INDUSTRIAL PROCESSES

Industrial processes are a set of several conditions to which materials are subjected to obtain new and more valuable products. Industrial processes involve application of physical, chemical, electrical or mechanical conditions to materials so that they undergo changes which may result in better products.

In Uganda, the most popular industries include among others, agricultural, pharmaceutical, foods and beverages, plastics, lavatory, etc. These industries utilize natural and non-natural resources.

CHEMICAL INDUSTRIES IN UGANDA

Name as many chemical industries in Uganda which you know and also name the products made by these industries.

NATURAL RESOURCES PROCESSING IN UGANDA

Natural resources are resources which occur naturally without the direct contribution of man to their formation.

Identify some natural resources in Uganda.
What products do we get from these natural resources?

Natural resources include air, sunlight, water,soil, stones, plants, animals, fossil fuels.

ROCKS PROCESSING INDUSTRY

Rocks are an example of natural resources.

Rocks can be processed to obtain different products depending on the number of processes they go through. For example, simple quarrying can change rocks into smaller stones for concrete or hardcore used in construction works. Further processing of some rocks can give rise to cement, lime and other products.

CEMENT AND LIME INDUSTRY

Cement and lime are the most common products used in construction works for roads, houses, roads and other infrastructure.

CEMENT

Cement is the most essential construction material that acts as a binding agent for concrete, laying bricks and more. From limestone to clay and supplementary additives, each ingredient contributes to the durability and strength of cement. Let us learn about the essential raw materials used for cement production.

COMPOSITION OF CEMENT

There are two primary cement manufacturing components that form the distinctive properties of cement.

Calcareous materials: These materials are rich in calcium and magnesium and typically include limestone, chalk, marl, shells, and other sources abundant in calcium carbonate. These are the primary sources of calcium, which undergoes a calcination process during cement production to form quicklime or calcium oxide that has binding properties of the cement.

Argillaceous materials: Complementing the calcareous materials, argillaceous components enrich cement's composition. The argillaceous materials including silica, alumina, iron oxide and more are added to the mix. This blend of elements adds to the cement's strength, durability, and binding characteristics.

RAW MATERIALS REQUIRED FOR CEMENT PRODUCTION

Here are the essential raw materials used for cement manufacturing:

- **Limestone:** It is the primary source of calcareous compounds. Limestone is a sedimentary rock abundant in nature with high calcium content. It is quarried from natural reserves which then undergo a series of processes including crushing, grinding, and calcination to make quicklime.
- **Clay or Shale:** These materials are sourced from clay pits or shale deposits to supplement the cement-making process. Their high silica and alumina content aids in enhancing the binding properties of the final product.
- **Pozzolans:** These include volcanic ash, silica fumes, and certain industrial by-products. The addition of pozzolans in cement enhances its strength, durability, and resistance to chemical attacks. It makes it more resistant to harsh environmental conditions. These are used to manufacture Portland Pozzolana Cement (PPC), a popular choice for many construction projects.
- **Iron Ore:** It is used to add iron oxide to the mix to enrich the cement's colour while contributing to the fusion of raw materials for cement production and the strength of the final product.
- **Gypsum:** It regulates the cement's setting time. Its controlled addition helps in rapid solidification which ensures workability and allows ample time for construction processes.
- **Fly ash:** It is a by-product of coal combustion in power plants used in cement to enhance the compressive strength of concrete while addressing environmental concerns by reusing industrial waste. It also contributes to workability, reduces heat evolution during cement hydration, and long-term strength and durability.

MANUFACTURING PROCESS

STEP 1: EXTRACTION OF RAW MATERIALS

The raw materials needed to produce cement (calcium carbonate, silica, alumina and iron ore) are generally extracted from limestone rock, chalk, clayey schist or clay. Suitable reserves can be found in most countries.

These raw materials are extracted from the quarry by blasting. They are then crushed and transported to the plant where they are stored and homogenized.

STEP 2: *RAW MATERIAL GRINDING AND BURNING*

Very fine grinding produces a fine powder, known as raw meal, which is preheated and then sent to the kiln. The material is heated to 1,500°C before being suddenly and dramatically cooled by bursts of air.

This produces **clinker**, the basic material required for the production of all cements.

Clinker is the main ingredient in cement. These hardened granules are obtained by firing a mixture of approximately 80% limestone and 20% clay to a high temperature. Cement is obtained by grinding clinker, in some cases supplementing it with additives.

STEP3:CEMENT GRINDING,STORAGE AND SHIPPING/DISTRIBUTION

A small amount of gypsum (3-5% is added to the clinker to regulate how the cement will set. The mixture is then very finely ground to obtain "pure cement". During this phase, different mineral materials, called "cement additives", may be added alongside the gypsum.

Used in varying proportions, these additives, which are of natural or industrial origin, give the cement specific properties such as reduced permeability, greater resistance to sulfates and aggressive environments, improved workability, or higher-quality finishes.

Finally, the cement is stored in silos before being shipped in bulk or in bags to the sites where it will be used.

DANGERS OF CEMENT MANUFACTURING PROCESS

a) Emission of carbon dioxide

Why does manufacturing cement produce CO_2?

Cement manufacturing is the source of 5percent; of global carbon dioxide (CO_2) emissions. The cement industry is a natural producer of CO_2:

- 60 percent; of emissions are due to the transformation of raw materials at high temperatures (decarbonation of limestone),
- 40 percent; results from the combustion needed to heat the cement kilns to 1500°C.

b) Topographical destruction resulting in soil erosion inhabitability of land by humans and other animals e.g in quarries where rocks are extracted, etc. Other risks are soil erosion,
c) The process consumes a lot heat energy which sometimes is produced by burning fossil fuels.

LIME

Lime is not freely available in nature but is obtained by burning natural materials such as limestone, seashells, kankar, coral, etc.

The main sources of obtaining lime are the stones which possess clay, magnesium carbonate, soluble silica, alkalis and metallic oxides, sulphates, iron compounds and carbonaceous matter.

GENERAL CLASSIFICATION OF LIME AND THEIR USES

Lime is classified based on the calcination of limestone, and they are:

FAT LIME

Fat lime is white in colour, which has high calcium oxide content. This lime can set and become hard only in the presence of carbon dioxide.

It is also called high-calcium lime, pure lime, rich lime or white lime. But, it is mostly known as fat lime as it slakes quickly. It contains specific properties such as very slowly hardening, a high degree of plasticity and soluble in water.

USES OF FAT LIME

- It is used in plastered surfaces for whitewashing.
- It is used as lime mortar (a combination of lime and sand) for plastering and pointing works.
- It is used as a Lime Surkhi mortar for foundations, thick masonry walls, etc., where surkhi is the powder obtained by pounding burnt bricks.

