C2: Chemical Resources

1. The structure of the Earth

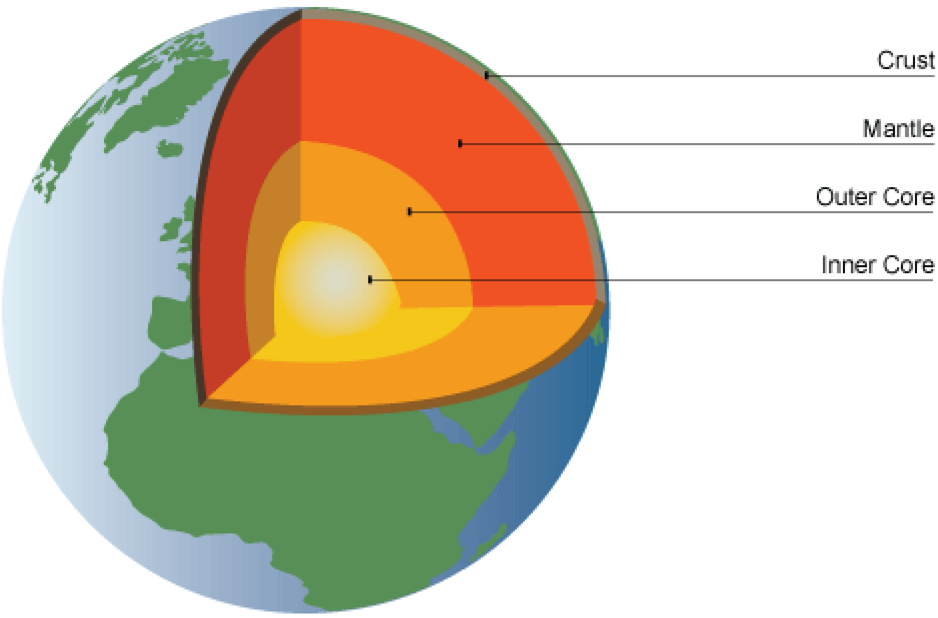
The Earth has a layered structure made up of the core, mantle and crust. The crust and upper part of the mantle is broken into large pieces called tectonic plates. These move slowly over the mantle.

Volcanoes occur when molten rock pushes up through weaknesses in the crust. The molten rock cools and solidifies to form igneous rocks.

The structure of the Earth

The Earth is almost a sphere. These are its main layers, starting with the outermost:

1. **crust** - relatively thin and rocky
2. **mantle** - has the properties of a solid, but can flow very slowly
3. **outer core** - made from liquid nickel and iron
4. **inner core** - made from solid nickel and iron.



Cross section showing structure of the Earth

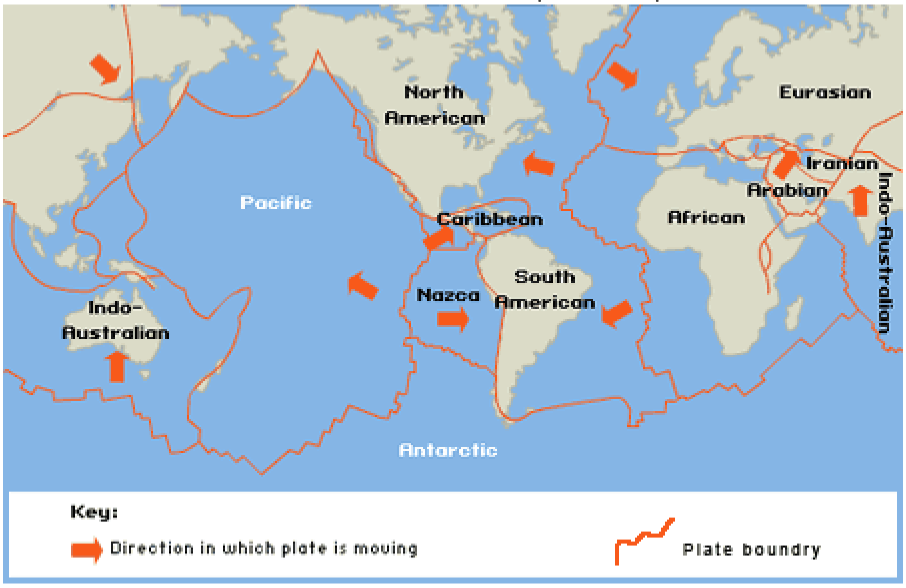
The radius of the core is just over half the radius of the Earth. The core itself consists of a solid inner core and a liquid outer core. It is difficult to study the structure of the Earth because:

- the crust is too thick to drill all the way through
- scientists need to study seismic waves made by earthquakes or man-made explosions.

  - **Plate tectonics**
  - Many theories have been put forward to explain the nature of the Earth's surface. For example, it was thought that mountains formed because the Earth was cooling down, and in

doing so contracted. This was believed to form wrinkles, or mountains, in the Earth’s crust. Today, scientists accept the theory of plate tectonics. It explains a wide range of evidence, and many scientists have tested it and discussed it.

- **Tectonic plates**
- The lithosphere consists of the crust and outer part of the mantle. It is the relatively cold outer part of the Earth’s structure. The lithosphere is broken into large pieces called tectonic plates. These are less dense than the mantle underneath.
- Tectonic plates move very slowly relative to one another, around 2.5 cm per year. Although this doesn't sound like very much, over millions of years the movement allows whole continents to shift thousands of kilometres apart. This process is called continental drift.



