Chromatography	Different dissolved substances	Colours in ink

Inside an atom

Atoms have a tiny **nucleus** in the middle, with **electrons** moving around it in shells.



Particle	Where	Relative mass	Charge
Proton	Nucleus	1	+1
Neutron	Nucleus	1	0
Electron	Shells	Very small	-1

Atoms have the same number of protons and electrons, so they have no overall charge.

- **Atomic number** = number of protons.
- **Mass number** = protons + neutrons.

$$\text{neutrons} = \text{mass number} - \text{atomic number}$$

Worked example 1

Fluorine has a mass number of 19 and an atomic number of 9. How many neutrons?

Step 1: Take away: $19 - 9$

Answer: 10 neutrons

Isotopes are atoms of the same element with different numbers of neutrons.

Relative atomic mass

Most elements are a mix of isotopes. The **relative atomic mass** is the average mass, taking into account how common each isotope is.

Worked example 2

Chlorine is 75% chlorine-35 and 25% chlorine-37. What is its relative atomic mass?

Step 1: Multiply each mass by its %: $35 \times 75 = 2625$ and $37 \times 25 = 925$

Step 2: Add them: $2625 + 925 = 3550$

Step 3: Divide by 100: $3550 \div 100$

Answer: 35.5

Electron shells

Electrons fill shells from the inside out. The first shell holds **2**. The next two shells hold **8** each.

Worked example 3

Sodium has 11 electrons. What is its electron arrangement?

Step 1: First shell: 2 (9 left)

Step 2: Second shell: 8 (1 left)

Step 3: Third shell: 1

Answer: 2, 8, 1

How the model of the atom changed

- First, atoms were thought to be tiny solid spheres.
- The electron was discovered. This led to the **plum pudding** model: a ball of positive charge with electrons in it.
- The alpha scattering experiment showed atoms are mostly empty space, with a tiny positive nucleus.
- Bohr showed electrons are in shells. Later, Chadwick found the neutron.

The periodic table

Elements are arranged in order of **atomic number**.

- **Groups** are the columns. Elements in the same group have the same number of electrons in their outer shell, so they react in similar ways.
- **Periods** are the rows.
- **Metals** are on the left. **Non-metals** are on the right.

Mendeleev made an early periodic table. He left gaps for elements that had not been found yet, and he was proved right.

Group 0: the noble gases

They have a full outer shell, so they are very **unreactive**. Boiling points go up as you go down the group.

Group 1: the alkali metals

They have **1** electron in their outer shell. They react with water to make a metal hydroxide and hydrogen.

They get **more reactive** down the group. This is because the outer electron is further from the nucleus, so it is lost more easily.

Group 7: the halogens

They have **7** electrons in their outer shell. They exist as pairs of atoms, like Cl_2 .

They get **less reactive** down the group. A more reactive halogen can push a less reactive one out of its compound. This is called **displacement**.

Example: chlorine + potassium bromide $\rightarrow$ potassium chloride + bromine

Key words

Element	A substance made of only one type of atom.
Compound	Two or more elements chemically joined.
Mixture	Substances mixed but not chemically joined.
Isotope	Same element, different number of neutrons.
Group	A column in the periodic table.

Period

A row in the periodic table.

Checklist: I can...

Tick each box when you feel confident.

- ☐ tell elements, compounds and mixtures apart
- ☐ name ways to separate mixtures
- ☐ work out protons, neutrons and electrons
- ☐ write electron arrangements like 2, 8, 1
- ☐ describe Groups 0, 1 and 7

Have a go

Show your working for each one.

1. Magnesium has 12 electrons. Write its electron arrangement.

2. An atom has a mass number of 23 and an atomic number of 11. How many neutrons?

3. Which is more reactive: sodium or potassium?

4. Which method would you use to get salt from salty water?

5. Why are noble gases unreactive?

2

Bonding and structure

How atoms join together.