HYDRAULIC LIME

Hydraulic lime is the lime that contains small quantities of silica, alumina and iron oxide, which are collectively in the chemical composition with calcium oxide.

It is also known as water lime because it can set under water and become hard even in the absence of carbon dioxide.

Based on the percentage of the clay, hydraulic lime is available in different forms such as Feebly hydraulic lime, Moderately hydraulic lime and Eminently hydraulic lime. The increase in clay content makes slaking difficult and increases hydraulic properties.

USES OF HYDRAULIC LIME

- It resembles cement as it contains 30% of clay and can be used in major civil engineering works.
- It can set in thick walls where there is no free-flowing of air.
- It forms a thin paste with water.

POOR LIME

This lime is also known as ***lean lime or impure lime***. As it contains more than 30% of clay, which makes lime to slake slowly.

It sets and hardens ***very slowly*** compared to other types of limes. It has very poor binding properties and can form a thin paste with water. It is used for inferior types of works because of its inferior quality.

INDIAN STANDARD CLASSIFICATION OF LIME AND THEIR USES:

As per Bureau of Indian Standards (IS: 712 - 1984), limes are classified into six classes, and they are:

Class A: Eminently Hydraulic Lime

It is available in hydrated form and can be used for structural works like arches, domes, etc.

Class B: Semi-hydraulic Lime

It is available as both quick lime and hydrated lime. This mortar is used for masonry works.

Class C: Fat Lime

It is available in quick or hydrated form. It is used for finishing coat in plastering, whitewashing etc. It is used for masonry mortar with the addition of pozzolanic material.

Class D: Magnesium or Dolomite Lime

It is also available in a hydrated or quick form. It can be used for whitewashing and finishing coat for plastering.

Class E: Kankar Lime

It is produced by burning lime nodules which are seen in soils like black cotton soil containing silica in the hydrated form. It is also preferred for masonry works.

Class F: Siliceous Dolomite Lime

It is usually used as an undercoat and finishing coat of plaster.

PROPERTIES OF LIME

Lime is one of the oldest binding materials used in several ancient architectural works. A good quality lime should own the following properties:

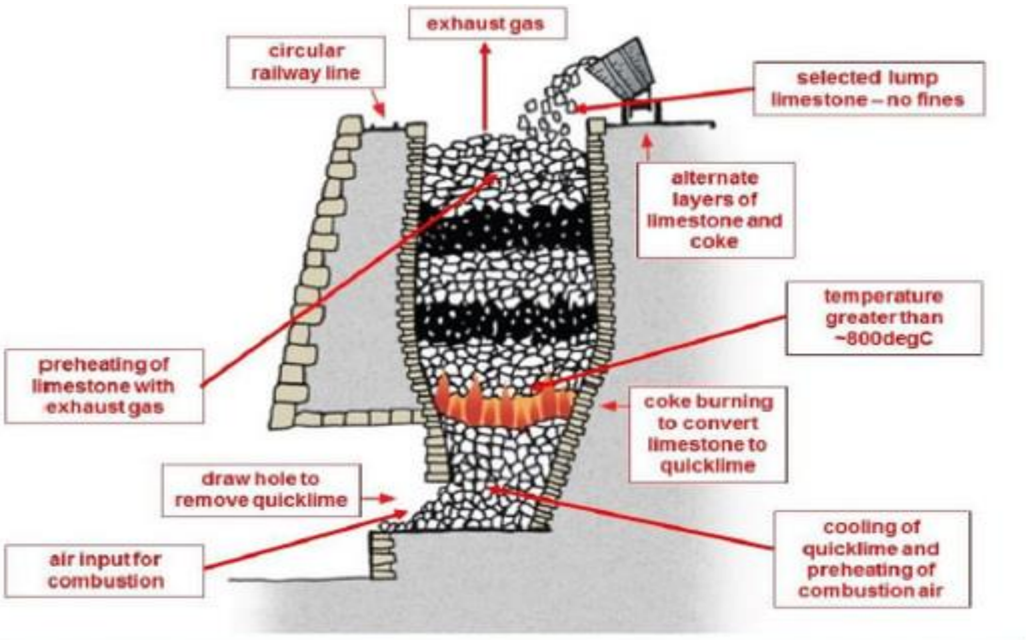
- It should possess good plasticity.
- It should be flexible and easily workable.
- When used in mortar, it should provide greater strength to the masonry.
- It should solidify in less time and become hard.
- It should comprise of excellent binding properties which adhere to brick or stone masonry units perfectly.
- It possesses high durable properties as it is less shrinkable when used in mortar.
- It should be highly resistant to moisture and can be used for pointing works.

Precautions in Handling Lime

Lime is a health hazard if breathed in and also affects the skin resulting in skin diseases. It can be avoided by coating the skin with oil.

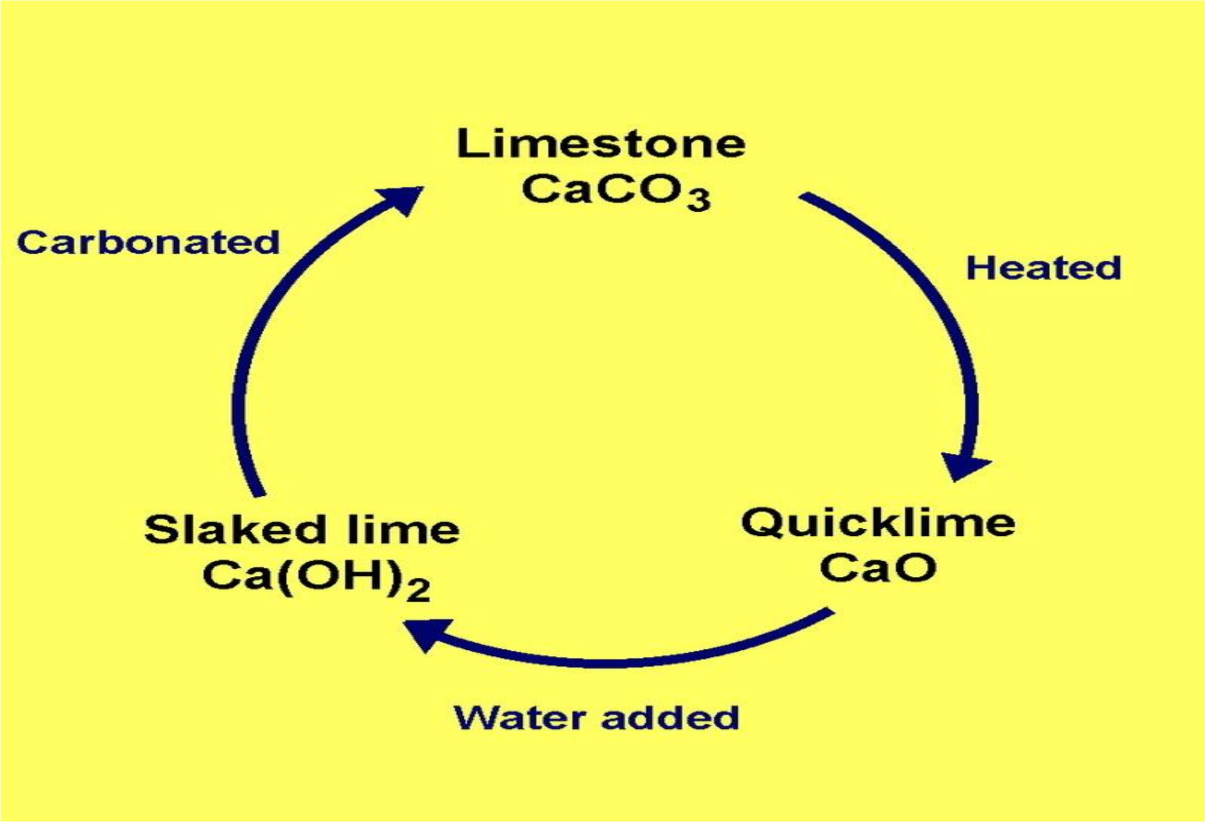
Slaking of lime is an exothermic reaction and generates a large amount of heat. Proper care should be taken by workers by using goggles, respirants, gloves, and boots as protection while working with lime

