

AQA GCSE Chemistry — Chemistry

Topic 10

Using resources

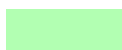
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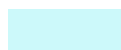
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Finite resource

- a resource being used up faster than it is replaced, so supplies will run out.

Define Sustainable development

- development that meets the needs of current generations without compromising the ability of future generations to meet their own needs.

Define Desalination

- removing dissolved salts from salty or sea water, by distillation or membranes.

HIGHER TIER

Define Phytomining HT ONLY

- using plants to absorb metal compounds; they are harvested and burned to give an ash containing metal compounds.

Define Life cycle assessment (LCA)

- an assessment of a product's environmental impact across raw materials, manufacture, use and disposal.

Define Sacrificial protection CHEMISTRY ONLY

- protecting a metal with a more reactive metal that corrodes instead of it.

Define Composite CHEMISTRY ONLY

- a matrix or binder surrounding and binding together fibres or fragments of a reinforcement.

Define Thermosetting polymer CHEMISTRY ONLY

- chains joined by cross-links; does not melt when heated.

Define Renewable resource

- a resource replaced at the same rate as, or faster than, it is used.

Define Potable water

- water safe to drink, with sufficiently low levels of dissolved salts and microbes.

Define Sterilisation

- killing microbes in water using chlorine, ozone or ultraviolet light.

Define Effluent

- the liquid left above the sludge after sedimentation of sewage.

HIGHER TIER

Define Bioleaching HT ONLY

- using bacteria to produce leachate solutions containing metal compounds.

Define Corrosion CHEMISTRY ONLY

- the destruction of materials by chemical reactions with substances in the environment.

Define Alloy CHEMISTRY ONLY

- a mixture of a metal with one or more other elements.

Define Thermosoftening polymer CHEMISTRY ONLY

- separate tangled chains; melts when heated.

Define Haber process CHEMISTRY ONLY

- the manufacture of ammonia from nitrogen and hydrogen over an iron catalyst.

Define NPK fertiliser CHEMISTRY ONLY

- a formulation of salts containing appropriate percentages of nitrogen, phosphorus and potassium.

10.1 Using the Earth's resources and obtaining potable water

10.1.1 Using the Earth's resources and sustainable development

Humans use the Earth's resources for warmth, shelter, food and transport. **Natural resources**, supplemented by agriculture, provide food, timber, clothing and fuels, and **finite resources** from the Earth, oceans and atmosphere are processed to provide energy and materials.

Chemistry improves agricultural and industrial processes and contributes to **sustainable development** — development that meets the needs of current generations without compromising the ability of future generations to meet their own needs.

Natural products supplemented or replaced by agricultural and synthetic products: natural rubber by synthetic rubber; cotton and wool by nylon and polyester; wood as a fuel by fossil fuels; wild-caught food by farmed crops.

Finite or renewable? Ask: *is it replaced as fast as we take it?*

- **Finite** — crude oil, natural gas, coal, metal ores, limestone: formed over millions of years, used far faster than replaced.
- **Renewable** — timber, cotton, wool, biofuels, fresh water from rainfall: replaced within a human lifetime if managed.

ANALOGY

Finite resources are a savings account with no income paid in — every withdrawal shrinks the balance and it never refills.

Renewable resources are a monthly wage: you can spend from it forever, but only if you spend no faster than it arrives.

10.1.2 Potable water

Water of appropriate quality is essential for life. For humans, drinking water should have sufficiently low levels of dissolved salts and microbes. Water safe to drink is **potable water**.

WATCH OUT

Potable water is not pure water in the chemical sense. Pure water contains only H_2O ; potable water still contains dissolved substances — just few enough to be safe.

The methods used depend on the available supplies of water and local conditions. In the **UK**, rain provides water with low levels of dissolved substances (**fresh water**) that collects in the ground and in lakes and rivers; most potable water is produced as below.