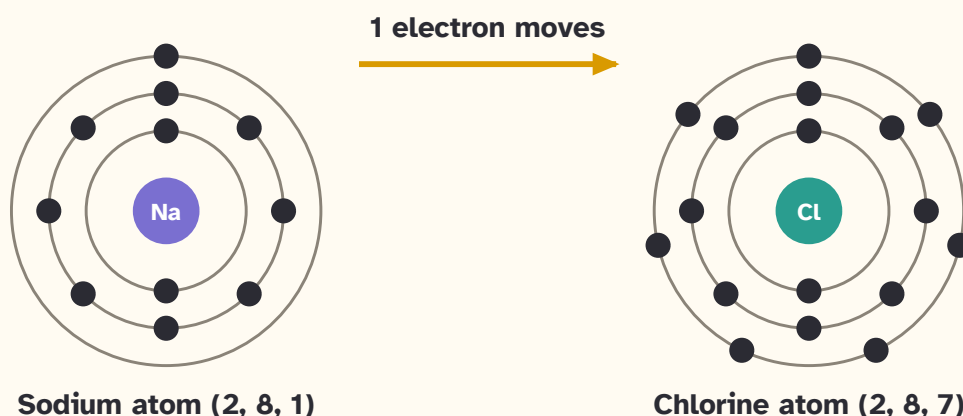
Three types of bond

Bond	Between	What happens
Ionic	A metal and a non-metal	Electrons are transferred (given and taken)
Covalent	Non-metals	Electrons are shared in pairs
Metallic	Metals	Outer electrons are free to move around

Ionic bonding

Metal atoms **lose** electrons to become **positive ions**. Non-metal atoms **gain** electrons to become **negative ions**. Opposite charges attract strongly.

Example: sodium loses 1 electron to become Na^+ . Chlorine gains 1 electron to become Cl^- . Together they make sodium chloride.



Sodium becomes Na^+ and chlorine becomes Cl^- . Both now have full outer shells.

We show this with **dot and cross diagrams**.

Ionic compounds form a **giant lattice**. They have **high melting points**. They **conduct electricity** when melted or dissolved, because the ions can move.

Worked example 1

Magnesium forms Mg^{2+} ions. Chlorine forms Cl^- ions. What is the formula of magnesium chloride?

Step 1: The charges must add up to zero

Step 2: One Mg^{2+} needs two Cl^- ions

Answer: MgCl_2

Covalent bonding

Non-metal atoms share pairs of electrons. Each shared pair is a covalent bond.

Small molecules like water (H_2O), carbon dioxide (CO_2) and methane (CH_4):

- have **low** melting and boiling points, because the forces **between** the molecules are weak
- do **not** conduct electricity

Polymers are very long molecules, made of lots of small units joined together.

Giant covalent structures

Substance	Structure	Properties
Diamond	Each carbon makes 4 bonds	Very hard. Very high melting point. Does not conduct.
Graphite	Each carbon makes 3 bonds, in layers	Soft, layers slide. Conducts electricity, because it has free (delocalised) electrons.
Silicon dioxide	Lots of strong bonds	Hard. High melting point.
Graphene	A single layer of graphite	Very strong. Conducts electricity.
Fullerenes	Carbon in balls or tubes	Nanotubes are strong and conduct.

Metals and alloys

Metals have a sea of free (delocalised) electrons. This means metals:

- conduct electricity and heat
- can be bent and shaped, because the layers can slide

An **alloy** is a mixture of a metal with other elements. Alloys are harder, because the different sized atoms stop the layers sliding.

States of matter

We write state symbols in equations:

- (s) = solid
- (l) = liquid
- (g) = gas
- (aq) = aqueous, which means dissolved in water

Key words

Ion	An atom that has lost or gained electrons, so it has a charge.
Ionic bond	Attraction between positive and negative ions.
Covalent bond	A shared pair of electrons.
Delocalised	Electrons that are free to move.
Alloy	A metal mixed with other elements.

Checklist: I can...

Tick each box when you feel confident.

- ☐ name the three types of bond
- ☐ explain ionic bonding
- ☐ describe small molecules and giant structures
- ☐ compare diamond and graphite
- ☐ explain why alloys are harder

Have a go

Show your working for each one.

1. What type of bond forms between a metal and a non-metal?

2. Why does graphite conduct electricity?

3. Why do small molecules have low boiling points?

4. Sodium forms Na^+ and oxygen forms O^{2-} . Write the formula of sodium oxide.

5. Why are alloys harder than pure metals?

3

Quantitative chemistry

Masses, equations and concentrations.

Conservation of mass

In a reaction, no atoms are made or lost. So the **total mass before = total mass after**.

Sometimes the mass seems to change. If a gas escapes, the mass goes down. If a gas from the air joins in (like oxygen when metal burns), the mass goes up.

Worked example 1

10 g of calcium carbonate is heated. It makes 5.6 g of calcium oxide and some carbon dioxide gas. What mass of carbon dioxide is made?

Step 1: Mass before = mass after

Step 2: Carbon dioxide = 10 – 5.6

Answer: 4.4 g

Balancing equations

There must be the same number of each type of atom on both sides. You can only change the big numbers in front.

Worked example 2

Balance: $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$

Step 1: There are 2 O on the left but only 1 on the right. Put a 2 in front of H_2O

Step 2: Now there are 4 H on the right. Put a 2 in front of H_2

Answer: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

Relative formula mass

The **relative formula mass** (M_r) is all the relative atomic masses added up. You find these on the periodic table.

