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C9. Industrial inorganic chemistry

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C9.01 Extraction of metals by carbon reduction

1. Iron and steel

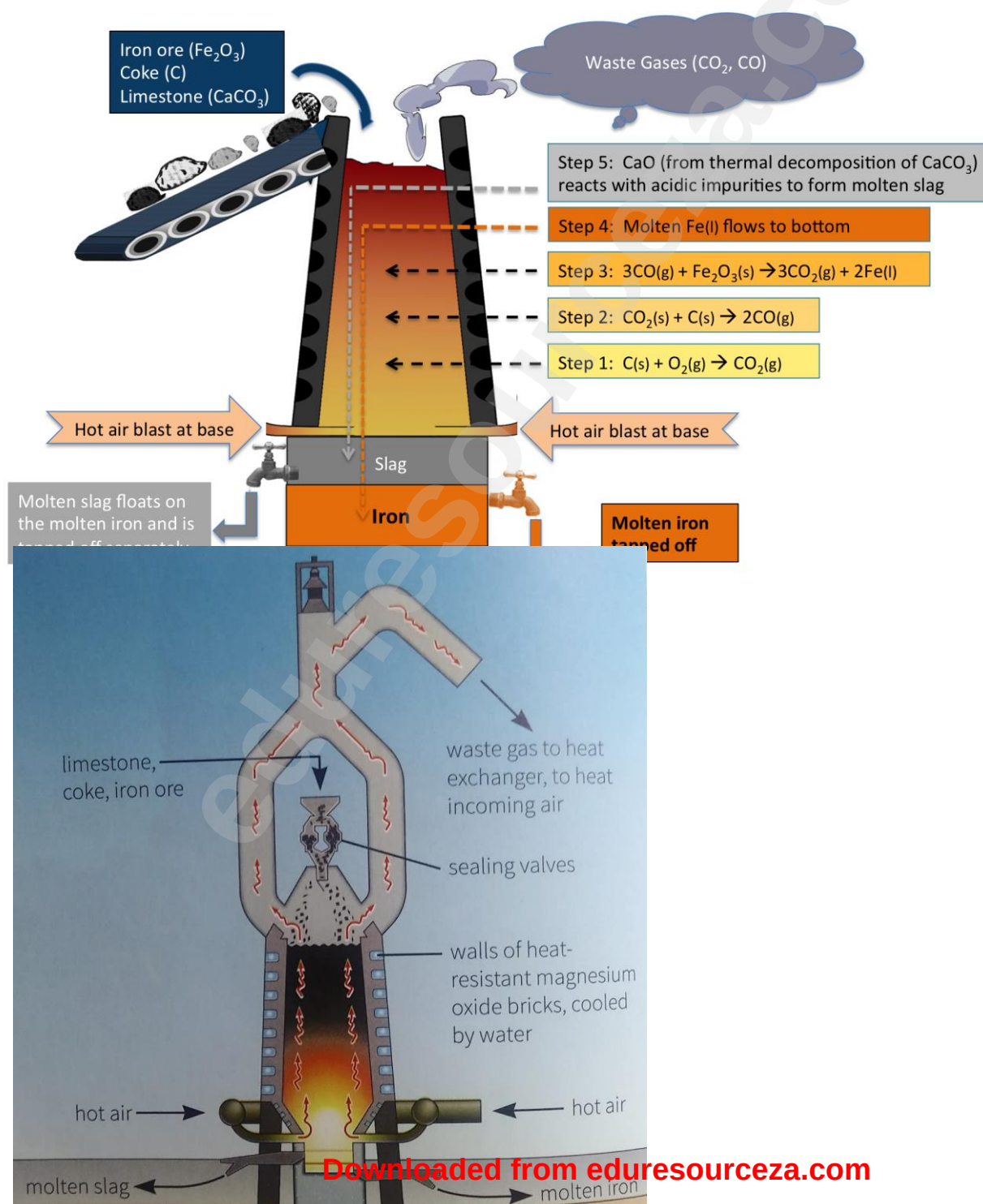
Steel is combined with 0.2 ~ 1.5% carbon to make alloy