DIAGRAM FOR THE MANUFACTURE OF LIME



early continuous operation lime kiln – apart from the feeding system the principles apply equally to a field kiln

The Lime Cycle



Lime is the high-temperature product of the calcination of limestone. Although limestone deposits are found in every state, only a small portion is pure enough for industrial lime manufacturing. To be classified as limestone, the rock must contain at least 50 percent calcium carbonate. When the rock contains 30 to 45 percent magnesium carbonate, it is referred to as dolomite, or dolomitic limestone. Lime can also be produced from aragonite, chalk, coral, marble, and sea shells.

Lime is manufactured in various kinds of kilns by one of the following reactions:
$CaCO_3$ + heat → CO_2 + CaO (high calcium lime)

$CaCO_3 + MgCO_3 + heat \rightarrow 2CO_2 + CaO + MgO$ (dolomitic lime)
In some lime plants, the resulting lime is reacted (slaked) with water to form hydrated lime.

The basic processes in the production of lime are:
(1) quarrying raw limestone;
(2) preparing limestone for the kilns by crushing and sizing;
(3) calcining limestone;
(4)processing the lime further by hydrating; and
(5) miscellaneous transfer, storage, and handling operations.

The heart of a lime plant is the kiln. The prevalent type of kiln is the rotary kiln, accounting for about 90 percent of all lime production in the United States. This kiln is a long, cylindrical, slightly inclined, refractory-lined furnace, through which the limestone and hot combustion gases pass counter currently. Coal, oil, and natural gas may all be fired in rotary kilns. Product coolers and kiln feed preheaters of various types are commonly used to recover heat from the hot lime product and hot exhaust gases, respectively.
The next most common type of kiln in the United States is the vertical, or shaft, kiln. This kiln can be described as an upright heavy steel cylinder lined with refractory material. The limestone is charged at the top and is calcined as it descends slowly to discharge at the bottom of the kiln. A primary advantage of vertical kilns over rotary kilns is higher average fuel efficiency. The primary disadvantages of vertical kilns are their relatively low production rates and the fact that coal cannot be used without degrading the quality of the lime produced. There have been few recent vertical kiln installations in the United States because of high product quality requirements.
Other, much less common, kiln types include rotary hearth and fluidized bed kilns. Both kiln types can achieve high production rates, but neither can operate with coal. The "calcimatic" kiln, or rotary hearth kiln, is a circular kiln with a slowly revolving doughnut-shaped hearth. In fluidized bed kilns, finely divided limestone is brought into contact with hot combustion air in a turbulent zone, usually above a perforated grate. Because of the amount of lime carryover into the exhaust gases, dust collection equipment must be installed on fluidized bed kilns for process economy.
Another alternative process that is beginning to emerge in the United States is the parallel flow regenerative (PR) lime kiln. This process combines two advantages.

- First, optimum heating conditions for lime calcining are achieved by concurrent flow of the charge material and combustion gases.
- Second, the multiple-chamber regenerative process uses the charge material as the heat transfer medium to preheat the combustion air. The basic PR system has 2 shafts, but 3 shaft systems are used with small size grains to address the increased flow resistance associated with smaller feed sizes.

In the 2-shaft system, the shafts alternate functions, with 1 shaft serving as the heating shaft and the other as the flue gas shaft. Limestone is charged alternatively to the 2 shafts and flows downward by gravity flow. Each shaft includes a heating zone, a combustion/burning zone, and a cooling zone. The 2 shafts are connected in the middle to allow gas flow between them. In the heating shaft, combustion air flows downward through the heated charge material. After being preheated by the charge material, the combustion air combines with the fuel (natural gas or oil), and the air/fuel mixture is fired downward into the combustion zone. The hot combustion gases pass from the combustion zone in the heating shaft to the combustion zone in the flue gas shaft. The heated exhaust gases flow upward through the flue gas shaft combustion zone and into the preheating zone where they heat the charge material. The function of the 2 shafts reverses on a 12-minute cycle. The bottom of both shafts is a cooling zone. Cooling air flows upward through the shaft countercurrently to the flow of the calcined product. This air mixes with the combustion gases in the crossover area providing additional combustion air. The product flows by gravity from the bottom of both shafts.
About 15 percent of all lime produced is converted to hydrated (slaked) lime. There are 2 kinds of hydrators: atmospheric and pressure. Atmospheric hydrators, the more prevalent type, are used in continuous mode to produce high-calcium and dolomitic hydrates. Pressure hydrators, on the

other hand, produce only a completely hydrated dolomitic lime and operate only in batch mode. Generally, water sprays or wet scrubbers perform the hydrating process and prevent product loss. Following hydration, the product may be milled and then conveyed to air separators for further drying and removal of coarse fractions.

THE MAJOR USES OF LIME

Metallurgical (aluminum, steel, copper, silver, and gold industries) and ***Environmental*** (flue gas desulfurization, water softening, pH control, sewage-sludge destabilization, and hazardous waste treatment), and construction (soil stabilization, asphalt additive, and masonry lime).

Research more on these and make more notes.

ENVIRONMENTAL DANGERS OF LIME MANUFACTURE

How does lime production affect the environment?

Also, the process of lime production involves the emission of large quantities of carbon dioxide, which **contributes to global climate change**.

MITIGATION

The partial replacement of lime with wood ash wastes could lessen environmental problems associated with manufacturing mortars, such as air, water, and soil pollution.