Step	What happens	Why
Choose an appropriate source of fresh water	Water low in dissolved substances	Less treatment needed, so cheaper
Pass through filter beds	Water passes through sand and gravel	Removes insoluble solids
Sterilise	Chlorine , ozone or ultraviolet light	Kills microbes, so it does not cause disease

Desalination. If supplies of fresh water are limited, desalination of salty or sea water may be required:

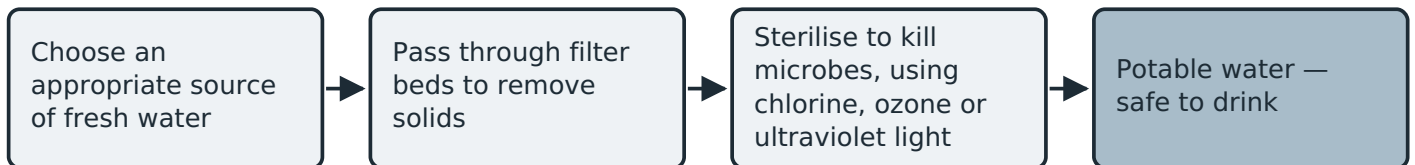
- **distillation** — boil the water and condense the steam, leaving the salts behind
- **membrane processes such as reverse osmosis** — water is forced at high pressure through a membrane that holds back dissolved ions.

Both **require large amounts of energy**, so they are expensive. Sea water is therefore not used routinely in the UK: fresh water is plentiful, and filtering plus sterilising it needs far less energy than removing dissolved salts.

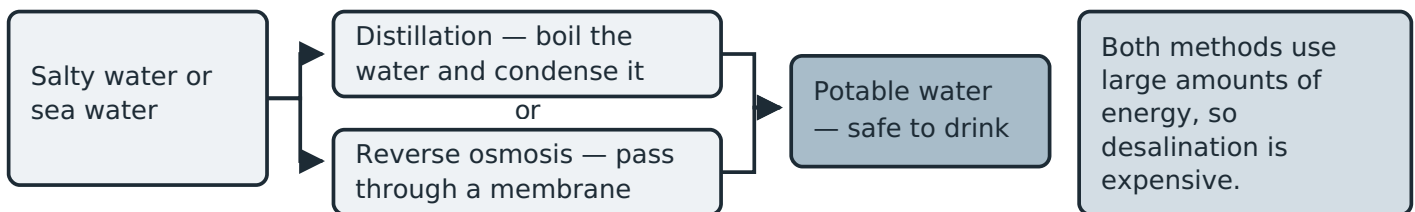
Relative ease of obtaining potable water: ground/fresh water is easiest (filter and sterilise only); **waste water** is harder (organic matter, harmful microbes and sometimes harmful chemicals must be removed); **salt water** is hardest (large amounts of energy).

Producing potable water: fresh water treatment and desalination

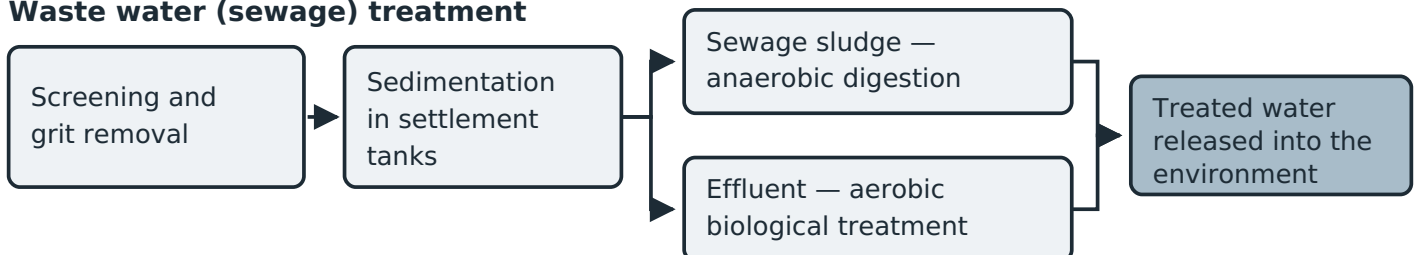
Potable water from fresh water (ground water, lakes and rivers)



Potable water from salty water or sea water — desalination



Waste water (sewage) treatment



Potable water is not pure water in the chemical sense — it still contains dissolved substances.

Ease of obtaining potable water: fresh water is easiest, then waste water; salty water is hardest because desalination needs the most energy.

10.1.3 Waste water treatment

Urban lifestyles and industrial processes produce large amounts of waste water requiring treatment before release into the environment. Sewage and agricultural waste water require removal of organic matter and harmful microbes; **industrial waste water** may require removal of organic matter and harmful chemicals.

10.1.4 Alternative methods of extracting metals HT ONLY

The Earth's resources of metal ores are limited and copper ores are becoming scarce, so new ways of extracting copper from **low-grade ores** have been developed. These avoid traditional mining methods of digging, moving and disposing of large amounts of rock.