Worked example 3

Find the M_r of water, H_2O . ($H = 1$, $O = 16$)

Step 1: 2 hydrogen atoms: $2 \times 1 = 2$

Step 2: Add the oxygen: $2 + 16$

Answer: 18

Worked example 4

Find the M_r of carbon dioxide, CO_2 . ($C = 12$, $O = 16$)

Step 1: 2 oxygen atoms: $2 \times 16 = 32$

Step 2: Add the carbon: $12 + 32$

Answer: 44

Concentration

Concentration tells you how much substance is dissolved in a volume of solution.

$$\text{concentration} = \text{mass} \div \text{volume}$$

concentration in g/dm^3 , mass in g, volume in dm^3

Worked example 5

10 g of salt is dissolved in 2 dm^3 of water. What is the concentration?

Step 1: Write the equation: $\text{concentration} = \text{mass} \div \text{volume}$

Step 2: Put in the numbers: $10 \div 2$

Answer: 5 g/dm^3

Top tip

To change cm^3 into dm^3 , divide by 1000. So $500 \text{ cm}^3 = 0.5 \text{ dm}^3$.

Moles

Higher tier only

A mole is a fixed amount of a substance. One mole contains 6.02×10^{23} particles. This is called the Avogadro constant.

Higher tier only

Moles = mass $\div$ Mr. Example: 36 g of water (Mr = 18) is $36 \div 18 = 2$ moles.

Higher tier only

In a reaction, the reactant that runs out first is the limiting reactant. It decides how much product is made. The other reactant is in excess.

Key words

Conservation of mass	Total mass before a reaction = total mass after.
Relative formula mass (M_r)	All the relative atomic masses in a formula added up.
Concentration	Mass of substance in a certain volume of solution.
Mole	A fixed amount of particles (Higher only).

Checklist: I can...

Tick each box when you feel confident.

- ☐ use conservation of mass
- ☐ balance a simple equation
- ☐ calculate relative formula mass
- ☐ calculate concentration in g/dm^3

Have a go

Show your working for each one.

1. Find the M_r of NaCl. (Na = 23, Cl = 35.5)

2. Find the M_r of CaCO_3 . (Ca = 40, C = 12, O = 16)

3. 20 g is dissolved in 0.5 dm³. Find the concentration.

4. A metal is burned in air and its mass goes up. Why?

5. Higher: How many moles are in 88 g of CO_2 ($M_r = 44$)?

4

Chemical changes

Metals, acids and electrolysis.

The reactivity series

This lists metals from most reactive to least reactive. Carbon and hydrogen are added to help compare.

Potassium, Sodium, Calcium, Magnesium, (Carbon), Zinc, Iron, (Hydrogen), Copper, Silver, Gold

Top tip

Remember it with: **P**lease **S**end **C**harlie **M**onkeys **C**ute **Z**ebra **I**n **H**ot **C**ountries
Signed **G**orilla.

- A more reactive metal can **displace** a less reactive metal from its compound.
- When metals react with oxygen, they make metal oxides. Gaining oxygen is called **oxidation**.
- Losing oxygen is called **reduction**.

Getting metals from rocks

Gold is so unreactive it is found as the metal itself. Most metals are found as compounds in rocks called **ores**.

Metals **less reactive than carbon** can be got by heating the ore with carbon. The carbon takes the oxygen away (reduction).

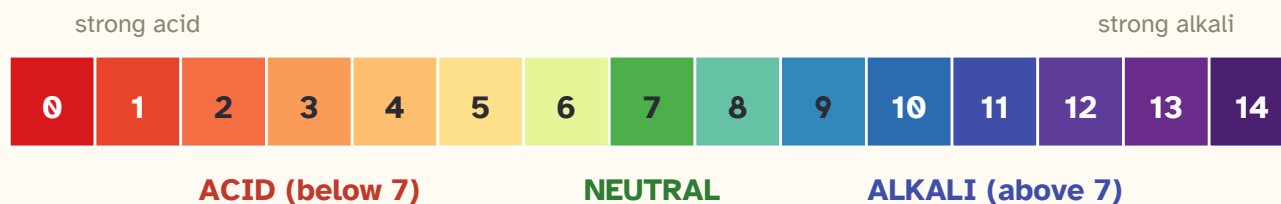
Example: iron oxide + carbon → iron + carbon dioxide

Higher tier only

Oxidation is loss of electrons. Reduction is gain of electrons. Remember OIL RIG: Oxidation Is Loss, Reduction Is Gain. An ionic equation only shows the particles that change.

