10 · Using resources

AQA · GCSE · Chemistry

Choose a resource route by the job it must do

A town needs safe water, a bridge that resists corrosion and fertiliser for farms. The cheapest raw material is not automatically the best choice: treatment, lifetime, energy and waste all matter. Compare the same useful service, state the conditions and explain the chemistry behind a decision.

This reference covers 4.10.1.1–4.10.4.2 for Separate Chemistry. Alternative biological metal extraction and equilibrium/rate evaluation of the Haber process are **Higher tier (HT)**. Written RP8 questions assess knowledge; actual supervised analysis and purification require a practical record.

Resources, replacement and sustainable development (4.10.1.1)

Earth's resources provide warmth, shelter, food and transport. Agriculture supplements natural supplies of food, timber and fibres. Natural wool/cotton can be supplemented or replaced by synthetic fibres such as polyester; a synthetic product is not automatically more sustainable.

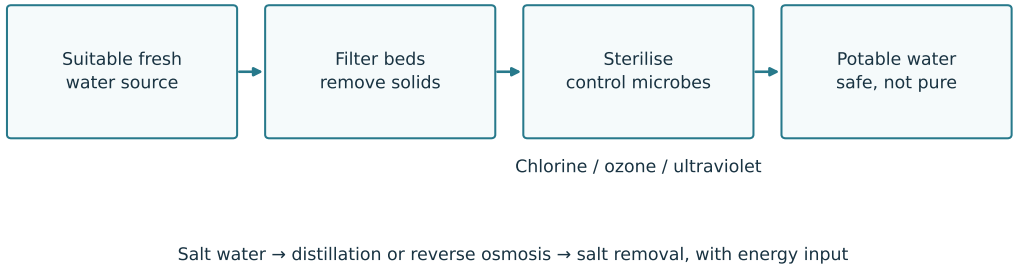
A **finite resource** has a limited supply that is not replaced on the time scale of use, such as a metal ore or fossil fuel. A **renewable resource** can be replenished on a useful time scale, such as sustainably managed timber. Renewable does not mean unlimited: cutting trees faster than they grow still reduces the stock.

Sustainable development meets current needs without compromising future generations' ability to meet theirs. Chemistry can improve crop production, material lifetime and industrial efficiency. Evaluate an improvement using evidence, including its costs and wastes.

Worked scale comparison. Fictional resource stocks are 20 tonnes and 20 000 tonnes. The ratio is $20\,000/20 = 1000 = 10^3$: three orders of magnitude. Check common units first. A large stock alone does not establish sustainability; extraction rate and replenishment also matter.

Potable water: choose the treatment for the source (4.10.1.2)

Potable water is safe to drink, with sufficiently low dissolved salts and harmful microbes. It is not chemically pure water because it contains dissolved substances. Clear-looking water may still contain salts, microbes or dissolved chemicals.



In the UK, rain supplies fresh water collecting in the ground, lakes and rivers. Choose an appropriate source, pass water through filter beds to remove suspended solids, then **sterilise** using chlorine, ozone or ultraviolet light. Filtration does not remove all dissolved salts; sterilising controls microbes rather than removing salts.

If fresh supplies are limited, **desalination** removes salt from sea/salt water. Distillation boils water and condenses its vapour, leaving most dissolved salts behind. **Reverse osmosis** uses pressure to drive water through a suitable membrane while retaining salts. Both need substantial energy: heating/condensing or producing pressure. Select a route using the local source, energy supply and required quality, rather than treating ordinary filtration as desalination.

RP8 knowledge. Compare water samples using pH and dissolved-solids measurements, then investigate distillation under teacher supervision. For residue, measure a known sample volume, weigh a dry container, evaporate water safely, cool and reweigh; repeat heating/cooling to constant mass where appropriate. Residue mass is final minus empty-container mass. Distillation needs collection and cooling of vapour, not just boiling a sample dry. Never drink laboratory samples or assume one measurement certifies safety.