2. The production of iron in the blast furnace

Main ore of iron - **hematite**(Fe_2O_3)

charge is sintered - the ore is heated with coke and limestone

- Hot gases rise up the furnace
- Molten iron flows down the furnace
- How to remove impurity - **SiO_2 (sand)** - put limestone
 - $\text{CaCO}_3 \xrightarrow{\text{heating}} \text{CaO} + \text{CO}_2$
 - $\text{CaO} + \text{SiO}_2 \Rightarrow \text{CaSiO}_3$



Blast furnace extraction of iron

- uses iron ore, coke, limestone and hot air
- involves the reduction of iron oxide by carbon monoxide
- uses limestone to remove the main impurity sand as slag(calcium silicate)

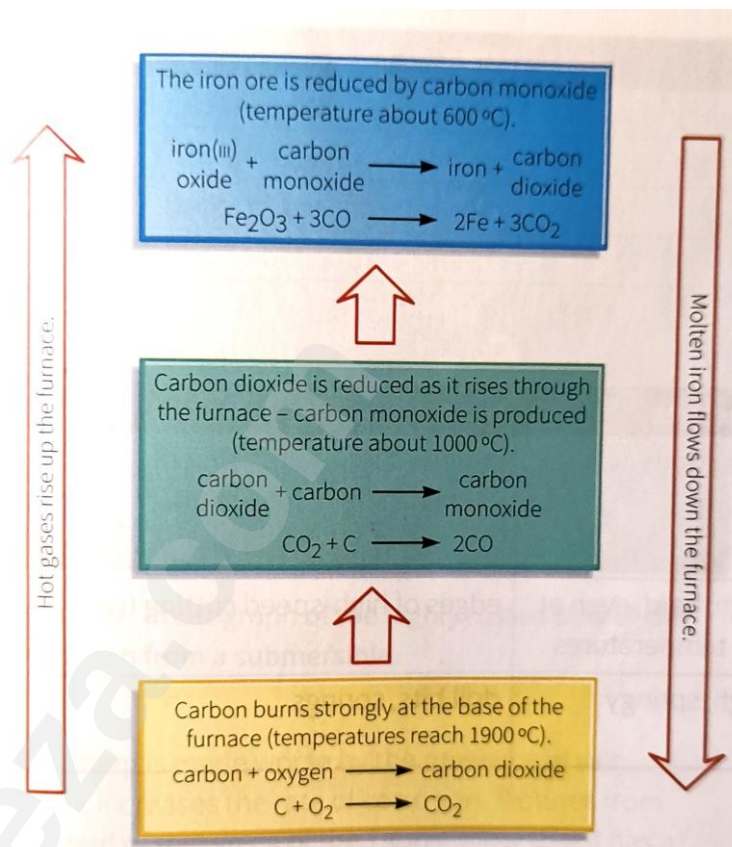
3. Steel-making

- iron -> blast furnace -> pig iron, cast iron
- not pure - carbon contained makes the iron brittle
- use CaO - to get rid of impurities, silicon and phosphorus
- use basic oxygen process - to reduce carbon by burning it off as carbon dioxide
 - furnace is charged with scrap steel and molten iron
 - oxygen is blown in through an oxygen lance
 - molten steel, slag, poured from the furnace by tilting it in different direction

4. Carbon steels and alloy steels

carbon steels: amount of carbon in steels 0.2% ~ 1.4%

- tend to rust unless protected.
- so we make **alloy steels**



Metal	Carbon content	Properties	Uses
cast iron	2.5-4.5	cheaper than steel, easily moulded	gear box, engine block
mild steel	<0.25	easily worked, not brittle	car bodies
medium steel	0.25-0.45	tougher than mild steel	car springs, bridges
high-carbon steel	0.45-1.5	hard and brittle	cutting tools, razor blade