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- Plate boundaries
- **Earthquakes and volcanoes**
- Where tectonic plates meet, the Earth's crust becomes unstable as the plates push against each other, or ride under or over each other. Earthquakes and volcanic eruptions happen at the boundaries between plates, and the crust may ‘crumple’ to form mountain ranges.

Volcanoes

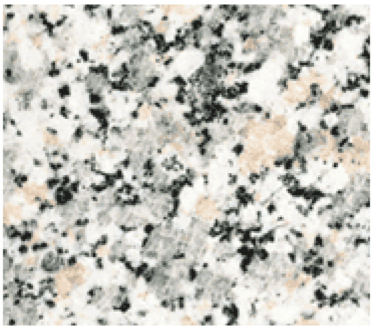
Magma is molten rock under the Earth’s surface. Lava is molten rock that escapes onto the Earth’s surface, for example from a volcanic eruption.

Volcanic eruptions

Volcano

Some eruptions produce runny lava, while others produce thick lava that escapes violently. Geologists study volcanoes to try to predict future eruptions, and to gather information about the Earth's structure. Volcanoes can be very destructive, but some people choose to live near them because volcanic soil is very fertile. It contains minerals needed by plants for healthy growth.

Igneous rocks



Crystals in igneous rock

Igneous rocks are made when molten rock cools down and solidifies. The slower the molten rock cools, the larger the crystals become. For example, gabbro has larger crystals than basalt because the molten rock that formed gabbro cooled more slowly.

Igneous rocks- Higher tier

Different types of igneous rocks form lava (molten rock on the Earth's surface):

- basalt is rich in iron - it formed from runny lava produced in a fairly safe volcanic eruption
- rhyolite is rich in silica - it formed from thick lava produced in an explosive eruption.

Plate tectonics- Higher tier

Alfred Wegener

The theory of plate tectonics and continental drift was proposed at the beginning of the last century by German scientist, Alfred Wegener.

Alfred Wegener (1880 - 1930)

Wegener suggested that mountains were formed when the edge of a drifting continent collided with another, causing it to crumple and fold. For example, the Himalayas were formed when India came into contact with Asia. It took more than 50 years for Wegener's theory to be accepted, beacuse:

- it was difficult to work out how whole continents could move
- it was not until the 1960s that enough evidence was discovered to support the theory fully.

Subduction

The plates move because of convection currents in the semi-rigid mantle. Oceanic crust is denser than continental crust. Where tectonic plates meet, the oceanic plate goes under the continental plate. This is called subduction. The oceanic plate is partially re-melted. Check your understanding of this using the animation below.

2. Construction materials

Granite, limestone and marble are used as construction materials. Cement, which is made from limestone, is used to make concrete. However reinforced concrete has better properties for construction work than concrete alone.

Rocks

The materials used in the construction industry include:

- aluminium and iron - metals obtained from ores
- brick - made from clay
- glass - made from sand
- cement and concrete - made using limestone
- granite, limestone and marble - rocks mined or quarried from the ground.

Granite is much harder than marble, which is much harder than limestone.

Limestone and marble

Limestone and marble are both forms of calcium carbonate, $CaCO_3$. They are important materials, but they need to be obtained through mining or quarrying. The UK's limestone deposits are in areas of great natural beauty, and this creates environmental problems. The table summarises some benefits and drawbacks of quarrying limestone.

Some of the effects of the limestone industry

Benefits	Drawbacks
Limestone is a valuable natural resource that is used to make things such as glass and concrete.	Limestone quarries take up land. They are visible from long distances and may permanently disfigure the local environment.
Limestone quarrying provides employment opportunities that support the local economy in towns near the quarry.	Quarrying is a heavy industry that creates dust, noise and heavy traffic. This has a negative impact on local people's quality of life.

Reactions of calcium carbonate

Limestone and marble are mostly calcium carbonate. This breaks down when heated strongly. The reaction is called thermal decomposition. Here are the equations for the thermal decomposition of calcium carbonate:

$$\text{calcium carbonate} \xrightarrow{\text{heat}} \text{calcium oxide} + \text{carbon dioxide}$$

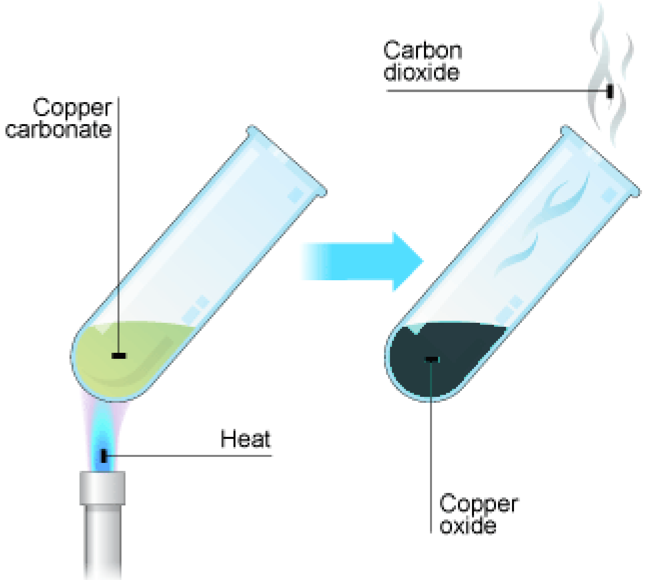
$$CaCO_3 \xrightarrow{\text{heat}} CaO + CO_2$$

Other metal carbonates decompose in the same way. For example, here are the equations for the thermal decomposition of copper(II) carbonate:

$$\text{copper(II) carbonate} \xrightarrow{\text{heat}} \text{copper(II) oxide + carbon dioxide}$$

$$CuCO_3 \xrightarrow{\text{heat}} CuO + CO_2$$

Copper(II) carbonate is often used at school to show thermal decomposition. It is easily decomposed and its colour change, from green copper(II) carbonate to black copper(II) oxide, is easy to see.