Acids and alkalis

The **pH scale** goes from 0 to 14.



- **Acids** have a pH below 7. They make H^+ ions in water.
- **Neutral** is pH 7.
- **Alkalis** have a pH above 7. They make OH^- ions in water.

You can measure pH with universal indicator or a pH probe.

When an acid and an alkali react, they cancel out. This is called **neutralisation**: $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$

Higher tier only

Strong acids (hydrochloric, nitric, sulfuric) fully ionise in water. Weak acids (ethanoic, citric, carbonic) only partly ionise. When the H^+ ion concentration goes up 10 times, the pH goes down by 1.

Reactions of acids

Acid reacts with	Makes
a metal	salt + hydrogen
an alkali (metal hydroxide)	salt + water
a metal oxide	salt + water
a metal carbonate	salt + water + carbon dioxide

Naming salts: hydrochloric acid makes **chlorides**. Sulfuric acid makes **sulfates**. Nitric acid makes **nitrates**.

Worked example 1

What salt is made when magnesium reacts with hydrochloric acid?

Step 1: The metal gives the first word: magnesium

Step 2: Hydrochloric acid gives: chloride

Answer: magnesium chloride (and hydrogen gas)

Top tip

Required practical: make a pure, dry salt. Add an insoluble base to acid until no more reacts. Filter off the extra solid. Then warm the solution and leave it to crystallise.

Electrolysis

Electrolysis uses electricity to split up an ionic compound. The compound must be **melted or dissolved**, so the ions can move.

- Positive ions move to the **negative** electrode (cathode).
- Negative ions move to the **positive** electrode (anode).

Worked example 2

Molten lead bromide is electrolysed. What forms at each electrode?

Step 1: Lead ions are positive, so they go to the negative electrode

Step 2: Bromide ions are negative, so they go to the positive electrode

Answer: lead at the negative electrode, bromine at the positive electrode

Aluminium is got from aluminium oxide by electrolysis. Cryolite is added to lower the melting point and save energy. The positive carbon electrodes burn away and must be replaced.

In **solutions** (dissolved in water):

- At the negative electrode: you get **hydrogen** if the metal is more reactive than hydrogen. Otherwise you get the metal.
- At the positive electrode: you get **oxygen**, unless there are chloride, bromide or iodide ions. Then you get the halogen.

Higher tier only

Half equations show what happens at each electrode. For example, at the negative electrode: $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$.

Key words

Oxidation	Gaining oxygen.
Reduction	Losing oxygen.
Neutralisation	An acid and alkali react to make water.
Salt	Made when an acid reacts. Named after the metal and the acid.
Electrolysis	Splitting an ionic compound using electricity.
Cathode / anode	The negative / positive electrode.

Checklist: I can...

Tick each box when you feel confident.

- ☐ use the reactivity series
- ☐ explain oxidation and reduction
- ☐ use the pH scale
- ☐ name the products of acid reactions
- ☐ predict products of electrolysis

Have a go

Show your working for each one.

1. What is the pH of a neutral solution?

2. What gas is made when an acid reacts with a carbonate?

3. Name the salt made from zinc and sulfuric acid.

4. Why can iron be got from its ore by heating with carbon?

5. In electrolysis, where do positive ions go?

6. Higher: What is the difference between a strong and a weak acid?

5

Energy changes

Reactions that get hot or cold.

Exothermic and endothermic

	Exothermic	Endothermic
Energy	Given out to the surroundings	Taken in from the surroundings
Temperature	Goes up	Goes down
Examples	Burning, neutralisation, hand warmers	Thermal decomposition, sports injury cold packs

Top tip

Exothermic = energy **exits**. **Endothermic** = energy **enters**.

Worked example 1

A reaction starts at 20 °C and ends at 32 °C. Is it exothermic or endothermic?