- **Phytomining** — plants absorb metal compounds; the plants are harvested and burned to produce **ash containing metal compounds**.
- **Bioleaching** — bacteria produce **leachate solutions containing metal compounds**.

The metal compounds are then processed to obtain the metal: copper is obtained from solutions of copper compounds by **displacement using scrap iron** or by **electrolysis**.

Evaluating these methods. Advantages: far less rock dug, moved and dumped, so less landscape damage and waste; they work on ores too poor for traditional extraction. Disadvantages: both are slow; bioleaching can produce toxic substances.

Stage of sewage treatment	What happens
Screening and grit removal	Large solids and grit are physically removed
Sedimentation	Solids settle as sewage sludge ; liquid effluent stays above
Anaerobic digestion of sludge	Microorganisms break it down without oxygen , giving biogas to burn for energy and a solid usable as fertiliser
Aerobic biological treatment of effluent	Air is pumped through so aerobic bacteria multiply and break down remaining organic matter and microbes

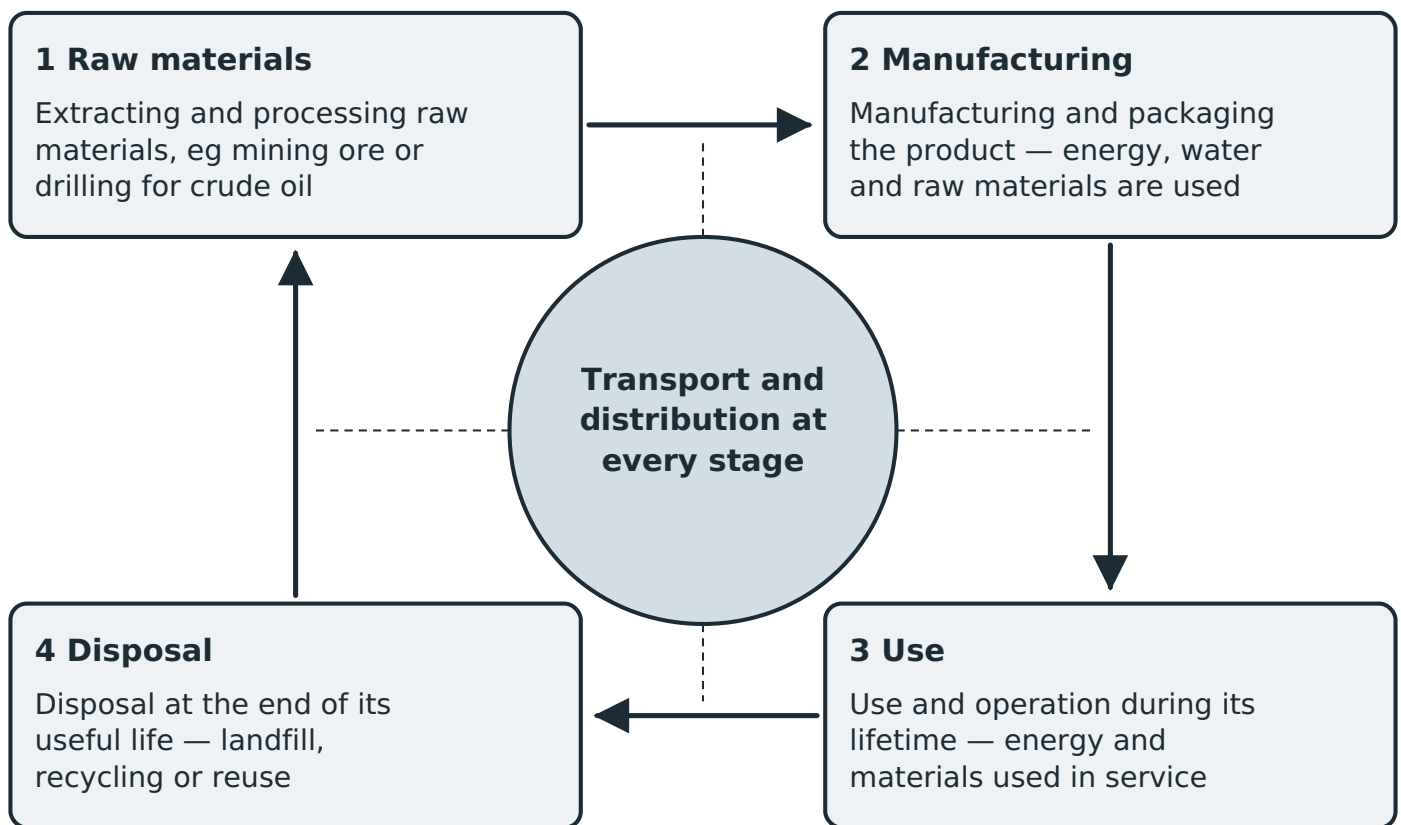
10.2 Life cycle assessment and recycling

10.2.1 Life cycle assessment

Life cycle assessments (LCAs) assess a product's **environmental impact** in four stages. Transport and distribution must be included at every stage.