Δ Cast iron and carbon steels

Steele	Typical composition		Properties	Uses
stainless steel	iron	74%	tough, doesn't corrode	• cutlery • surgical instrument • kitchen sinks • chemical plant
	chromium	18%		
	nickel	8%		
Tungsten steel	iron	95%	tough, even in high temp hard	• edge of high speed cutting tools
	tungsten	5%		
Manganese steel	iron	87%	tough, springy	• drill bits • springs
	Manganese	13%		

Δ Typical alloy steels

5. The rusting of iron and its prevention

corrode: metal is attacked by air, water, substances

rusting: corrosion of iron and steel

- Rust: red-brown powder consisting mainly of **hydrated iron oxide** ($\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$)
- need water and oxygen
- sea water salt => increase the rate of corrosion

✂ experiment

- air + distilled water => rusty iron nails
- dry air + anhydrous calcium chloride(drying agent) => no rust
- air+ layer of olive oil(prevent air dissolving in the water) + water => no rust
- pure oxygen + distilled water => very rusty iron nails



Aluminium

- more reactive, but the other way
- single of aluminium oxide forms, sticking strongly to the surface of the metal
- micro-layer seals the metal surface, protects it from further attack

Iron

- rust forms flakes, which doesn't form a single layer
- attack can continue over time

6. Rust prevention

painting

- only protects the metal as long as the paint layer is unscratched
- re-painting is necessary
- very widespread

Oiling and greasing

- moving parts of machinery forms a protective film, preventing rusting
- should be repeated

Plastic coatings

- used to form a protective layer on refrigerators, garden chairs
- vinyl chloride, pvc

Electroplating

- a layer of chromium or tin
- tin can - tin 으로 도금되어있음
- used because of its unreactivity and non-toxic
- protective layer broken - starts to rust

Galvanising

- object may be created with a layer of the more reactive metal, zinc
- scratched 되도 works

Sacrificial protection

- reactive metal are attached to the iron surface
- zinc, magnesium attached to oil rigs, hull of ships

7. The extraction of copper

copper - less reactive, extracted from copper pyrites (CuFeS_2)

- good for piping, electrical wiring
- must be refined by electrolysis

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C9.02 The extraction of metals by electrolysis

Extracting metals - very expensive and energy costs high

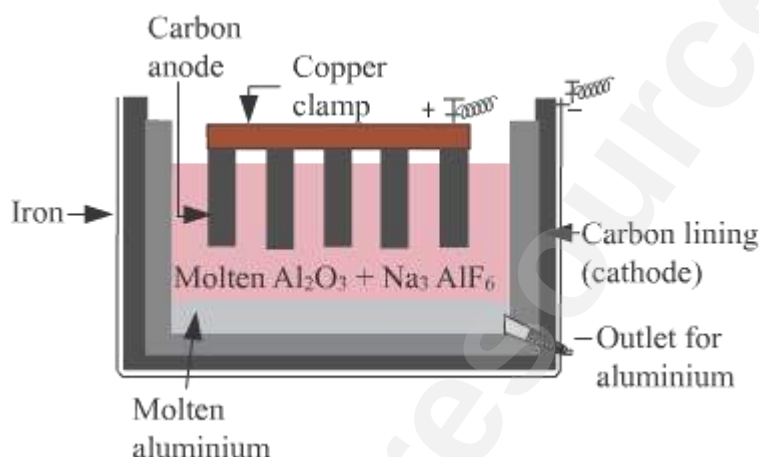
- Mining the ore
- Purification of the ore
- Electrolysis of the molten ore

1. The extraction of aluminium

Aluminium is from the major ore of **Bauxite**

2. The Hall-Heroult process

1. The **bauxite** is treated with **sodium hydroxide** to obtain pure aluminium oxide(alumina)
2. Alumina goes to electrolysis plant
3. Al_2O_3 - dissolved in molten cryolite(sodium aluminium fluoride)
4. It lowers the working temp of the electrolytic cell
5. At cathode - $\text{Al}^{3+} + 3\text{e}^- \Rightarrow \text{Al}$
6. At anode - $\text{C}(\text{s}) + \text{O}_2(\text{g}) = \text{CO}_2(\text{g})$