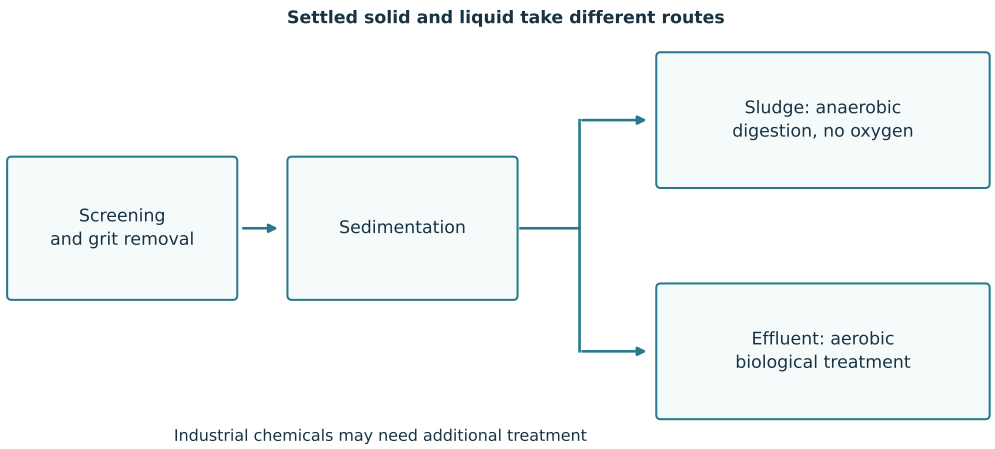
Worked residue. A 50.0 cm^3 sample leaves 0.120 g solid. Convert 50.0 cm^3 = 0.0500 dm^3, so concentration = 0.120/0.0500 = 2.40 g/dm^3. This measures residue under the stated method, not microbial safety.

Waste water follows two treatment branches (4.10.1.3)

Sewage and agricultural waste water need removal of organic matter and harmful microbes. Industrial waste can also contain harmful chemicals requiring suitable additional treatment. Treatment before environmental release does not automatically make the water potable.

Screening removes large objects and grit removal takes out heavy grit. **Sedimentation** separates settled **sludge** from liquid **effluent**. These then take different routes: **anaerobic digestion** treats sludge without oxygen; **aerobic biological treatment** uses oxygen to treat organic matter in

the effluent. Do not send both products through one imagined serial chain.

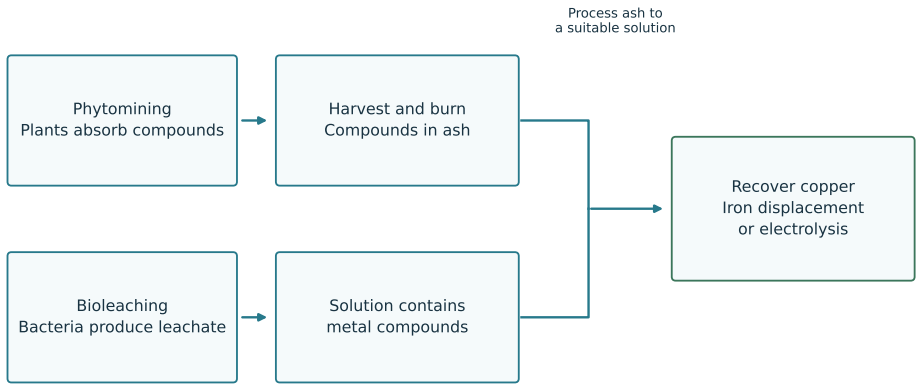


For comparable local conditions, suitable ground water usually needs less treatment than waste water; salt water needs energy-intensive salt removal. This is a reasoned comparison, not an absolute ranking for every contaminated source. Check dissolved substances, organic matter, microbes and available processes.