EXTRACTION AND PURIFICATION OF METALS

The method of extraction depends on the position of the metal in the reactivity series.

Extraction of Metals from Ores

Which metal can be extracted from the azure ore?

Copper metal can be extracted from the azure mineral, as shown above. A rock that contains important minerals is called an **ore**. The concentration of valuable minerals in an ore may be high or low. Certain places on Earth are more likely to have certain ores. Also, in some places, there is a high content of metals in the ores. For example, if you want copper, you must look at regions with particular geology. Copper is often found where hot fluids once come off a magma intrusion. Aluminum is found in intensely weathered soils in tropical areas.

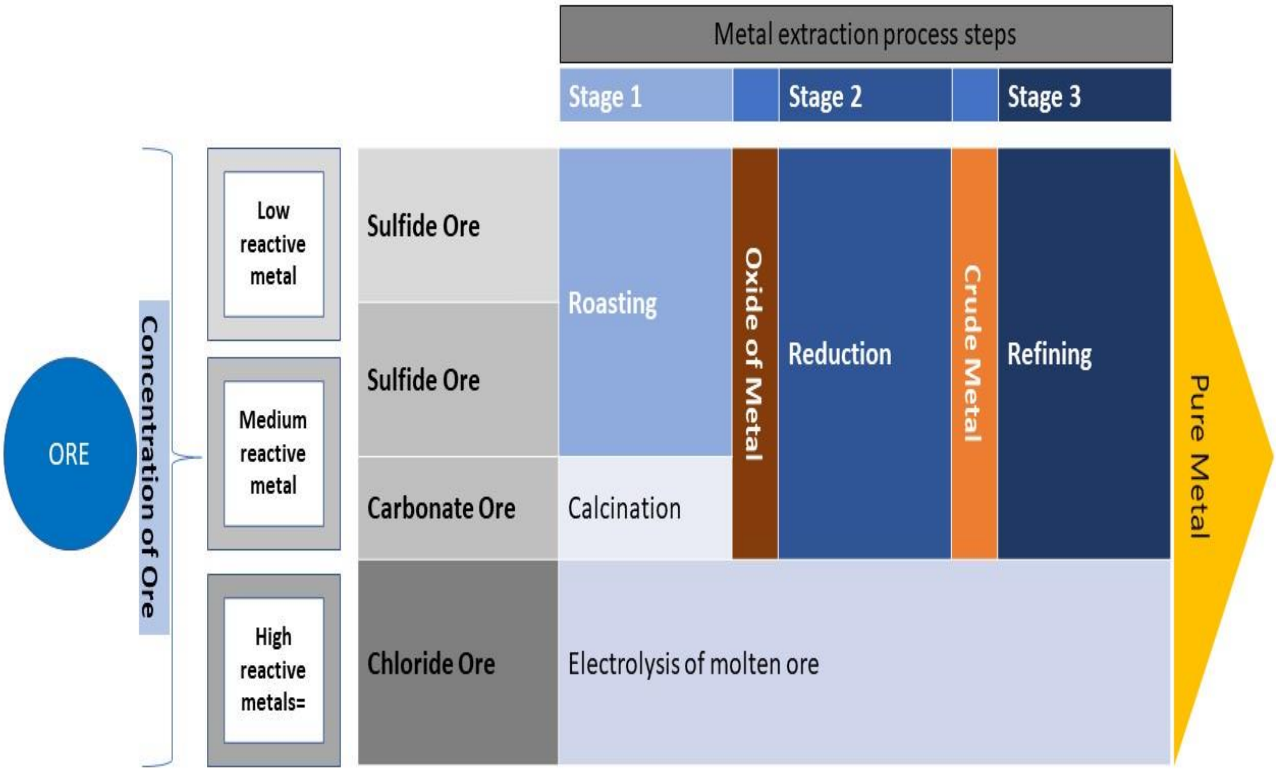
Extraction of Metals

We already know that as per the reactivity series of metals, the most reactive metals are at the top of the series while the least reactive ones are at the bottom. Metals that are least reactive such as gold, platinum, and silver occur in a free state in the Earth's crust. However, in their ore these metals can be associated with sulfide minerals such as pyrites, chalcopyrites, etc. However, other low reactive metals such as mercury exist as its sulfide in cinnabar ore.

Metals such as zinc and iron, etc., that come in the middle of the series are moderately reactive and occur as their oxides, sulfides and carbonates, in the Earth's crust. For example, zinc occurs as its sulfide in the ore zinc blende and as carbonate in the ore smithsonite while iron occurs as sulfides in iron pyrite and as an oxide in magnetite ore.

The most reactive metals, such as sodium, can occur as its chloride in rock salt ore and as nitrate in Chile saltpetre. Therefore, metals can be classified on the basis of their reactivity as metals with low reactivity, metals with moderate reactivity, and metals with high reactivity.

Now, there are various steps, such as the concentration of ore, roasting, calcination, reduction, electrolysis, and refining,that can be involved in the extraction of metals from their respective ores. Metals with different reactivities undergo different steps for their extraction, as shown in the **Figure** below.



Steps in the extraction of metals from their ores.

Concentration of Ores

The very first step, which is the concentration of ore, involves the removal of gangue particles that can be achieved using gravity separation, froth floatation, magnetic separation, and or leaching processes.

- The **gravity separation method** is used when gangue particles are lighter than the ore. This method is generally used for the concentration of oxides and carbonate ores. The method involves the passing of crushed ore particles through a stream of water during which the lighter gangue particles are washed away.
- The **froth floatation method** is used to remove gangue particles from sulfide ores. In this method, the crushed ore and water are added to a tank in which a frother, such as pine oil, is added and then air is blown under pressure to create the froth. The gangue particles will be wetted by water and the metal comes up with the froth.
- The **magnetic separation method** is used when either metal or gangue particles have magnetic properties. In this method, the crushed ore is passed over conveyor belts with magnetic rollers.
- The **leaching method** is used to concentrate ores of aluminium, silver, and gold, etc. In this method, the crushed ore is treated with a solvent that dissolves the ore leaving behind the impurities.

Metal Extraction Processes

Roasting and Calcination

Roasting is the heating of concentrated metal ore in presence of air. It is mainly done for metal sulfide ores to convert them into their respective oxides. For example, cinnabar is a sulfide ore of mercury with the chemical formula of . When the ore is heated in presence of air, it is first converted into mercuric oxide and then upon further heating, liquid mercury is formed:

When zinc blende undergoes roasting, zinc sulfide present in the ore is converted into zinc oxide:

Calcination is the process in which ore is heated in the absence or in a limited supply of air. This method is commonly used to convert metal carbonates and metal hydroxides into their respective oxides.