C9.03 Ammonia and

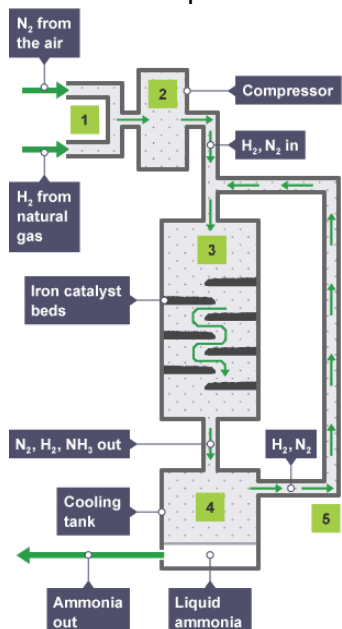
fertilisers

Ammonia general properties

- colourless
- distinctive smell
- less dense than air
- very soluble in water to give an alkaline solution
- unreactive gas, change into compounds useful for plant growth(**nitrogen fixation**)
 - important for agriculture

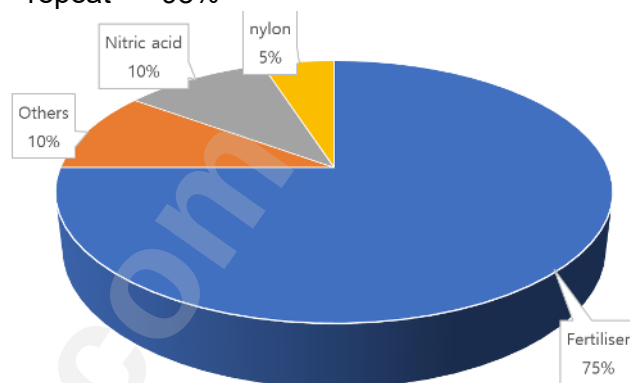
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- plant cannot directly use nitrogen from the air => so we make agricultural fertilisers



Haber process $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$

1. two gases mixed in 1:3 ratio, compressed to 200 atmosphere
2. go across beds of catalyst, containing finely divided iron (450°C)
3. reaction is reversible, doesn't go completion
4. proportion of ammonia => 15% => repeat => 98%
5. higher b.p => condenses easily
=> liquid 됨



1. Ammonium nitrate and other fertilisers

Ammonium nitrate => most important of nitrogenous fertilisers

- contains 35% by mass of nitrogen
- $\text{NH}_3(\text{aq}) + \text{HNO}_3(\text{aq}) \Rightarrow \text{NH}_4\text{NO}_3(\text{aq})$
- can be crystallised into pellet form suitable for spreading on the land
- $(\text{NH}_4)_2\text{SO}_4$ = ammonium sulfate

two types of nitrogen compounds that plants can use with good solubility

- ammonium compounds (NH_4^+)
 - make the soil slightly acidic
 - can be mixed with calcium carbonate for neutralisation
 - Nitro chalk => compound fertilisers
- nitrates (NO_3^-)