The thermal decomposition of copper(II) carbonate is easily demonstrated

Cement and concrete

Cement and concrete are made from limestone,

- cement is made by heating powdered limestone with clay
- concrete is made by mixing cement with sand, water and aggregate (crushed rock).

Chemical reactions happen in the mixtures and eventually they set hard.

Reinforced concrete

Concrete is often reinforced with steel. A steel support is made by joining steel bars or cables together and this is then usually surrounded by a mould. Concrete is poured into the mould, where it fills the gaps in the steel support and sets hard. Reinforced concrete is an example of a **composite material**.

Reinforced concrete- Higher tier

Reinforced concrete is a composite material made from concrete and steel. It is a better construction material than concrete alone because:

- concrete is hard and strong when squashed, but weak when stretched
- steel is flexible and strong when stretched.

The composite material combines the best properties of both materials, so that it is hard and strong when squashed or stretched. This makes it useful for building bridges.

3. Metals and alloys

Copper can be extracted from its ore by heating it with carbon. Impure copper is purified by electrolysis in which the anode is impure copper, the cathode is pure copper and the electrolyte is copper sulphate solution.

An alloy is a mixture of two elements, one of which is a metal. Alloys often have more useful properties than the metals they contain.

Extraction and purification of copper

Copper is less reactive than carbon, so it can be extracted from its ores by heating it with carbon. For example, copper is formed if copper oxide is heated strongly with charcoal, which is mostly carbon:

copper(II) oxide + carbon → copper + carbon dioxide

$2CuO + C \rightarrow 2Cu + CO_2$

Removing oxygen from a substance is called reduction. The copper oxide is reduced to copper in the reaction above.

Electrolysis

Copper is purified by **electrolysis**. Electricity is passed through solutions containing copper compounds, such as copper(II) sulphate. Pure copper forms on the negative electrode.

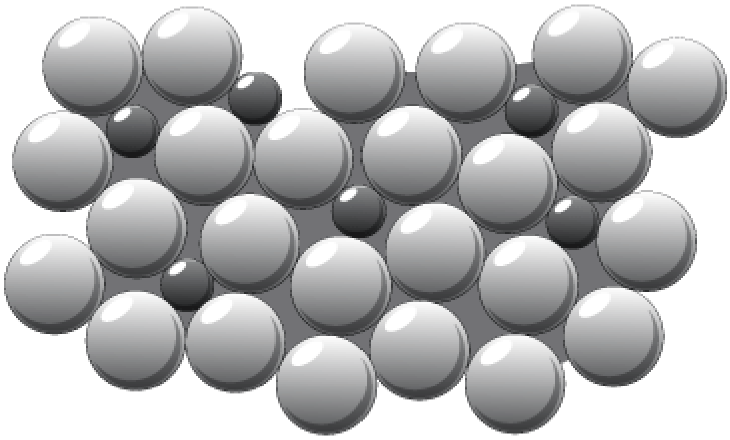
Problems

The world is running out of ores that are rich in copper. The recycling of copper is cheaper, and uses less energy and resources than extracting fresh copper from its ores.

Alloys

An alloy is a mixture of two elements, one of which is a metal. Alloys often have properties that are different to the metals they contain. This makes them more useful than the pure metals alone. For example, alloys are often harder than the metal they contain.

Alloys contain atoms of different sizes, which distorts the regular arrangements of atoms. This makes it more difficult for the layers to slide over each other, so alloys are harder than the pure metal they contain.



It is more difficult for layers of atoms to slide over each other in alloys

The table summarises the compositions and uses of three common alloys.

A summary of three common alloys, the metals they contain, and their typical uses

alloy	main metal(s) in alloy	typical use
amalgam	mercury	dental fillings
brass	copper and zinc	musical instruments, coins, door knockers
solder	lead and tin	joining electrical wires and components

You should be able to explain why a metal is suited to a particular use. You will be given the data you need to help you do this. For example, solder has a low melting point and conducts electricity well. This means it will join electrical wires and components without damaging them.

Copper and alloys- Higher tier

Electrolysis

For the purification of copper it is important that:

- the anode (positive electrode) is made from impure copper
- the cathode (negative electrode) is made from pure copper
- the electrolyte (the solution that conducts electricity) is copper(II) sulfate solution.

During electrolysis, the anode loses mass as copper dissolves, and the cathode gains mass as copper is deposited.

A half-equation shows you what happens at one of the electrodes during electrolysis. Electrons are shown as e–. These are the half-equations:

- anode: $Cu - 2e^- \rightarrow Cu^{2+}$ (oxidation)
- cathode: $Cu^{2+} + 2e^- \rightarrow Cu$ (reduction).

Oxidation happens at the anode because electrons are lost. Reduction happens at the cathode because electrons are gained. Remember OIL RIG: Oxidation Is Loss of electrons, Reduction Is Gain of electrons.

Smart alloys

Smart alloys have unusual properties. Nitinol is an alloy of nickel and titanium, and is known as a shape memory alloy. If nitinol is bent out of shape, it returns to its original shape when it is either heated or an electric current is passed through it. This property makes it useful for making spectacle frames - they return to their original shape if they are put in hot water after they have been bent.