Step 1: Change: $32 - 20 = 12$ °C rise

Step 2: The temperature went up

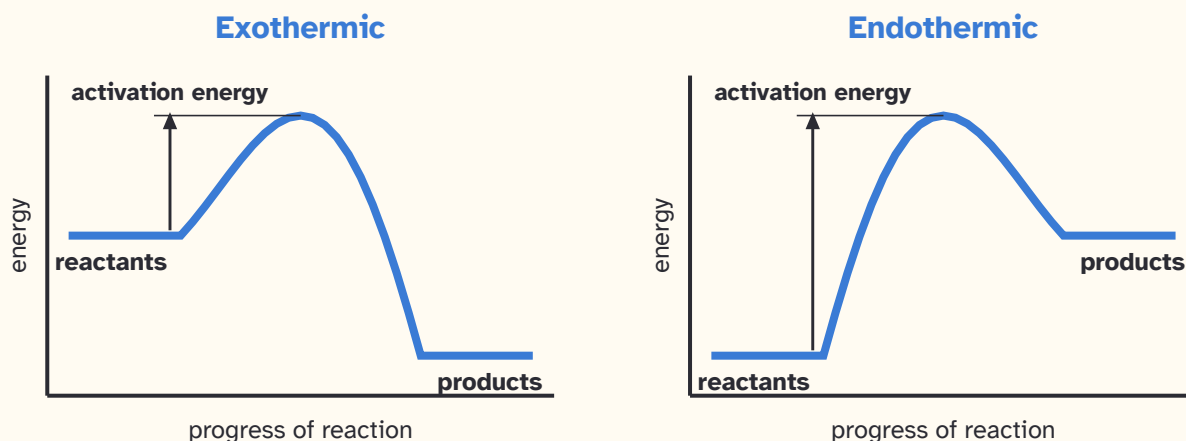
Answer: exothermic (12 °C rise)

Top tip

Required practical: mix solutions in a polystyrene cup with a lid and measure the temperature change.

Reaction profiles

A reaction profile is a graph showing the energy of the reactants and products.



- **Exothermic:** products are **lower** than reactants.
- **Endothermic:** products are **higher** than reactants.
- The hump is the **activation energy**. This is the smallest amount of energy needed for particles to react.

Bond energies

Higher tier only

Breaking bonds takes energy in (endothermic). Making bonds gives energy out (exothermic).

Higher tier only

Energy change = energy to break bonds – energy released making bonds.

Example: breaking takes 500 kJ/mol and making releases 700 kJ/mol. $500 - 700 = -200$ kJ/mol. It is negative, so the reaction is exothermic.

Key words

Exothermic	Gives out energy. Temperature rises.
Endothermic	Takes in energy. Temperature falls.
Activation energy	The minimum energy needed for a reaction.

Checklist: I can...

Tick each box when you feel confident.

- ☐ tell exothermic and endothermic apart
- ☐ calculate a temperature change
- ☐ draw and label reaction profiles

Have a go

Show your working for each one.

1. A reaction goes from 22 °C to 15 °C. Is it exothermic or endothermic?

2. Give one use of an exothermic reaction.

3. What is activation energy?

4. Higher: Breaking bonds takes 900 kJ/mol. Making bonds releases 600 kJ/mol. Find the energy change.

6

Rates and equilibrium

How fast reactions go, and reactions that reverse.

Rate of reaction

The rate tells you how fast a reaction goes.

$$\text{mean rate} = \text{amount of product made} \div \text{time}$$

e.g. cm^3/s or g/s

Worked example 1

A reaction makes 60 cm^3 of gas in 30 s. What is the mean rate?

Step 1: Write the equation: $\text{rate} = \text{amount} \div \text{time}$

Step 2: Put in the numbers: $60 \div 30$

Answer: $2 \text{ cm}^3/\text{s}$

On a graph, a **steeper** line means a **faster** reaction. When the line goes flat, the reaction has finished.

Higher tier only

To find the rate at one moment, draw a tangent to the curve and work out its gradient.

Collision theory

Particles only react if they **collide** with enough energy. The minimum energy is the activation energy.

Change	Why it speeds up the reaction
Higher temperature	Particles move faster. They collide more often and with more energy.
Higher concentration or pressure	Particles are more crowded, so they collide more often.

Change	Why it speeds up the reaction
Bigger surface area (smaller pieces)	More particles are exposed, so there are more collisions.
Adding a catalyst	Gives a different route with a lower activation energy.

A **catalyst** speeds up a reaction but is not used up. Enzymes are catalysts in living things.

Top tip

Required practical: the disappearing cross. Time how long it takes for a cross under a flask to disappear as the solution goes cloudy.

Reversible reactions

Some reactions can go both ways. We use the symbol $\rightleftharpoons$.

Example: hydrated copper sulfate (blue) $\rightleftharpoons$ anhydrous copper sulfate (white) + water

If one direction is exothermic, the other is endothermic. The same amount of energy is moved each way.

In a closed container, a reversible reaction reaches **equilibrium**. This is when the forward and backward reactions go at the same rate.

Higher tier only

If you change the conditions, the equilibrium moves to work against the change (Le Chatelier's principle). Raising the temperature favours the endothermic direction. Raising the pressure favours the side with fewer gas molecules. Adding more reactant makes more product.

Key words

Rate	How fast a reaction goes.
Collision theory	Particles must collide with enough energy to react.
Catalyst	Speeds up a reaction without being used up.
Equilibrium	Forward and backward reactions go at the same rate.

Checklist: I can...