2. Fertilisers

straight N fertilisers

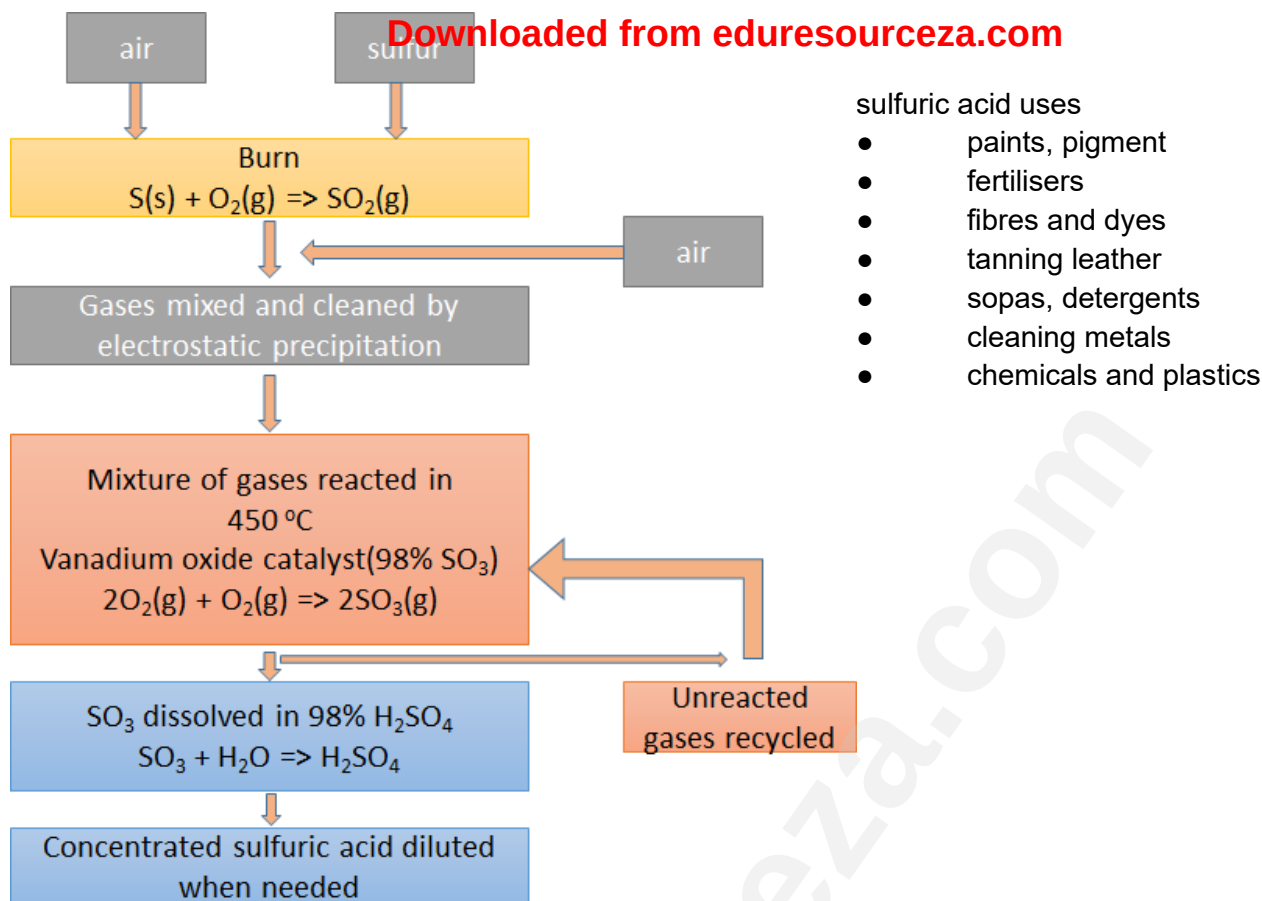
- solid nitrogen-containing fertilisers, NH_4NO_3 , $(\text{NH}_4)_2\text{SO}_4$

NPK compound fertilisers

- mixture of nitrogen, phosphorus, potassium
- so mixture of ammonium nitrate, ammonium phosphate, potassium chloride

C9.04 Sulfur and sulfuric acid

- made by **contact process**



sulfuric acid uses

- paints, pigment
- fertilisers
- fibres and dyes
- tanning leather
- soaps, detergents
- cleaning metals
- chemicals and plastics

- sulfur oxide to sulfur trioxide -

reversible

- oleum - to prevent environmental problem, it is transported with so concentrated state(98%)
 - $\text{H}_2\text{SO}_4 + \text{SO}_3 \rightarrow \text{H}_2\text{S}_2\text{O}_7$
 - $\text{H}_2\text{S}_2\text{O}_7 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$