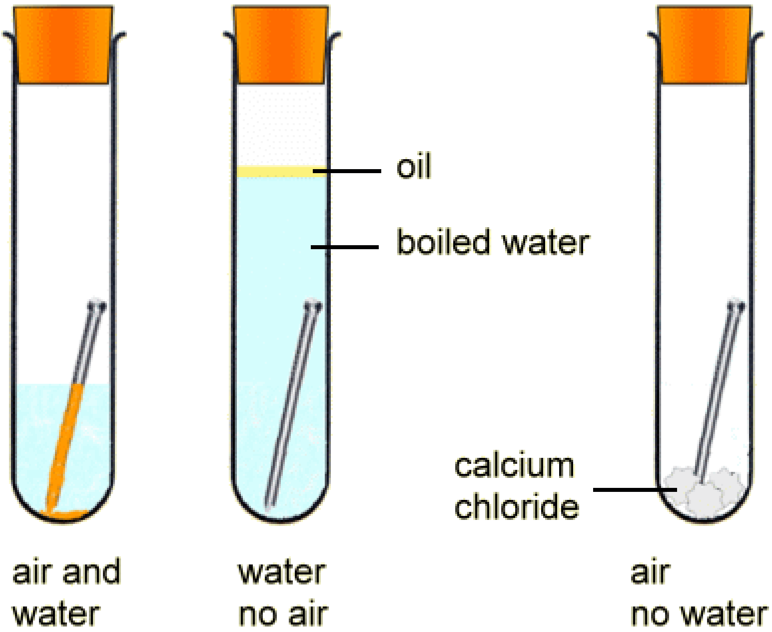
4. Making cars

Iron and steel rust when they come into contact with water and oxygen. They rust faster in salty water or acid rain. Aluminium, on the other hand, does not corrode easily, because its surface is protected by a layer of aluminium oxide.

Steel and aluminium have advantages and disadvantages when used to make cars, which are recycled to re-use valuable materials and cut down on waste.

Rusting

Iron and steel rust when they come into contact with water and oxygen. Both water and oxygen are needed for rusting to occur. In the experiment below, the nail does not rust when air or water is not present. Remember that 21 per cent of the air is oxygen.



Calcium chloride absorbs water in the right-hand test tube

Rusting is an **oxidation** reaction. The iron reacts with water and oxygen to form **hydrated iron(III) oxide**, which we see as rust. This is the word equation for the reaction:

iron + water + oxygen → hydrated iron(III) oxide

Salt dissolved in water does not cause rusting, but it does speed it up, as does acid rain.

Aluminium

Unlike iron and steel, aluminium does not rust or corrode in moist conditions. Its surface is protected by a natural layer of aluminium oxide. This prevents the metal below from coming into contact with air and oxygen.

Block of aluminium metal - image does not show the transparent oxide layer

Car bodies

Most iron is converted into steel (an alloy) before being used. Compared to iron, steel is:

- harder and stronger
- less likely to rust.

Iron versus aluminium

Iron and aluminium are used to build cars. They are both malleable - they can be bent or pressed into shape. The table summarises some differences in their properties.

A summary of the differences between iron and aluminium

property	iron	aluminium
density	high	low
magnetic?	yes	no
corrodes easily?	yes	no

Aluminium has some advantages over steel. Since it has a lower density than iron or steel, a car body made from aluminium will be lighter than the same car body made from steel. This results in improved fuel economy.

Also, aluminium does not corrode easily, so a car body made from aluminium will corrode less than one made from steel. It should last longer as a result.

However, aluminium is more expensive than steel. So a car made from aluminium is likely to be more expensive than one made from steel.

Making cars and recycling them

Cars are complex machines and many different materials are used in their manufacture.

The main materials used in the manufacture of cars

material	typical use	reason for use
steel	body panels and chassis	strong and malleable
copper	electrical wiring	good conductor of electricity
aluminium	body panels and interior fittings	lightweight and rust-proof
glass	windows	transparent
plastics	body panels, lights and dashboard	tough and easily moulded to desired shape
fibres	seats and carpets	good heat insulators, and can be woven into fabrics

Recycling

European Union law requires that at least 85 per cent of a car's materials can be recycled, rising to 95 per cent by 2015. Recycling reduces the amount of waste, and the use of natural resources.

5. Making ammonia

Ammonia is a raw material used in the manufacture of fertilisers, explosives and cleaning fluids. It is produced using a reaction between nitrogen and hydrogen called the Haber process. Production costs are based on different factors, including the price of energy, labour, raw materials, equipment and the rate of reaction.

Ammonia

Ammonia NH_3 is an important raw material in the manufacture of fertilisers. Some ammonia is converted into nitric acid which itself is used in the manufacture of fertilisers and explosives. Ammonia is also a useful ingredient in some cleaning fluids.

An ammonia production plant. Photo courtesy of WMC Resources Ltd

Ammonia is a vital route by which nitrogen in the air can be made available to plants to enable them to build protein molecules. Plants cannot use nitrogen directly from the air. They need nitrogen compounds, dissolved in water, which they absorb through their roots.

Without synthetic, ammonia-based fertilisers, the world would be unable to grow enough food to feed its population.

The Haber process

The raw materials for this process are hydrogen and nitrogen:

- hydrogen is obtained by reacting natural gas with steam, or from cracking oil fractions
- nitrogen is obtained from the air.