Zinc oxide and carbon dioxide gas are formed when smithsonite, the carbonate ore of zinc, is heated in absence of air:

Similarly, calcium oxide and carbon dioxide gas are formed when limestone, the carbonate ore of calcium, is heated in a limited supply of air:

Reduction and Electrolytic Reduction

The metal oxides produced in the roasting and the calcination processes further undergo reduction to produce impure metal. Reduction can be done using an appropriate reducing agent such as carbon or hydrogen or carbon monoxide. When zinc oxide is reduced with carbon, impure zinc metal and carbon monoxide gas is produced:

When copper oxide is heated in presence of hydrogen, copper oxide is reduced to copper:

The reduction of metal oxide can also be achieved by using a displacement reaction in which a more reactive metal replaces the less reactive one. Since aluminium is a more reactive metal than copper, when copper oxide is heated with aluminium metal, copper and aluminium oxide are produced. This is known as the **thermite reaction** in which aluminium metal is oxidized by some other metal:

A thermite reaction is used to join railway tracks. When iron oxide is heated with aluminium, iron and aluminium oxide are produced along with a large amount of heat that keeps the metal in a molten state which is helpful for joining the railway tracks.

The highly reactive metals such as sodium and magnesium, etc., cannot be obtained by the reduction of their respective metal oxides because these metals have a high affinity for oxygen. Therefore, these metals can be isolated by the **electrolytic reduction** of their molten salts.

The electrolytic cell consists of an anode and a cathode made of graphite and an electrolyte which is the molten metal salt. The molten salts contain their respective ions. For example, molten sodium chloride contains sodium ions and chloride ions. When an electric current is passed through the cell, the sodium ions present in the electrolyte get reduced at the cathode and converted into pure sodium metal while the chloride ions are oxidized at the anode and released as chlorine gas.

At the cathode:

At the anode:

The overall reaction:

Refining of the Metal

The impure metal produced in the reduction process needs to be refined in order to obtain pure metal. One of the refining methods is **electrolytic refining** in which a strip of impure metal is made at the anode while pure metal is made at the cathode. The metal salt solution is used as the electrolyte in this process.

When an electric current is passed through the cell, the pure metal from the anode goes into the electrolyte and the same amount of pure metal then is deposited at the cathode. During this process, the insoluble impurities settled below the anode as anode mud.

Impure copper can be purified by the electrolytic refining method. An impure copper strip acts as the anode, pure copper strip as the cathode, and the aqueous solution of copper sulfate as the electrolyte. When an electric current is passed through the cell, copper at the anode will be oxidized into copper ions and go into the electrolyte solution. The copper ions in the electrolyte are reduced and get deposited at the cathode.

Summary

- A rock that contains important minerals is called ore.
- Metals are found as free or in a combined state with their respective ores.
- In order to extract pure metals from their respective ores, various steps such as the concentration of ores, roasting, calcination, reduction, electrolytic reduction, and electrolytic refining are involved depending upon the type of metal ore.

EXPLAIN

1. How can the impure metal from its sulfide ore can be extracted

2. Which process is used to convert concentrated metal carbonate ore into its metal oxide

3. Which method can be used for the concentration of zinc blende ore

4. What is the process used to extract highly reactive metals from their salts

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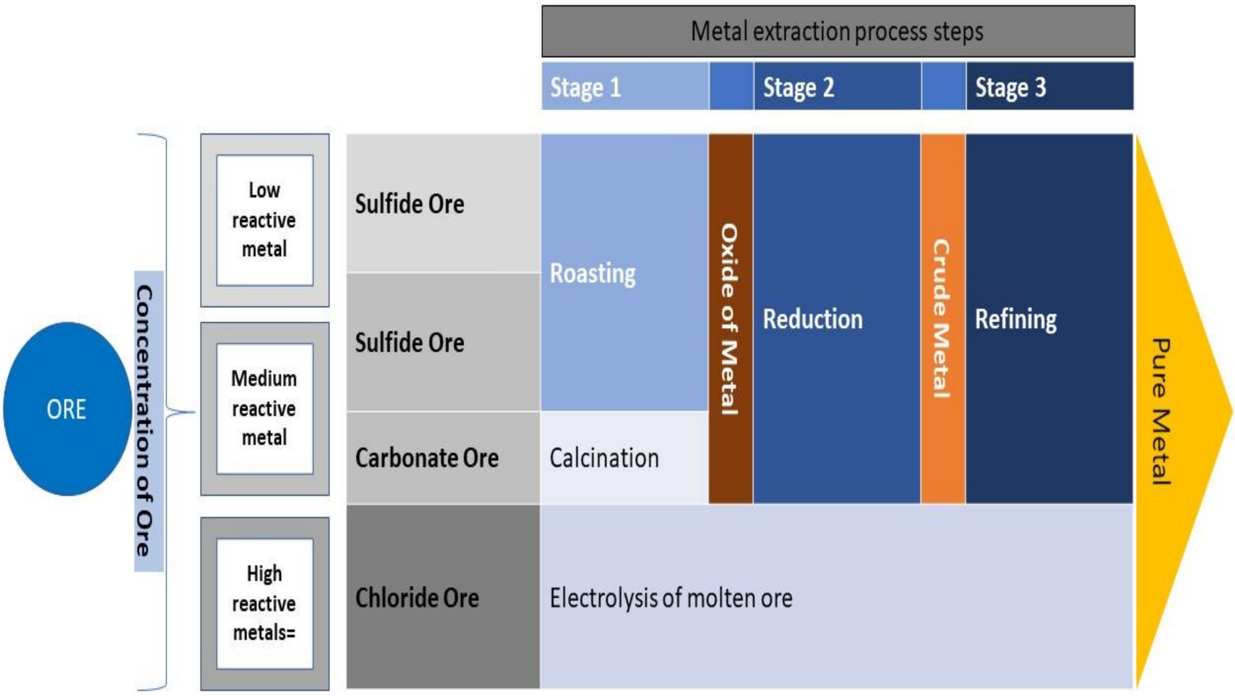

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At the cathode: $M^{n+} + ne \longrightarrow M$

At the anode: $X^{n-} \longrightarrow X_n$

Write the overall reaction equation

Refining of the Impure Metal

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Questions

1. How can the impure metal from its sulfide ore be extracted?

2. Which process is used to convert concentrated metal carbonate ore into its metal oxide?

3. Which method can be used for the concentration of zinc blende ore?

4. What is the name of the process used to extract highly reactive metals from their salts?

Extracting copper from its ores

The method used to extract copper from its ores depends on the nature of the ore. Sulfide ores such as chalcopyrite ($CuFeS_2$) are converted to copper by a different method from silicate, carbonate or sulfate ores. Chalcopyrite (also known as copper pyrites) and similar sulfide ores are the commonest ores of copper. The ores typically contain low percentages of copper and have to be concentrated before refining (e.g., via froth flotation).