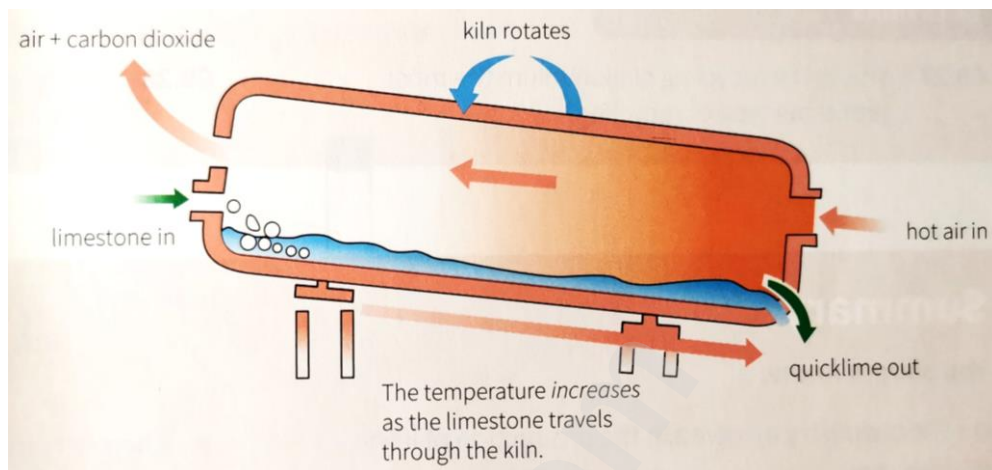
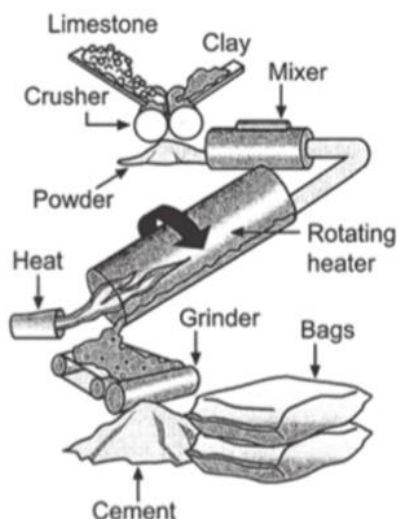
C9.06 Limestone

1. Direct uses of limestone

- powered limestone - to neutralise acid soils, lakes acidified by acid rain
- cheaper than calcium oxide(lime) - because it needs to be heated
- Cement - made by heating powdered limestone with clay in a rotary kiln
- concrete - mixture of cement and aggregate(stone chippings and gravel)
 - mixed with water, can harden

- reinforced concrete, made by allowing concrete to set around steel rods

Cement Production



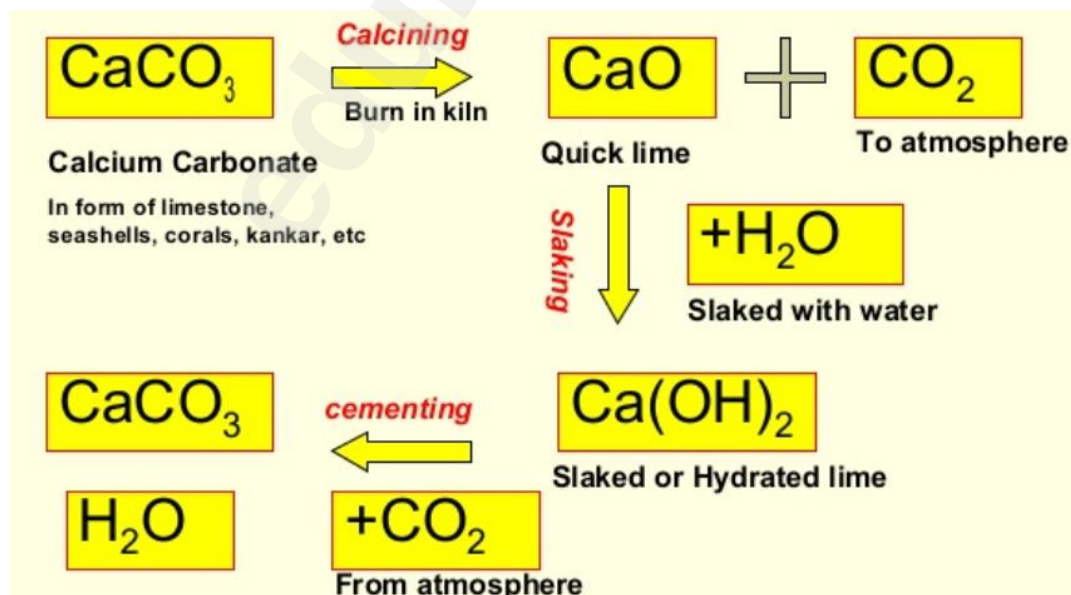
↳ The manufacture of lime in a lime kiln