Tick each box when you feel confident.

- ☐ calculate mean rate
- ☐ explain collision theory
- ☐ list four ways to speed up a reaction
- ☐ describe reversible reactions and equilibrium

Have a go

Show your working for each one.

1. A reaction makes 100 cm^3 of gas in 50 s. Find the mean rate.

2. Why does heating speed up a reaction?

3. Why does powder react faster than a lump?

4. What does a catalyst do?

5. Higher: What happens to an equilibrium if you raise the temperature?

7

Organic chemistry

Crude oil, fuels and hydrocarbons.

Crude oil

Crude oil is made from the remains of tiny sea creatures (plankton) buried in mud millions of years ago. It is **finite**: it will run out.

It is a mixture of **hydrocarbons**. These are compounds made of **hydrogen and carbon only**.

Alkanes

Most hydrocarbons in crude oil are **alkanes**. Their general formula is $C_n H_{2n+2}$.

Name	Formula
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}

Top tip

Remember the order: **M**onkeys **E**at **P**eanut **B**utter.

Worked example 1

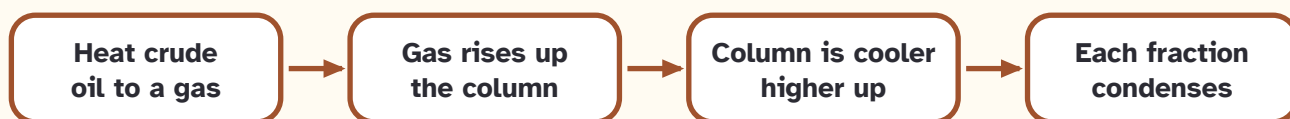
An alkane has 5 carbon atoms. What is its formula?

Step 1: Hydrogens = $(2 \times 5) + 2 = 12$

Answer: C_5H_{12}

Fractional distillation

Crude oil is separated into **fractions**. Each fraction has molecules with a similar number of carbon atoms.



Fractions include petrol, diesel, kerosene (for planes), heating oil, fuel oil and liquefied petroleum gas.

Bigger molecules are...	
Boiling point	Higher
Viscosity (thickness)	More viscous (thicker)
Flammability	Less flammable

Burning hydrocarbons

When hydrocarbons burn in plenty of oxygen (complete combustion):



Cracking

Long hydrocarbons are not very useful. **Cracking** breaks them into shorter, more useful molecules. It makes shorter alkanes and **alkenes**.

- **Catalytic cracking:** heat the vapour and pass it over a hot catalyst.
- **Steam cracking:** mix the vapour with steam at a very high temperature.

Alkenes are more reactive than alkanes. They are used to make polymers (plastics).

Test for alkenes: add bromine water. It turns from **orange to colourless**.

Key words

Hydrocarbon	A compound of hydrogen and carbon only.
Alkane	A hydrocarbon with formula C_nH_{2n+2} .
Fraction	A group of hydrocarbons with similar boiling points.
Viscosity	How thick a liquid is.
Cracking	Breaking long hydrocarbons into shorter ones.

Checklist: I can...

Tick each box when you feel confident.

- ☐ describe crude oil and hydrocarbons
- ☐ write alkane formulas
- ☐ explain fractional distillation
- ☐ explain cracking and the test for alkenes

Have a go

Show your working for each one.

1. Write the formula of an alkane with 6 carbon atoms.

2. What is a hydrocarbon?

3. How do you test for an alkene?

4. Why is cracking useful?

8

Chemical analysis

Purity, chromatography and gas tests.

Pure substances

In chemistry, a **pure** substance is a single element or compound, with nothing mixed in.

Pure substances melt and boil at **one exact temperature**. Impure ones melt over a range of temperatures.

A **formulation** is a mixture made in exact amounts for a job. Examples: paints, medicines, fuels, cleaning products, alloys, fertilisers.

Chromatography

Chromatography separates the different substances in a mixture, like the colours in ink.

- Draw a **pencil** line near the bottom of the paper. Put spots of ink on it.
- Stand the paper in a solvent (like water). Keep the line above the solvent.
- The solvent moves up and carries the substances with it. They move different distances.
- A pure substance makes only **one spot**.

$$R_f = \text{distance moved by substance} \div \text{distance moved by solvent}$$

no units. Always less than 1.

Worked example 1

A spot moved 3 cm. The solvent moved 6 cm. What is the R_f value?

Step 1: Write the equation: $R_f = \text{substance} \div \text{solvent}$

Step 2: Put in the numbers: $3 \div 6$

Answer: 0.5

Top tip

Use pencil, not pen, for the line. Pen ink would dissolve and move up the paper too.