Stage	What is assessed
Extracting and processing raw materials	Finite resources and energy used; land damage from mining and quarrying
Manufacturing and packaging	Energy and water used; wastes; packaging
Use and operation during its lifetime	Energy or fuel used; how long it lasts
Disposal at the end of its useful life	Landfill space; recyclability; pollution from incineration

The four stages of a life cycle assessment



Use of water, resources, energy sources and production of some wastes can be quantified fairly easily. Allocating numerical values to pollutant effects requires value judgements, so an LCA is not a purely objective process.
Selective or abbreviated LCAs can be misused, eg for advertising claims.

How objective is an LCA?

- Use of water, resources, energy sources and production of some wastes can be **fairly easily quantified**.
- Allocating numerical values to **pollutant effects** is less straightforward and requires value judgements, so LCA is not a purely objective process.
- Selective or abbreviated LCAs can be devised, but can be misused to reach pre-determined conclusions, eg for advertising claims.

	Plastic bag	Paper bag
Raw material	Crude oil (finite)	Timber (renewable)
Energy per bag / kJ	210	900
Water per bag / dm ³	1	20
Number of uses	4	1
Disposal	Not biodegradable	Biodegradable, recyclable

10.2.2 Ways of reducing the use of resources

Reduction in use, reuse and recycling by end users reduces the use of limited resources, use of energy sources, waste and environmental impacts.

- Metals, glass, building materials, clay ceramics and most plastics come from **limited raw materials**, and much of the **energy** used also comes from limited resources.
- Obtaining raw materials by quarrying and mining causes environmental impacts.
- **Reuse: glass bottles** can be reused, or crushed and melted to make different glass products.
- **Recycling:** products that cannot be reused are recycled for a different use. **Metals** are recycled by melting and recasting or reforming.
- The amount of separation needed depends on the material and the properties required of the final product — eg some scrap steel can be added to iron from a blast furnace, reducing the iron that must be extracted from ore.

10.3 Using materials CHEMISTRY ONLY

10.3.1 Corrosion and its prevention CHEMISTRY ONLY

Corrosion is the destruction of materials by chemical reactions with substances in the environment; **rusting** of iron is an example. Both air and water are necessary for iron to rust.

Barrier methods keep out air and water: greasing, painting or electroplating. **Aluminium** has an oxide coating that protects the metal from further corrosion.

Sacrificial protection. Some coatings are reactive and contain a **more reactive metal**, eg zinc is used to galvanise iron. Zinc is more reactive than iron, so it corrodes in preference to the iron. This still works if the coating is scratched, because the protection is chemical, not just a barrier.

ANALOGY

Paint is a locked door — strong until someone scratches a hole in it. Zinc is a bodyguard who keeps working after the door is broken, reacting instead of the iron — but only until the bodyguard is used up, which is why sacrificial blocks on ships must be replaced.

10.3.2 Alloys as useful materials CHEMISTRY ONLY

Most metals in everyday use are alloys. Different-sized atoms distort the layers so they cannot slide easily, making alloys harder than the pure metal.

Alloy	Made from	Property	Use
Bronze	Copper + tin	Hard, corrosion resistant	Statues, bells
Brass	Copper + zinc	Harder than copper, workable	Taps, door fittings, instruments
Gold jewellery	Gold + silver, copper, zinc	Harder than pure gold	Jewellery
High carbon steel	Iron + more carbon	Strong but brittle	Cutting tools
Low carbon steel	Iron + less carbon	Softer, more easily shaped	Car bodies
Stainless steel	Iron + chromium and nickel	Hard, corrosion resistant	Cutlery, pans
Aluminium alloys	Aluminium + other metals	Low density	Aircraft bodies

Carats. The proportion of gold in the alloy is measured in carats: 24 carat is 100% (pure gold) and 18 carat is 75% gold.