Figure 1: Chalcopyrite extracted from Zacatecas, Mexico. from Rob Lavinsky (iRocks.com) under a CC-BY-SA-3.0 license.

The Process

The concentrated ore is heated strongly with silicon dioxide (silica) and air or oxygen in a furnace or series of furnaces.

- The copper(II) ions in the chalcopyrite are reduced to copper(I) sulfide (which is reduced further to copper metal in the final stage).
- The iron in the chalcopyrite ends up converted into an iron(II) silicate slag which is removed.
- Most of the sulfur in the chalcopyrite turns into sulfur dioxide gas. This is used to make sulfuric acid via the Contact Process.

An overall equation for this series of steps is:

$2CuFeS_2+2SiO_2+4O_2 \rightarrow Cu_2S+2FeSiO_3+ 3SO_2$

The copper (I) sulfide produced is converted to copper with a final blast of air.

$Cu_2S + O_2 \rightarrow 2Cu+SO_2$

The end product of this is called *blister copper* - a porous brittle form of copper, about 98 - 99.5% pure.

Exploring the redox processes in this reaction

It is worthwhile spending some time sorting out what the reducing agent is in these reactions, because at first sight there does not appear to be one! Or, if you look superficially, it seems as if it might be oxygen! But that'sn't the case! We'll start by looking at the second reaction because it is much easier to see what is happening.

$Cu_2S +O_2 \rightarrow 2Cu + SO_2(g)$

Let's look at the oxidation states of everything.

- In the copper (I) sulfide, the copper is +1 and the sulfur -2.
- The oxidation states of the elements oxygen (in the gas) and copper (in the metal) are 0.
- In sulfur dioxide, the oxygen has an oxidation state of -2 and the sulfur +4.

That means that both the copper and the oxygen have been reduced (decrease in oxidation state). The sulfur has been oxidized (increase in oxidation state). The reducing agent is therefore the sulfide ion in the copper(I) sulfide.

The other reaction is more difficult to deal with, because you can't work out all of the oxidation states by following the simple rules - there are too many variables in some of the substances. You have to use some chemical knowledge as well.

$2CuFeS_2 + 2SiO2 + 4O_2 \rightarrow Cu_2S + 2FeSiO_3 + 3SO_2$

In the $CuFeS_2$, you would have to know that the copper and iron are both in oxidation state +2, for example. You would also have to know that the oxidation state of the silicon remains unchanged at +4. So use that information to work out what has been oxidized and what reduced in this case!

You should find that copper has been reduced from +2 to +1; oxygen (in the gas) has been reduced from 0 to -2 (oxygen in the SiO_2 is unchanged); and three of the four sulfurs on the left-hand side have been oxidized from -2 to +4 (the other is unchanged). Once again, the sulfide ions are acting as the reducing agent.

Extracting of Copper from Other Ores

Copper can be extracted from non-sulfide ores by a different process involving three separate stages:

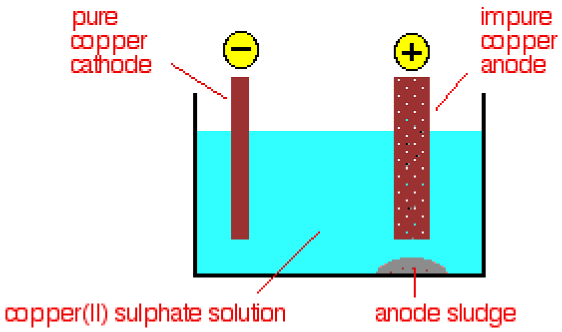
1. Reaction of the ore (over quite a long time and on a huge scale) with a dilute acid such as dilute sulfuric acid to produce a very dilute copper(II) sulfate solution.
2. Concentration of the copper(II) sulfate solution by solvent extraction. The very dilute solution is brought into contact with a relatively small amount of an organic solvent containing something which will bind with copper(II) ions so that they are removed from the dilute solution. The solvent must not mix with the water. The copper(II) ions are removed again from the organic solvent by reaction with fresh sulfuric acid, producing a much more concentrated copper(II) sulfate solution than before.
3. Electrolysis of the new solution. Copper(II) ions are deposited as copper on the cathode (for the electrode equation, see under the purification of copper below). The anodes for this process were traditionally lead-based alloys, but newer methods use titanium or stainless steel. The cathode is either a strip of very pure copper which the new copper plates on to, or stainless steel which it has to be removed from later.

Purification of copper

When copper is made from sulfide ores by the first method above, it is impure. The blister copper is first treated to remove any remaining sulfur (trapped as bubbles of sulfur dioxide in the copper - hence "blister copper") and then cast into anodes for refining using electrolysis.

Electrolytic Refining

The purification uses an electrolyte of copper(II) sulfate solution, impure copper anodes, and strips of high purity copper for the cathodes. The diagram shows a very simplified view of a cell.



At the cathode, copper (II) ions are deposited as copper.

$Cu^{2+(}aq) +2e^{-} \quad \rightarrow Cu(s)$

At the anode, copper goes into solution as copper (II) ions.

$Cu(s) \quad \rightarrow \quad Cu^{2+(}aq)+2e^{-}$

For every copper ion that is deposited at the cathode, in principle another one goes into solution at the anode. The concentration of the solution should stay the same. All that happens is that there is a transfer of copper from the anode to the cathode. The cathode gets bigger as more and more pure copper is deposited; the anode gradually disappears. In practice, it isn't quite as simple as that because of the impurities involved.

What happens to the impurities?

Any metal in the impure anode which is below copper in the electrochemical series (reactivity series) does not go into solution as ions. It stays as a metal and falls to the bottom of the cell as an "anode sludge" together with any unreactive material left over from the ore. The anode sludge will contain valuable metals such as silver and gold.

Metals above copper in the electrochemical series (like zinc) will form ions at the anode and go into solution. However, they won't get discharged at the cathode provided their concentration does not get too high. The concentration of ions like zinc will increase with time, and the concentration of the copper (II) ions in the solution will fall. For every zinc ion going into solution there will obviously be one fewer copper ion formed. (See the next note if you aren't sure about this.) The copper (II) sulfate solution has to be continuously purified to make up for this.

Uses of copper

Amongst other things copper is used for:

- electrical wiring. It is a very good conductor of electricity and is easily drawn out into wires.
- domestic plumbing. It does not react with water, and is easily bent into shape.
- boilers and heat exchangers. It is a good conductor of heat and does not react with water.
- making brass. Brass is a copper-zinc alloy. Alloying produces a metal harder than either copper or zinc individually. Bronze is another copper alloy, but with tin.
- coinage. In many countries, as well as the more obvious copper-colored coins, "silver" coins are also copper alloys - this time with nickel; these are known as cupronickel alloys. UK pound coins and the gold-colored bits of euro coins are copper-zinc-nickel alloys.