Tests for gases

Gas	Test	Result
Hydrogen	Lit splint	Squeaky pop
Oxygen	Glowing splint	Relights
Carbon dioxide	Bubble through limewater	Limewater turns milky (cloudy)
Chlorine	Damp litmus paper	Bleached white

Key words

Pure	A single element or compound, with nothing mixed in.
Formulation	A mixture made in exact amounts for a purpose.
Chromatography	A way to separate substances in a mixture.
R_f value	Distance moved by a substance ÷ distance moved by the solvent.

Checklist: I can...

Tick each box when you feel confident.

- ☐ explain what pure means
- ☐ calculate an R_f value
- ☐ carry out the four gas tests

Have a go

Show your working for each one.

1. A spot moves 4 cm and the solvent moves 10 cm. Find the R_f .

2. How do you test for oxygen?

3. What happens to limewater with carbon dioxide?

4. How can you tell from a chromatogram if a substance is pure?

9

The atmosphere

How the air formed and how we are changing it.

The early atmosphere

- Volcanoes gave out gases. The early atmosphere was mostly **carbon dioxide**, with little or no oxygen. There was also water vapour and some nitrogen.
- The water vapour cooled and condensed to form the **oceans**.
- Some carbon dioxide dissolved in the oceans. Some got locked up in rocks and fossil fuels.

About 2.7 billion years ago, **algae** and then plants began to photosynthesise. This took in carbon dioxide and gave out **oxygen**.

The atmosphere today

Gas	Amount
Nitrogen	About 80% (four-fifths)
Oxygen	About 20% (one-fifth)
Carbon dioxide, water vapour, noble gases	Small amounts

Greenhouse gases and climate change

Carbon dioxide, methane and water vapour are greenhouse gases. They trap heat and keep the Earth warm enough to live on.

Humans are adding more greenhouse gases:

- Burning fossil fuels and cutting down forests add **carbon dioxide**.
- Farming cattle and rubbish in landfill add **methane**.

Most scientists agree this is causing **climate change**. Effects include rising sea levels, more extreme weather, and changes to where food can grow and where animals can live.

A **carbon footprint** is the total greenhouse gas given out by a product, service or event. We can reduce it by using renewable energy, saving energy and capturing carbon dioxide.

Air pollution

Pollutant	Where it comes from	Problem
Carbon monoxide	Fuels burning without enough oxygen	Poisonous. Has no colour or smell.
Sulfur dioxide	Fuels containing sulfur	Acid rain. Breathing problems.
Nitrogen oxides	Hot car engines	Acid rain. Breathing problems.
Soot (particulates)	Burning fuels	Global dimming. Damages lungs.

Key words

Greenhouse gas	A gas that traps heat in the atmosphere.
Climate change	Long-term changes to the Earth's weather patterns.
Carbon footprint	Total greenhouse gas given out over the life of something.
Acid rain	Rain made acidic by sulfur dioxide or nitrogen oxides.

Checklist: I can...

Tick each box when you feel confident.

- ☐ describe how the atmosphere formed
- ☐ give the gases in air today
- ☐ explain greenhouse gases and climate change
- ☐ name air pollutants and their effects

Have a go

Show your working for each one.

1. Which gas makes up about 80% of the air today?

2. Name two greenhouse gases.

3. How did oxygen get into the atmosphere?

4. Which pollutant causes acid rain?

10

Using resources

Water, metals and looking after the planet.

Resources

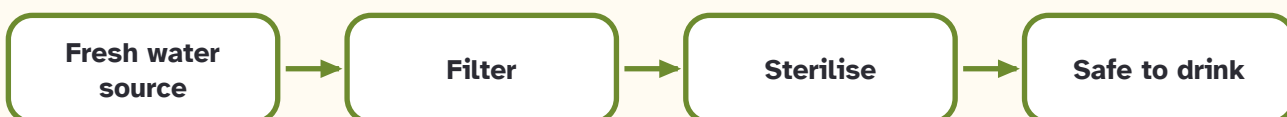
We use the Earth's resources for warmth, shelter, food and transport. Some are **finite** (will run out). Others are **renewable**.

Sustainable development means meeting our needs today without spoiling things for people in the future.

Drinking water

Potable water is safe to drink. It is not pure, because it has some dissolved substances in it.

In the UK, we make it from rain water in lakes, rivers and underground rocks:



- **Filter** it, to remove bits of solid.
- **Sterilise** it, to kill microbes. This uses chlorine, ozone or UV light.

Where there is little fresh water, sea water is made drinkable. This is called **desalination**. It uses distillation or reverse osmosis. Both need a lot of energy.