Recover copper from low-grade sources (4.10.1.4, HT only)

Copper ores are finite and high-grade supplies become scarcer. **Phytomining** uses plants to absorb metal compounds. Harvest and burn the plants; their ash contains those compounds. Further processing is needed: the plant has not produced a piece of pure copper.

Bioleaching uses bacteria to produce a **leachate** solution containing metal compounds. Copper can be recovered from a suitable solution by displacement with scrap iron or by electrolysis. Both routes need a recovery stage after obtaining the metal-containing material.



$$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$$

Iron is more reactive than copper and displaces it. Biological routes can avoid digging, moving and disposing of very large amounts of rock, but compare processing time, yield, energy, land use and waste using supplied information. “Biological” does not mean free, instant or impact-free.

Life cycle assessment: compare an equal service (4.10.2.1)

A **life cycle assessment** (LCA) considers extraction/processing of raw materials; manufacture/packaging; use/operation; and disposal at the end of useful life. Include transport and distribution at each stage. Compare the same service and lifetime, such as carrying the same shopping load the same number of times.

Water, resources, energy and some wastes can be quantified from suitable data. Measurement and assumptions still have uncertainty. Combining different pollutant effects into one score requires value judgements; an LCA is not purely objective. A disposal-only comparison may be useful for that stage but cannot establish the best whole-life product.

Worked equal-service decision. Fictional paper-bag figures for a shopping task total $6+4+2=12$ energy units. A reusable plastic bag needs 30 units to make and 1 unit per task to clean. After n tasks, paper needs $12n$ and plastic $30+n$. Equality gives $30 = 11n$, so $n = 2.73$; the reusable option uses less energy from the third complete task under these assumptions. This energy result does not also prove lower water use, litter or every pollutant effect. Record each category and the real reuse rate.

Reduce, reuse and recycle with a material reason (4.10.2.2)

Reducing material use can lower extraction, processing and waste. Reusing a whole glass bottle after collection and washing avoids remaking it; recycling crushes and remelts glass into another product. Metals can be melted and recast or reformed. Some scrap steel can be added to iron from a blast furnace, reducing the amount extracted from ore.

Separation requirements depend on the required final properties. Mixed materials and contamination may require more sorting; collection, transport, washing and remelting still use resources. Recyclable describes a possible route, not proof that collection and processing actually happen. Compare those burdens with avoided mining/quarrying and processing using supplied data.

Transfer. If recycling a stated batch uses 8 MJ but new production uses 50 MJ for the same material and quality, the supplied saving is $50-8 = 42$ MJ, or $42/50\times100 = 84\%$. Check whether collection was included before using that number in a claim.

Corrosion: barrier or sacrificial protection? (4.10.3.1)

Corrosion destroys a material through chemical reactions with its environment. Iron rusts only when both water and oxygen are available. In a comparison, ordinary damp air allows rusting; dry air lacks water; boiled water covered with oil limits oxygen entry. Keep the iron samples and exposure conditions comparable. One damp nail without controls cannot show that both substances are necessary.

Keep nail material, exposure time and temperature comparable. Schematic, not to scale.

Paint, grease and suitable electroplating form barriers. A scratch can expose iron to oxygen and water. Zinc galvanising adds **sacrificial protection**: zinc is more reactive than iron and oxidises preferentially, so nearby iron can remain protected at a scratch while suitable zinc contact remains. A less reactive coating cannot give that same protection. Aluminium's thin adherent oxide layer protects its surface; it is not evidence that aluminium never reacts.

Match alloys to properties and uses (4.10.3.2)

Most everyday metals are alloys. Different atom sizes can disrupt regular metal layers and make sliding harder; do not claim every **alloy** has identical properties.