Air is 78 per cent nitrogen and nearly all the rest is oxygen. When hydrogen is burned in air, the oxygen combines with the hydrogen, leaving nitrogen behind.

In the Haber process, nitrogen and hydrogen react together under these conditions:

- a high temperature - about 450ºC
- a high pressure
- an iron catalyst.

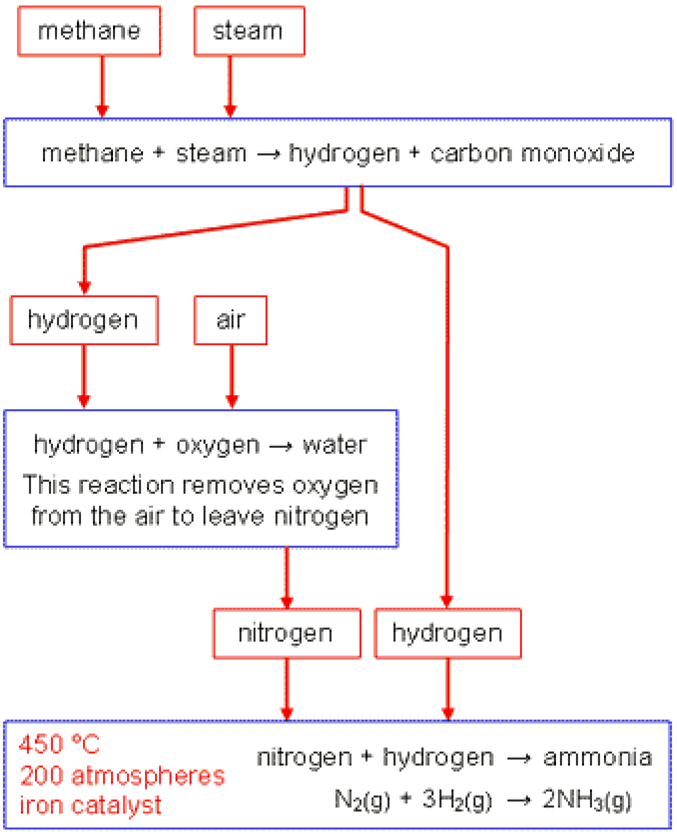
In addition, any unreacted nitrogen and hydrogen are recycled.

The reaction is reversible. In a chemical equation, the symbol $\rightleftharpoons$ is used instead of an ordinary arrow if the reaction is reversion:

nitrogen + hydrogen $\rightleftharpoons$ ammonia

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

The flow chart shows the main stages in the Haber process.



The Haber process for making ammonia

Manufacturing costs

Different factors affect the cost of making a new substance.

Factors that increase cost include:

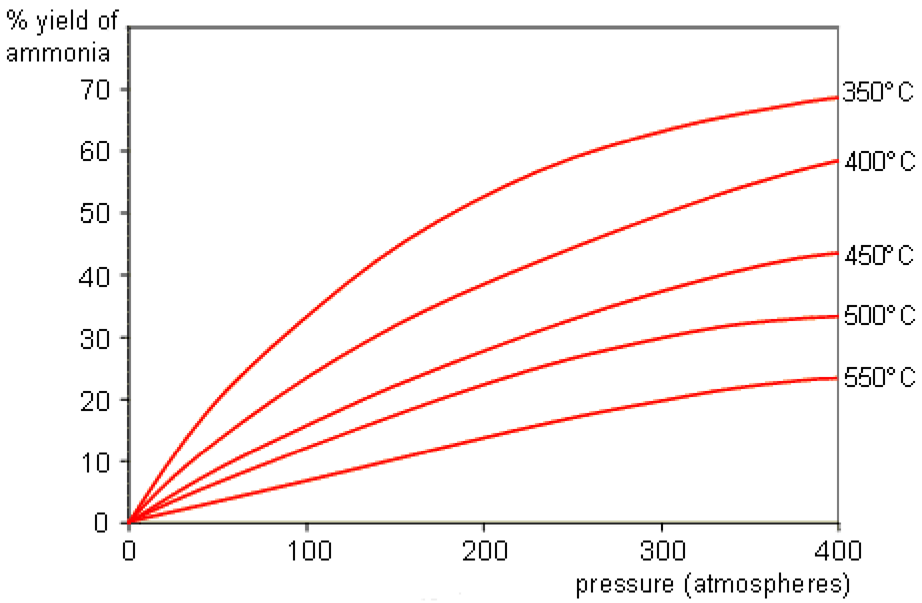
- high pressures (they increase the cost of the equipment)
- high temperatures (they increase the energy costs).

Factors that decrease

- catalysts (they increase the rate of reaction)
- recycling unreacted starting materials
- automating equipment (because fewer people need to be employed, cutting the wage bill).

Interpreting data

You should be able to interpret data (in tables or graphs) about the yield of product in reversible reactions like the Haber process. The percentage yield is the mass of product that is actually made, compared to the total possible mass of product.



Look at the graph. You can see that for any given temperature the yield of ammonia increases as the pressure increases. You can also see that, for any given pressure, the yield goes down as the temperature increases.

The Haber process - Higher tier

The pressure chosen for the Haber process is a compromise. A high pressure increases the percentage yield of ammonia but very high pressures are expensive.

The temperature chosen is also a compromise. A high temperature gives a fast reaction but decreases the percentage yield of ammonia. 450°C gives a reasonably fast reaction with a sufficiently high percentage yield of ammonia.

The use of an iron catalyst increases the rate of the reaction, but it does not alter the percentage yield of ammonia.