Top tip

Required practical: test the pH of a water sample, then distil it to make pure water.

Waste water

Sewage has to be treated before it goes back into rivers:

- **Screening:** remove large objects and grit.
- **Sedimentation:** let solids sink to make sludge.
- The sludge is broken down by bacteria without oxygen (**anaerobic digestion**).
- The liquid is cleaned by bacteria with oxygen (**aerobic** treatment).

New ways to get metals

Higher tier only

Copper ores are running out. New methods can get copper from low-grade ores. Phytomining: plants take up copper compounds, then they are burned and the copper is got from the ash. Bioleaching: bacteria make a solution containing copper compounds.

Life cycle assessment

A **life cycle assessment (LCA)** looks at the effect a product has on the environment at every stage:

- 1. Getting the raw materials
- 2. Making it
- 3. Using it
- 4. Getting rid of it

We can reduce our impact by **reducing, reusing and recycling**.

Key words

Finite	Will run out.
Sustainable	Meets our needs without harming future generations.
Potable water	Water that is safe to drink.
Desalination	Removing salt from sea water.
Life cycle assessment	Looking at a product's environmental impact from start to finish.

Checklist: I can...

Tick each box when you feel confident.

- ☐ explain sustainable development
- ☐ describe how drinking water is made
- ☐ describe sewage treatment
- ☐ list the stages of a life cycle assessment

Have a go

Show your working for each one.

1. What does potable water mean?

2. Give the two main steps to make UK fresh water safe.

3. Name the four stages of a life cycle assessment.

4. Higher: What is bioleaching?



Answers

Check your work. Well done for trying!

1. Atoms and the periodic table

1. 2, 8, 2
2. $23 - 11 = 12$
3. **Potassium** (it is lower in Group 1)
4. **Crystallisation**
5. They have a **full outer shell**.

2. Bonding and structure

1. **Ionic**
2. It has **delocalised (free) electrons**.
3. The forces **between the molecules** are weak.
4. **Na₂O**
5. Different sized atoms **stop the layers sliding**.

3. Quantitative chemistry

1. $23 + 35.5 = 58.5$
2. $40 + 12 + (3 \times 16) = 100$
3. $20 \div 0.5 = 40 \text{ g/dm}^3$
4. Oxygen from the air **joins with the metal**.
5. $88 \div 44 = 2 \text{ moles}$

4. Chemical changes

1. 7
2. **Carbon dioxide**
3. **Zinc sulfate**
4. Iron is **less reactive than carbon**.

5. To the **negative electrode** (cathode).

6. *A strong acid fully ionises in water. A weak acid only partly ionises.*

5. Energy changes

1. Temperature fell by 7 °C, so **endothermic**.

2. For example: **hand warmers** or self-heating cans.

3. The **minimum energy** needed for particles to react.

4. $900 - 600 = +300 \text{ kJ/mol}$ (**endothermic**)

6. Rates and equilibrium

1. $100 \div 50 = 2 \text{ cm}^3/\text{s}$

2. Particles move faster, so they **collide more often and with more energy**.

3. It has a **bigger surface area**, so more collisions.

4. It **speeds up** a reaction without being used up, by lowering the activation energy.

5. *It moves in the endothermic direction.*

7. Organic chemistry

1. $(2 \times 6) + 2 = 14$, so **C₆H₁₄**

2. A compound made of **hydrogen and carbon only**.

3. Add **bromine water**. It turns from orange to colourless.

4. It turns long, less useful molecules into **shorter, more useful** ones like petrol and alkenes.

8. Chemical analysis

1. $4 \div 10 = 0.4$

2. Put in a **glowing splint**. It relights.

3. It turns **milky (cloudy)**.

4. It makes **only one spot**.

9. The atmosphere

1. **Nitrogen**

2. Any two from: **carbon dioxide, methane, water vapour**

3. Algae and plants **photosynthesised**.

4. Sulfur dioxide (or nitrogen oxides)

10. Using resources

1. Water that is **safe to drink**.

2. Filter it, then **sterilise** it.

3. Raw materials, making it, using it, getting rid of it

4. Using bacteria to make solutions containing metal compounds.



All the equations

Every equation from this booklet in one place.

Topic	Equation	Units
Atoms and the periodic table	neutrons = mass number – atomic number	
Quantitative chemistry	concentration = mass ÷ volume	concentration in g/dm ³ , mass in g, volume in dm ³
Rates and equilibrium	mean rate = amount of product made ÷ time	e.g. cm ³ /s or g/s
Organic chemistry	hydrocarbon + oxygen → carbon dioxide + water	
Chemical analysis	R_f = distance moved by substance ÷ distance moved by solvent	no units. Always less than 1.