10.3.3 Ceramics, polymers and composites **CHEMISTRY ONLY**

Glass. Most glass is **soda-lime glass**, made by heating a mixture of sand, sodium carbonate and limestone. **Borosilicate glass**, made from sand and boron trioxide, melts at higher temperatures — hence its use for laboratory glassware.

Clay ceramics, including pottery and bricks, are made by shaping wet clay and then heating it in a furnace.

Polymers. Properties depend on which monomers they are made from and the conditions under which they are made. **LD** and **HD poly(ethene)** are both made from **ethene**:

- **LD poly(ethene)** — made at high temperature and very high pressure with a trace of oxygen; branched chains pack loosely, giving a flexible, low density polymer (carrier bags).
- **HD poly(ethene)** — made at a lower temperature and pressure with a catalyst; straighter chains pack closely, giving a rigid polymer with a higher melting point (water tanks, drainpipes).

	Thermosoftening	Thermosetting
Structure	Separate tangled chains, weak intermolecular forces between them	Chains joined by strong cross-links
On heating	Melts — chains slide apart	Does not melt — cross-links hold chains in place
Remouldable?	Yes, repeatedly	No; it chars
Use	Bottles, carrier bags	Plug casings, saucepan handles

ANALOGY

A thermosoftening polymer is cold spaghetti: tangled but separate strands, so warming lets them slide past each other and flow. A thermosetting polymer is the same spaghetti with every strand knotted to its neighbours — heat it all you like, the cross-links stop it flowing.

Composites. Most composites are made of two materials: a matrix or binder surrounding and binding together fibres or fragments of the **reinforcement**. Examples: reinforced concrete, fibreglass, carbon fibre, wood.

Given data, compare the properties of glass and clay ceramics, polymers, composites and metals quantitatively, and match properties to the job — low density for aircraft, corrosion resistance for a sink, flexibility for a bag.

10.4 The Haber process and the use of NPK fertilisers CHEMISTRY ONLY

10.4.1 The Haber process CHEMISTRY ONLY

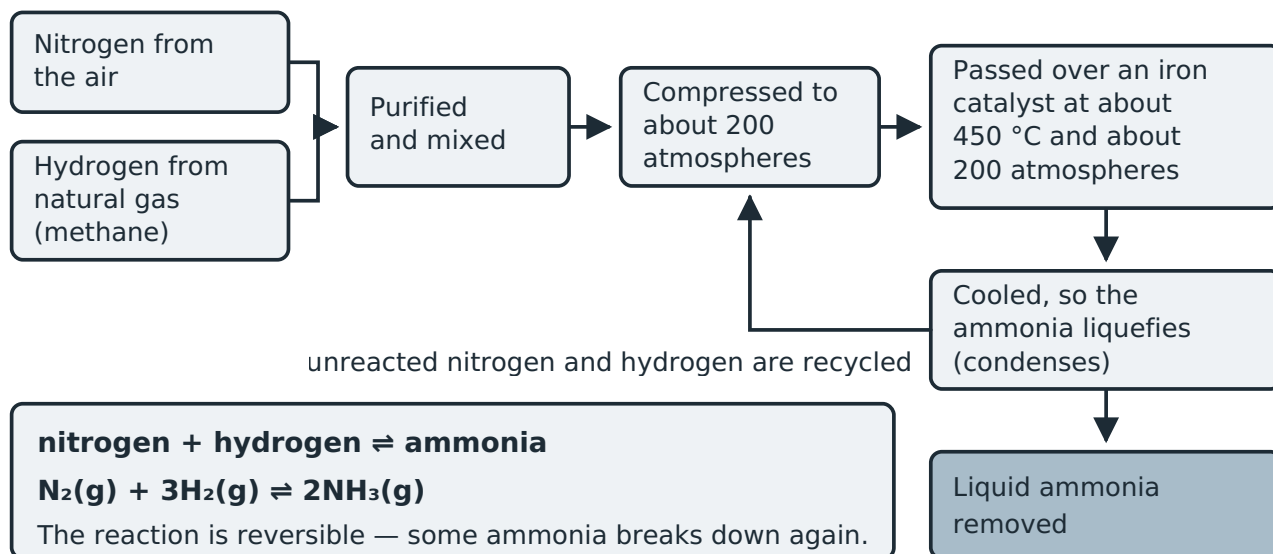
The **Haber process** manufactures **ammonia**, used to make **nitrogen-based fertilisers**. The raw materials are nitrogen and hydrogen: nitrogen from the air, hydrogen from natural gas (methane).