Economic considerations

When a chemical is manufactured, the optimum conditions used are the ones that give the lowest cost. These conditions are not necessarily the ones that give the fastest reaction or highest percentage yield. For example:

- the rate of reaction must be high enough to make enough product each day
- the percentage yield must be high enough to make enough product each day.
  Note that a low percentage yield could be accepted if unreacted started materials can be recycled (as they are in the Haber process).

6. Acids and bases

Bases are substances that can react with acids and neutralise them. Alkalis are bases that are soluble in water. The pH scale measures how acidic or alkaline a substance is. Substances with a pH lower than 7 are acidic, those with a pH of 7 are neutral and those with a pH greater than 7 are alkaline.

Acids and alkalis

The pH scale

The chemical properties of many solutions enable them to be divided into three categories - **acids, alkalis and neutral solutions**. The strength of the acidity or alkalinity is expressed by the **pH scale**.

- solutions with a pH less than 7 are **acidic**
- solutions with a pH of 7 are **neutral**
- solutions with a pH greater than 7 are **alkaline**.

If **universal indicator** is added to a solution it changes to a colour that shows the pH of the solution.

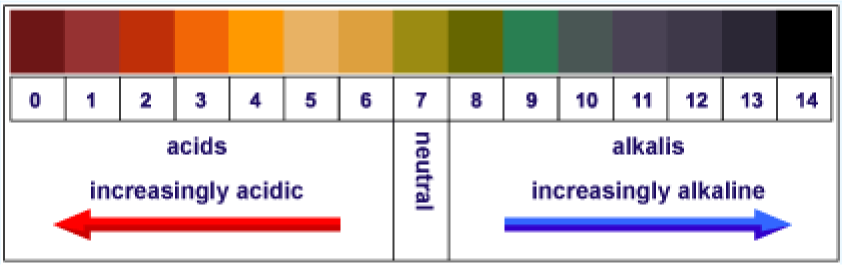


Diagram of pH scale and universal indicator colours

These are some examples of common substances and their pH values.

The pH scale

	pH	example substance
strong acidic	0	battery acid
	1	stomach acid
	2	lemon juice
	3	vinegar
	4	acid rain
	5	black coffee
	6	saliva

	pH	example substance
neutral	7	pure water
	8	sea water
	9	baking powder
	10	milk of magnesia
	11	ammonia
	12	soapy water
	13	bleach
strongly alkaline	14	drain cleaner

Bases and acids

Bases are substances that can react with acids and neutralise them. Bases such as metal oxides and metal hydroxides react with acids to form neutral products.

Examples of bases include:

- copper(II) oxide
- zinc hydroxide.

An alkali is a soluble base, a base that can dissolve in water. For example, copper(II) oxide is a base because it can neutralise acids but, because it does not dissolve in water, it is not an alkali.

Examples of alkalis include:

- sodium hydroxide
- potassium hydroxide.

All alkalis are bases.

Neutralisation

When an alkali is added to an acid the pH of the mixture rises. This is because the alkali reacts with the acid to form neutral products. The reverse situation also happens too: when an acid is added to an alkali the pH of the mixture falls. This is because the acid reacts with the alkali to form neutral products.

A reaction in which acidity or alkalinity is removed is called neutralisation. A neutralisation involving an acid and a base (or alkali) always produces salt and water.

acid + base → salt + water

Hydrogen ions and pH

In all solution, all acids contain hydrogen ions, H^+. The greater the concentration of these hydrogen ions, the lower the pH.

Naming salts

The name of the salt produced in a neutralisation reaction can be predicted. The first part of the name is 'ammonium' if the base used is ammonia. Otherwise, it is the name of the metal in the base. The second part of the name comes from the acid used:

- chloride, if hydrochloric acid is used
- nitrate, if nitric acid is used
- sulfate, if sulfuric acid is used
- phosphate, if phosphoric acid is used.

The table shows some examples.

Examples

acid	+	base	→	salt + water
hydrochloric acid	+	copper oxide	→	copper chloride + water
sulfuric acid	+	sodium hydroxide	→	sodium sulfate + water
nitric acid	+	calcium hydroxide	→	calcium nitrate + water
phosphoric acid	+	iron(III) oxide	→	iron(III) phosphate + water

Carbonates and acids

Carbonates also neutralise acids. As well as a salt and water, **carbon dioxide** is also produced. The name of the salt can be predicted in just the same way.

For example:

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

Neutralisation equations- Higher tier

Ions in solution

- acids in solution contain hydrogen ions, H^+.
- alkalis in solution contain hydroxide ions, OH^-.

Neutralisation can be written as an **ionic equation**:

$$H^+ + OH^- \rightleftharpoons H_2O$$

Neuralisation equations

You need to be able to write balanced symbol equations for neutralisation reactions between acids and bases, and between acids and carbonates. The equations will involve these acids:

- hydrochloric acid, HCl
- nitric acid, HNO_3
- sulfuric acid, H_2SO_4.

The equations will involve these bases:

- ammonia, NH_3- in solution, this is NH_4OH
- potassium hydroxide, KOH
- sodium hydroxide, NaOH
- copper(II) oxide, CuO.

They will involve these carbonates:

- sodium carbonate, Na_2CO_3
- calcium carbonate, $CaCO_3$.