Alloy	Composition or feature	Suitable use and reason
Bronze	Copper and tin	Statues: useful strength and durability
Brass	Copper and zinc	Fittings/instruments: useful working and corrosion properties
Gold jewellery	Gold with silver/copper/zinc	Harder wearing than pure soft gold
High-carbon steel	Iron with a higher carbon content	Hard tools; strength but brittleness limits some uses
Low-carbon steel	Iron with a lower carbon content	Shaped car-body panels; softer and easier to form
Stainless steel	Iron with chromium and nickel	Cutlery: hard and corrosion resistant
Aluminium alloys	Low density	Aircraft structures where low mass matters

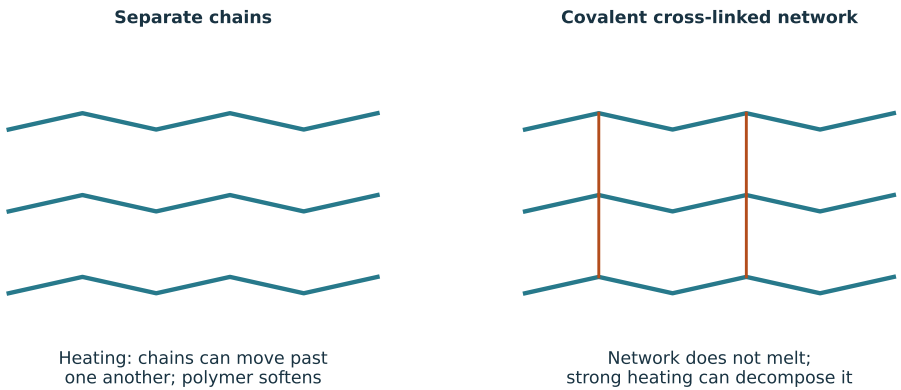
Gold purity is measured in carats: 24 **carat** is pure gold, and 18 carat is $18/24 = 75\%$ gold by mass. A 12 g ring then contains $12 \times 18/24 = 9$ g gold and 3 g other metals. For an unfamiliar alloy, use its supplied composition/property data rather than guessing from its name.

Ceramics, polymers and composites (4.10.3.3)

Soda-lime glass is made by heating sand, sodium carbonate and limestone. Borosilicate glass uses sand and boron trioxide and melts at a higher temperature. Clay ceramics, such as bricks and pottery, are made by shaping wet clay and heating it in a furnace. Hardness, brittleness and heat resistance affect the job each can do.

Low-density and high-density poly(ethene) both come from ethene. Different production conditions lead to different chain structures: branching makes close packing harder in LD material; straighter HD chains pack more closely. The same monomer does not force the same density or flexibility.

A **thermosoftening polymer** has separate chains without the cross-linked network considered here. Heating lets chains move past one another as intermolecular attractions are overcome, so it softens/melts and can be remoulded. Melting does not require breaking the chain's covalent backbone. A **thermosetting polymer** has covalent cross-links joining chains into a network; it does not melt on heating, and sufficiently strong heating can decompose it. Remelting is therefore not a suitable recycling route for that network.



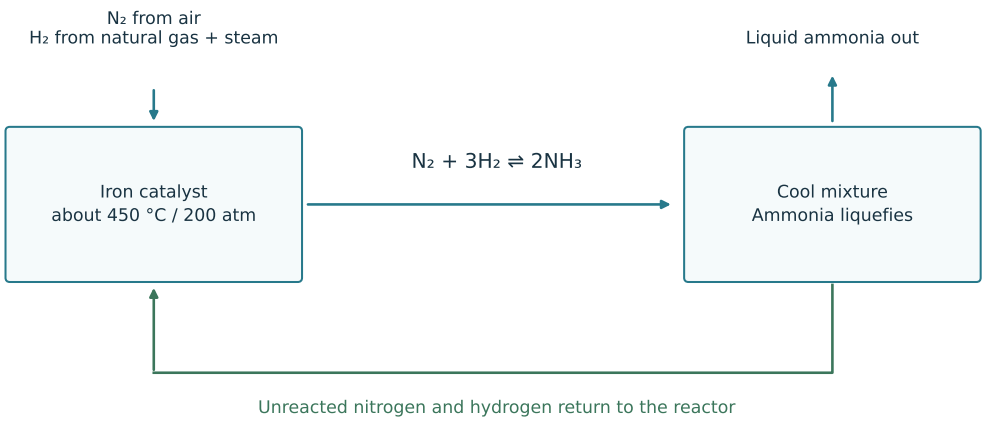
Lines represent chain backbones; orange links are covalent bonds. Schematic.