The purified gases are passed over a **catalyst of iron** at **about 450 °C** and **about 200 atmospheres**. Some reacts to form ammonia; the reaction is **reversible**, so some ammonia breaks back down. On cooling, the ammonia liquefies and is removed; the remaining hydrogen and nitrogen are recycled.

Condition	Value	Reason
Temperature	about 450 °C	The forward reaction is exothermic, so a lower temperature gives a higher yield but far too slow a rate. A compromise : lower yield, obtained quickly
Pressure	about 200 atm	Fewer gas molecules on the product side (4 → 2), so high pressure raises both yield and rate. Higher pressures are not used: vessels would be too expensive and dangerous and pumping costs too much energy
Catalyst	iron	Increases the rate , so equilibrium is reached sooner; does not change the yield
Recycling unreacted gases	N ₂ and H ₂ returned	The reaction never goes to completion, so recycling stops waste
Removing ammonia	cooled until it liquefies	Removing the product shifts the equilibrium right, making more ammonia

CHEMISTRY ONLY The Haber process: conditions, recycling and removal of ammonia

chemistry only



Condition	Why it is a compromise
About 450 °C	The forward reaction is exothermic, so a lower temperature would give a higher yield of ammonia — but the reaction would be too slow. 450 °C is a compromise between rate of production and yield.
About 200 atm	High pressure moves the equilibrium to the right (4 molecules of gas → 2) and increases the rate, but very high pressures need strong, expensive equipment and are dangerous — 200 atm is a compromise with cost and safety.
Iron catalyst	Speeds up the reaction so equilibrium is reached sooner. It does not change the position of equilibrium, so it does not change the yield.

ANALOGY

The Haber compromise is like taking a cake out of the oven early. A cool oven would give the perfect cake (high yield) but you would wait all day. 450 °C is the baker's choice — hot enough to get plenty of cakes out per day, accepting each is imperfect, and putting whatever did not cook back in (the recycling step).

Pressure	200 °C	450 °C	600 °C
50 atm	74%	25%	5%
200 atm	90%	42%	13%
800 atm	98%	70%	31%

WATCH OUT

The catalyst does not increase the yield. It speeds the forward and reverse reactions equally, so equilibrium is reached sooner, at the same position.

HIGHER TIER

HT ONLY You should also interpret graphs of reaction conditions versus rate and apply dynamic equilibrium to the Haber process: forward and reverse reactions occur at the same rate and concentrations stay constant.

10.4.2 Production and uses of NPK fertilisers **CHEMISTRY ONLY**

Compounds of nitrogen, phosphorus and potassium are used as fertilisers to **improve agricultural productivity**, and NPK fertilisers contain compounds of all three elements. **Industrial production** uses a variety of raw materials in several integrated processes; NPK fertilisers are **formulations** of various salts containing **appropriate percentages** of the three elements.

- **Nitrogen** — ammonia from the Haber process makes **ammonium salts** and **nitric acid**; ammonia neutralised by nitric acid gives ammonium nitrate.
- **Potassium** — **potassium chloride** and **potassium sulfate** are mined and used directly.
- **Phosphorus** — **phosphate rock** is mined but cannot be used directly as a fertiliser because it is insoluble, so it is treated with acid.

Industrial production compared with laboratory preparation of the same compound (eg ammonium sulfate by titration):

	Laboratory	Industrial
Scale	A few grams	Tonnes
Process	Batch , by hand	Continuous , integrated processes
Starting materials	Pure reagents bought in	Made on site (Haber ammonia) plus mined rock
Extra steps	None	Phosphate rock must first be treated with acid
Product	Pure dry crystals	A formulation blended to set percentages of N, P and K

Key ideas in chemistry (specification 4.11)

This section is specification 4.11, not part of 4.10. These ideas are of universal application, are embedded throughout the subject content and are assessed across all papers.

- Matter is composed of tiny particles called **atoms**; there are about **100 naturally occurring types of atom**, called **elements**.
- Elements show **periodic relationships** in their chemical and physical properties.
- These periodic properties can be explained in terms of the **atomic structure** of the elements.
- Atoms bond either by **transferring electrons** from one atom to another or by **sharing electrons**.
- The **shapes of molecules** and the arrangement of **giant structures** are of great importance in the way they behave.
- There are barriers to reaction, so reactions occur at **different rates**.
- Chemical reactions take place in only three ways: **proton transfer**, **electron transfer** and **electron sharing**.
- Energy is conserved in chemical reactions, so it can be neither created nor destroyed.