EXTRACTION OF IRON

The chief ores are magnetite (Triiron tetraoxide, Fe_3O_4) and haematite(Fe_2O_3)

Extraction of iron from its ore is the third and the penultimate process in the Metallurgy. The extraction of metals and its isolation occurs over a few major steps:

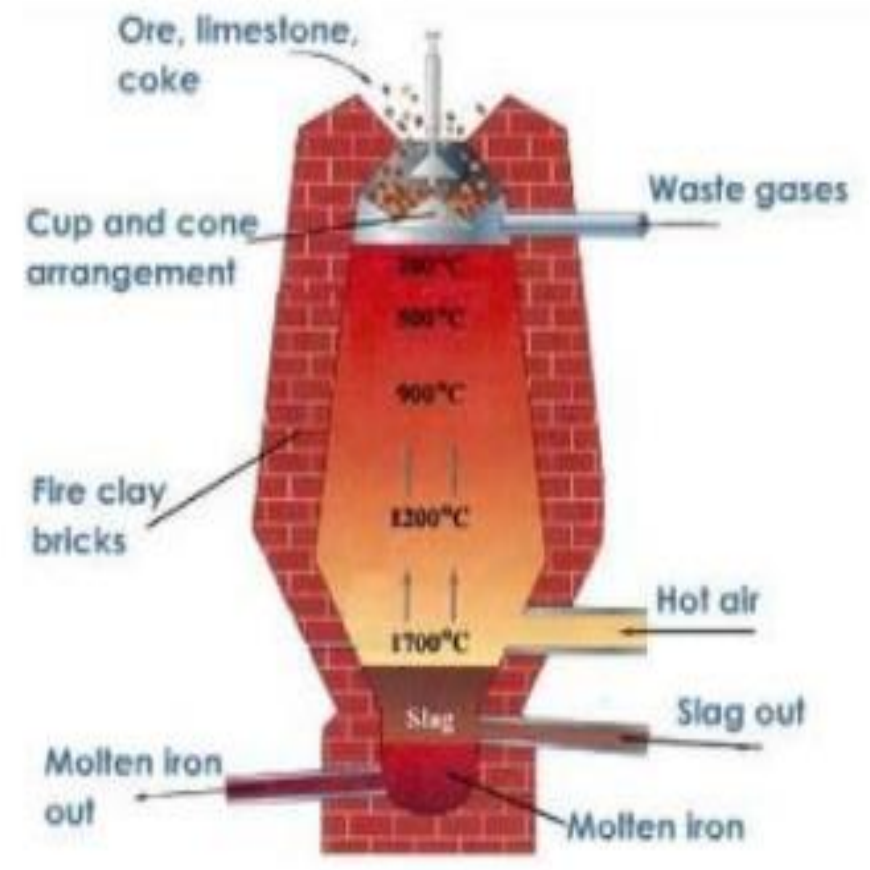
1. Concentration of Ore
2. Extraction of metal from concentrated Ore
3. Purification of the metal

How is iron extracted from its ore? It's a long process which begins with Concentration through calcination roasting. Concentration removes the water and other volatile impurities such as sulphur and carbonates. This concentrated ore is mixed with limestone ($CaCO_3$) and Coke and fed into the blast furnace from the top. It is in the blast furnace that extraction of iron occurs. The extraction of iron from its ore is a long and subdued process that helps in separating the useful components from the waste materials such as slag.

What happens in the Blast Furnace?

The purpose of a Blast Furnace is to reduce the concentrated ore chemically to its liquid metal state. A blast furnace is a gigantic, steel stack lined with refractory brick where the concentrated iron ore, coke, and limestone are dumped from the top, and a blast of hot air is blown into from the bottom. All the three ingredients are crushed into small round pieces and mixed and put on a hopper which controls the input.

Hot air is blown from the bottom and coke is burned to yield temperatures up to about 2200K. Burning coke provides the majority of the heat required for this process. At such high temperatures, Coke reacts with the oxygen in the hot air to form Carbon Monoxide (CO). The CO and heat now move upwards and meet the raw material running down from the top. The temperature in the upper parts of the Blast Furnace is considerably lower than the 2200K at the bottom. In this part, Haematite (Fe_2O_3) and or Magnetite (Fe_3O_4) are reduced to iron



$C + O_2 \longrightarrow CO_2 + \text{heat}$

Carbon dioxide rises and reacts with more coke

$CO_{2\,(g)} + C\,(s) \longrightarrow 2CO(g)$

Carbon monoxide formed reduces the ore to iron

$Fe_3O_{4(s)} + 4CO(g) \longrightarrow 3Fe(s) + 4CO_{2(g)}$

$Fe_2O_{3(s)} + 3CO(g) \longrightarrow 2Fe(s) + 3CO_{2(g)}$

The limestone also decomposes to CaO which removes the silicate impurity of the ore in the form of Slag. It can be easily separated out of molten iron. The iron manufactured in Blast Furnaces contain about 3 – 4 % of Carbon and smaller quantities of many other impurities such as sulphur, Silicon, etc. This is called Pig Iron. It is a hard but brittle metal and the impurities severely hamper its strength. Carbon seems to play a significant role in influencing the brittleness and hardness balance in iron. To further reduce the carbon content of pig iron, it is melted again with scraps of iron and coke and subjected to the blast of hot air. This kind of iron is called Cast Iron and has a slightly lower carbon content 2 – 3 %. This is even harder than pig iron.

Wrought Iron/ Malleable Iron

Wrought iron is the purest form of iron available commercially available and is prepared from cast iron by heating cast iron in a furnace lined with Haematite (Fe_2O_3). The Haematite reacts with Carbon in the cast iron to give pure iron and carbon monoxide gas which escapes.

$$Fe_2O_3(s) + 3C(s) \longrightarrow 3\,Fe(s) + 3\,CO(g)$$

Limestone is then added as flux, and it creates the slag. Impurities such as S, Si pass into the slag and the slag later can be easily separated to yield pure iron.

Questions

1. Distinguish between cast(pig) iron and wrought iron
2. State the uses of
   a) Pig iron
   b) Wrought iron.
3. Explain how steel is better suited than the two forms of iron above, for construction works and electronics

Extraction of Aluminium from Bauxite

- Aluminium is a reactive metal, above carbon in the reactivity series
- Its main ore, is **bauxite**, $Al_2O_3.2H_2O$ which is a hydrated form of aluminium oxide.
- Aluminium is higher in the reactivity series than carbon, so it cannot be extracted by reduction of the ore using carbon
- Instead, aluminium is extracted by **electrolysis** of molten ore.