For example:

sulfuric acid + potassium hydroxide → potassium sulfate + water

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

nitric acid + calcium carbonate → calcium nitrate + water + carbon dioxide

$2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

hydrochloric acid + ammonium hydroxide → ammonium chloride + water

$HCl + NH_4OH \rightarrow NH_4Cl + H_2$

7. **Fertilisers and crop yields**

Fertilisers contain minerals such as nitrogen, potassium and phosphorus, which help plants to grow. Fertilisers increase crop yields but cause the problem of *eutrophication* when they're washed into rivers and lakes by rainwater. Most chemical fertilisers are made by the reaction of an acid with an alkali.

Fertilisers

Fertilisers make crops grow faster and bigger so that crop yields are increased. They are water-soluble minerals. They must be able to dissolve in water so that plants can absorb them through their roots.

Fertilisers provide plants with the essential chemical elements needed for growth particularly nitrogen, phosphorus and potassium.

Ammonia is used in fertilisers for crops

The name or formula of a compound often suggests which elements are provided by a particular fertiliser. The table shows some examples.

Examples of fertilisers, their formula and the essential elements

fertiliser	formula	essential elements
ammonium nitrate	NH_4NO_3	nitrogen
ammonium sulfate	$(NH_4)_2SO_4$	nitrogen
ammonium phosphate	$(NH_4)_3PO_4$	nitrogen and phosphorus
potassium nitrate	KNO_3	potassium and nitrogen
urea	$(NH_2)_2CO$	nitrogen

Fertiliser problems

The world population is increasing all the time, so more food has to be produced. Without fertilisers the yields of crops would be reduced. However, if too much fertiliser is used it can pollute water supplies. It may also lead to eutrophication, a situation where there is not enough oxygen dissolved in the water for aquatic organisms to survive.

Making fertilisers

Most fertilisers are made by the **reaction** of an **acid** and an **alkali**.The table shows some examples.

fertiliser	acid	alkali
ammonium nitrate	nitric acid	ammonia
ammonium phosphate	phosphoric acid	ammonia
ammonium sulfate	sulfuric acid	ammonia
potassium nitrate	nitric acid	potassium hydroxide

Making a fertiliser in the lab

The preparation of a fertiliser in a lab involves the following equipment:

- a **measuring cylinder** to measure a particular volume of an alkali solution
- a burette to add acid a little at a time until the alkali has been neutralised
- a filter funnel to remove solid crystals of fertiliser after evaporating some of the water from the neutral fertiliser solution.

You should be able to predict the name of the acid and the alkali needed to make a given fertiliser. For example, to make ammonium nitrate you should be able to predict that nitric acid and ammonia will be needed. Check the **revision bite about neutralisation and naming salts** if you are unsure.

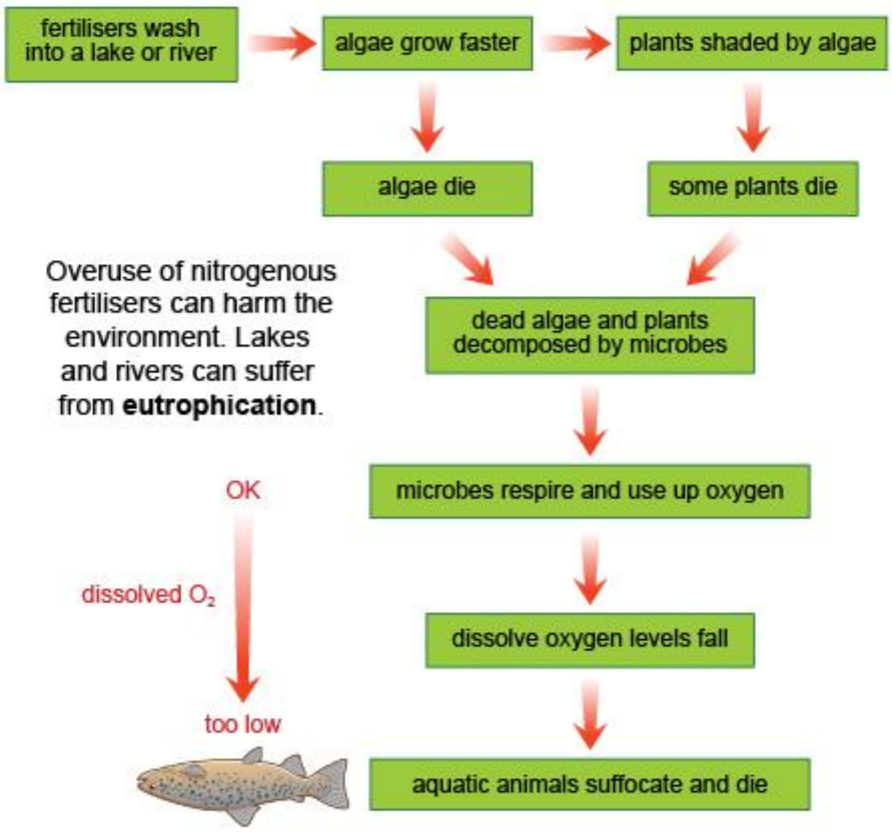
Fertilisers- Higher tier

How fertilisers work

Fertilisers increase crop production by replacing essential elements used by a previous crop or by boosting levels of such elements. Nitrogen in particluar is needed to build plant proteins, increasing growth.

Eutrophication

A major problem with the use of fertilisers occurs when they are washed off the land by rainwater into rivers and lakes. The increase of nitrate or phosphate in the water encourages the growth of algae. The algae form a bloom over the water surface. This prevents sunlight reaching other water plants, which then die. Bacteria break down the dead plants and as they respire these bacteria use up the oxygen in the water causing most other living organisms to die.