A **composite** has a **matrix** /binder surrounding and binding a **reinforcement** of fibres or fragments. Examples include glass fibres in resin, carbon fibres in polymer resin, and concrete with aggregate in a cement-based binder. "Carbon fibre" alone does not identify both components. Select materials by the required combination of strength, density, flexibility, temperature resistance and cost, using quantitative data when supplied.

Haber manufacture and the HT compromise (4.10.4.1)

The **Haber process** manufactures ammonia for nitrogen fertilisers. Nitrogen comes from air; hydrogen can be obtained from natural gas reacted with steam. Purified gases pass over iron at about 450 °C and about 200 atmospheres.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$



The reaction is reversible. Cooling the mixture liquefies ammonia for removal; unreacted nitrogen and hydrogen return to the reactor. Recycling improves use of feedstock, but does not prove zero waste or zero energy demand. These process steps are required at both tiers.

HT reasoning. The forward reaction is exothermic, so lower temperature favours equilibrium ammonia yield but slows reaction. Higher temperature raises rate but reduces equilibrium yield. Higher pressure favours ammonia because four reactant gas molecules become two product molecules, but strong equipment and compression cost money and energy. The industrial conditions balance rate, yield and cost; they are not the conditions for maximum possible equilibrium yield. Iron speeds both directions and approach to equilibrium without changing its position.

Worked feed check. With 2 mol nitrogen and 6 mol hydrogen, the theoretical maximum is 4 mol ammonia if all reactants converted. If only 1 mol nitrogen reacts on a pass, 3 mol hydrogen reacts and 2 mol ammonia forms; 1 mol nitrogen and 3 mol hydrogen remain for recycling. The per-pass conversion is not the same as overall conversion after repeated recycling.

NPK fertilisers: choose salts and compare manufacture (4.10.4.2)

An **NPK fertiliser** is a formulation of salts supplying nitrogen, phosphorus and potassium for plant growth. Ammonia can make ammonium salts and nitric acid. For example, ammonia neutralises nitric acid:

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

Potassium chloride, potassium sulfate and phosphate rock are obtained by mining. Phosphate rock is not directly suitable as fertiliser; treatment makes usable soluble salts. Recall these products:

Acid treatment of phosphate rock	Products to recognise
Nitric acid	Calcium nitrate and phosphoric acid
Sulfuric acid	Single superphosphate: calcium phosphate fertiliser with calcium sulfate
Phosphoric acid	Triple superphosphate: calcium phosphate fertiliser without the sulfate component

The phosphate fertiliser in single/triple superphosphate is calcium dihydrogen phosphate. Do not label every acid treatment simply "superphosphate", and do not confuse phosphoric acid with a potassium source.

For the same salt, compare laboratory and industrial routes using supplied information. A careful laboratory neutralisation/titration followed by evaporation and crystallisa-

tion can produce a pure solid: a titration is not inherently an impure product. Industry can integrate ammonia/acid manufacture, control continuous large-scale output and recover heat, while requiring equipment, energy and emissions management. Explain the actual trade-off; “industry is always better” is not an evaluation.

Independent transfer check

A school wants drinking water, a reusable container and fertiliser. Explain why filtration alone cannot desalinate seawater, why a reusable product needs an equal-service LCA, and why fertiliser manufacture still consumes resources when Haber gases are recycled. Then compare scratched paint with scratched zinc on iron. State the missing data or condition for each decision rather than claiming one option solves every problem.