2. The manufacture of lime(calcium oxide)

Lime(quicklime) is calcium oxide, produced by roasting limestone in a lime kiln =>decomposition

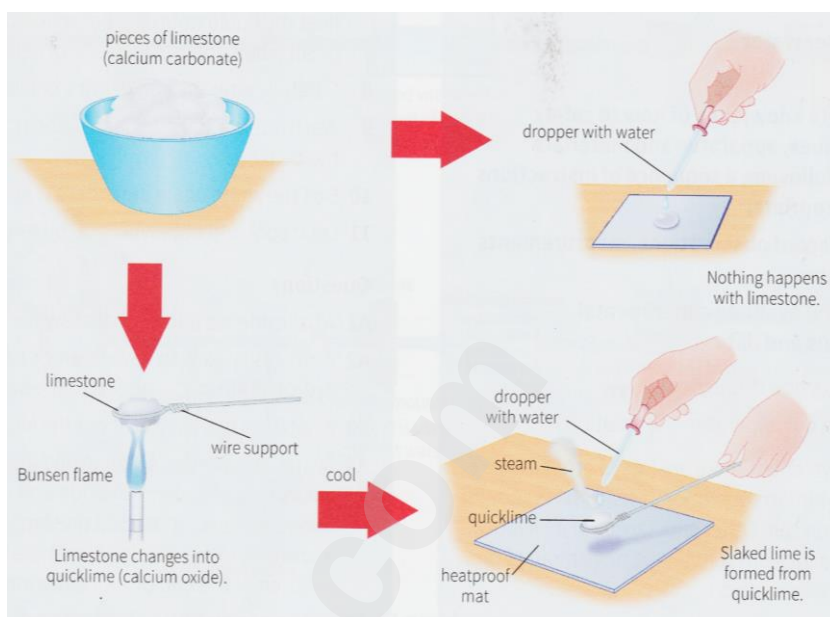


- used in agriculture to neutralise acid soils
- used with sodium carbonate and sand to make glass
- can be converted into slaked lime(hydrated lime), which is calcium hydroxide - $\text{Ca}(\text{OH})_2$



1. Limestone

- Sand + sodium carbonate = glass
- Neutralise acid
- Remove impurities of steel
- Gravel + sand + water = concrete
- Cement



C9.07 Recycling metals

Reasons

- conserves raw materials which the substances were made from
- often uses less energy to recycle something than would be needed to make it from raw materials
- avoids the need to bury the substances in landfill site,s possibly causing pollution

Aluminium

- cost so much to extract - recycle necessary
- 95% energy saved

Steel

- cheaper to recycle, but not efficient
- easy to recycle because it's magnetic, so can be separated from other rubbish

C9.05 The chlor-alkali industry

the electrolysis of concentrated sodium chloride solution(brine)

anode - chlorine produced

cathode - hydrogen produced

in water - hydroxide, sodium ion