Nitrates or phosphates from fertilisers can cause eutrophication in water

Preparation of a fertiliser

Synthetic fertilisers are prepared in the lab by the reaction of an acid with an alkali. A quantity of alkali is placed in a beaker and a solution of acid is run in until the solution is neutral. This can be measured with a pH meter or by removing samples for testing with universal indicator.

The neutral solution of salt is evaporated until crystals form. These are filtered out, washed and dried in a warm oven.

8. The chemistry of sodium chloride

Sodium chloride, common salt, is a useful raw material. Several useful substances can be obtained from it, including chlorine, hydrogen and sodium hydroxide.

Obtaining sodium chloride

Common salt is sodium chloride, NaCl. It can be made in a laboratory by the reaction of sodium with chlorine. However, it is found naturally in large amounts in sea water or in underground deposits. It is often obtained either by evaporating sea water or by mining underground deposits.

Mining

Salt can be mined as rock salt which is used to treat icy roads in the winter. It lowers the melting point of the ice on the roads so that it melts, even when the temperature is below 0ºC.

Salt can also be mined by solution mining. This happens in Cheshire in the North West of England. Water is pumped underground and into the salt deposit. Salt dissolves in the water, forming a concentrated salt solution. This is then pumped up to the surface ready for use by the chemical industry. Solution mining is a continuous process that is safer than sending miners underground.

Mining for salt can lead to subsidence. This happens when insufficient salt is left underground after mining. The weight of the ground above causes the ground to sink downwards and this subsidence can damage buildings and roads.

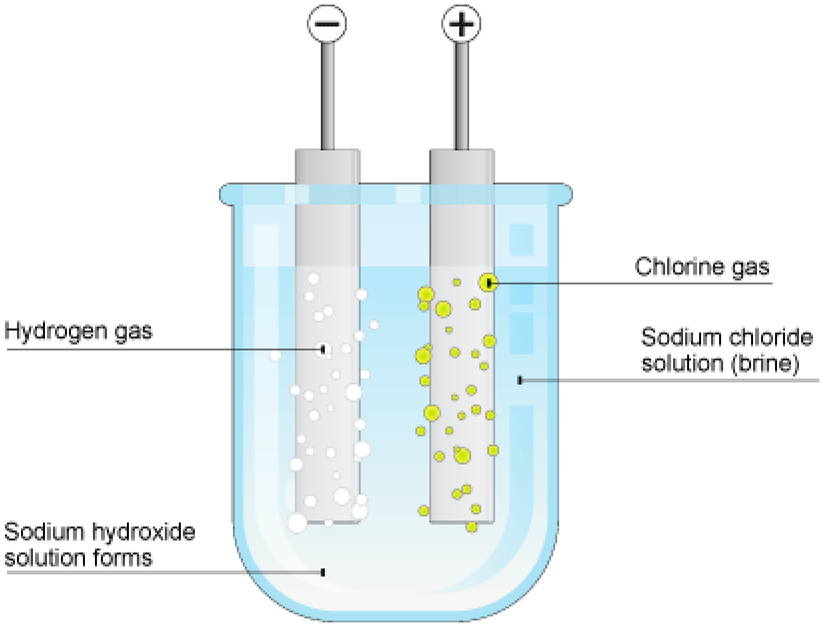
Uses of sodium chloride

Salt is widely used in the food industry as a preservative and flavour enhancer. While too much salt in our diet is bad for us, a certain amount is vital for human health.

Sodium chloride is the raw material for the manufacture of hydrogen, chlorine and sodium hydroxide by electrolysis. This is an important industrial process because these substances have many uses.

Electrolysis

Useful substances can be obtained by the electrolysis of sodium chloride solution.



Electrolysis of sodium chloride solution

During electrolysis:

- chlorine gas forms at the anode (positive electrode)
- hydrogen gas forms at the cathode (negative electrode)
- a solution of sodium hydroxide forms.

These products are reactive, so it is important to use inert (unreactive) materials for the electrodes.

Electrolysis- Higher tier

A half-equation shows you what happens at one of the electrodes during electrolysis. Electrons are shown as e^-. These are the half-equations:

- anode: $2Cl^- – 2e^- \rightarrow Cl2$ (oxidation)
- cathode: $2H^+ + 2e^- \rightarrow H2$ (reduction).

Oxidation happens at the anode because electrons are lost. Reduction happens at the cathode because electrons are gained. Remember OIL RIG: Oxidation Is Loss of electrons, Reduction Is Gain of electrons.

Sodium ions Na^+ and hydroxide OH^- are also present in the sodium chloride solution. They are not discharged at the electrodes. Instead, they make sodium hydroxide solution.

Products from sodium chloride

The products of the electrolysis of sodium chloride solution have important uses in the chemical industry.

Hydrogen

Hydrogen is used in the manufacture of ammonia and margarine (it is used to harden vegetable oils).

Chlorine

Chlorine is used to:

- kill bacteria in drinking water and swimming pool water
- make solvents
- make plastics such as polyvinyl chloride (PVC)
- make household bleach.

Sodium hydroxide

Sodium hydroxide is used to make soap and household bleach.

Bleach

Household bleach, sodium chlorate, is made when sodium hydroxide and chlorine react together:

sodium hydroxide + chlorine → sodium chloride + water + sodium chlorate

$2NaOH + Cl_2 \rightarrow NaCl + H_2O + NaClO$

Household bleach is used to clean and disinfect toilets, drains and kitchen surfaces.