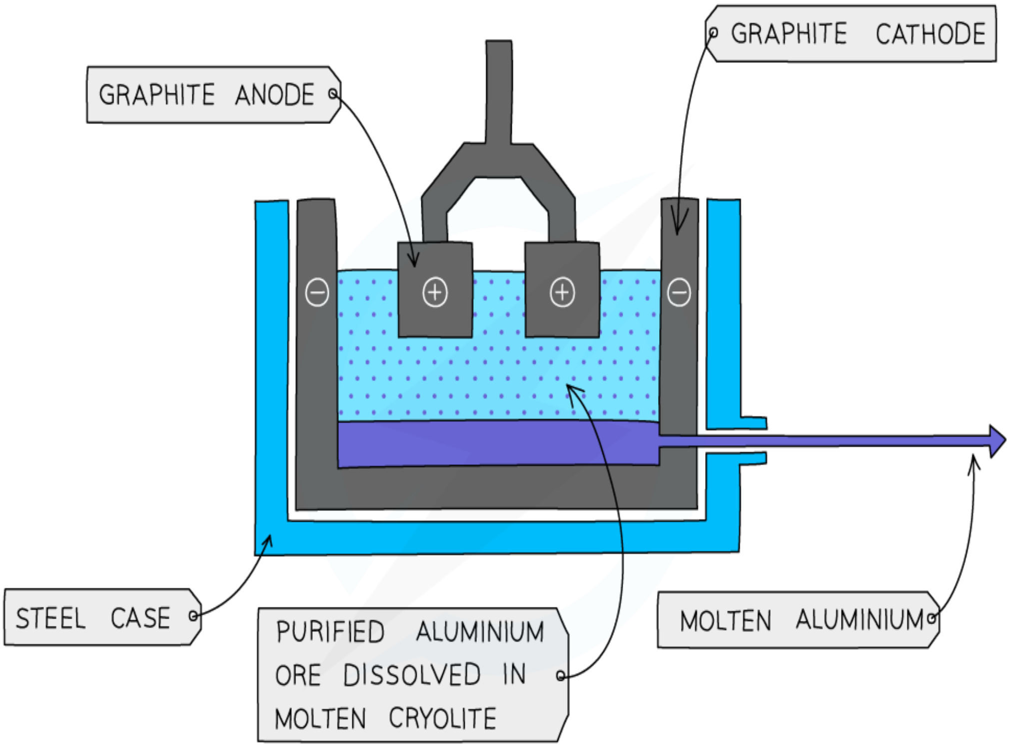


Diagram showing the extraction of aluminium by electrolysis

- Bauxite is first **purified** to produce aluminium oxide, Al_2O_3
- Aluminium oxide is then dissolved in **molten cryolite,** Na_3AlF_6

  - This is because aluminium oxide has a melting point of over 2000°C which would use a lot of energy and be very expensive
  - The resulting mixture has a lower melting point without interfering with the reaction
- The mixture is placed in an electrolysis cell, made from steel, lined with graphite
- The **graphite** lining acts as the negative electrode, with several large graphite blocks as the positive electrodes
- At the **cathode** (negative electrode)**:**
  - Aluminium ions gain electrons (reduction)
  - Molten aluminium forms at the bottom of the cell
  - The molten aluminium is siphoned off from time to time and fresh aluminium oxide is added to the cell

$$Al^{3+} + 3e^- \rightarrow Al$$

- At the **anode** (positive electrode)**:**
  - Oxide ions lose electrons (oxidation)
  - Oxygen is produced at the anode:

$$2O^{2-} \rightarrow O_2 + 4e^-$$

- The overall equation for the reaction is:

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

- The carbon in the **graphite** anodes reacts with the oxygen produced to produce **CO_2**

$$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$$

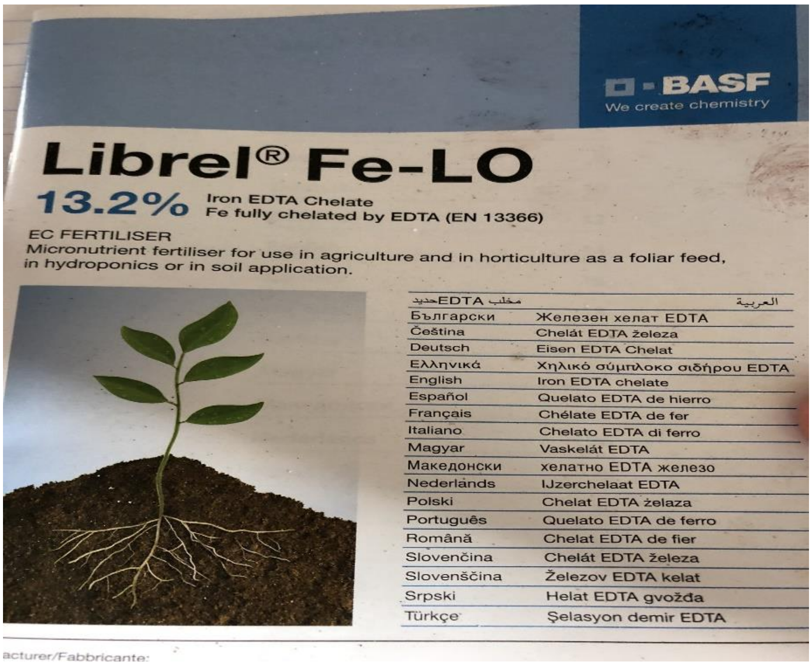
- As a result the anode wears away and has to be replaced regularly
- A lot of **electricity** is required for this process of extraction, this is a major **expense**

AGROCHEMICALS

Agrochemicals are **chemical products comprised of fertilizers, plant-protection chemicals or pesticides, and plant-growth hormones used in agriculture.**

Agrochemicals enable farmers to yield more crops from per acre of land for a longer period. As they protect crops from pests, disease and weeds ensuring good harvest. It has environmental benefits too as less area can produce huge yields therefore the rate of deforestation is reduced.

FERTILIZERS



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13.2% Iron EDTA Chelate
Fe fully chelated by EDTA (EN 13366)

EC FERTILISER
Micronutrient fertiliser for use in agriculture and in horticulture as a foliar feed,
in hydroponics or in soil application.

العربية	حديدEDTA مخلب
Български	Железен хелат EDTA
Čeština	Chelát EDTA železa
Deutsch	Eisen EDTA Chelat
Ελληνικά	Χηλικό σύμπλοκο σιδήρου EDTA
English	Iron EDTA chelate
Español	Quelato EDTA de hierro
Français	Chélate EDTA de fer
Italiano	Chelato EDTA di ferro
Magyar	Vaskelát EDTA
Македонски	хелатно EDTA железо
Nederlands	IJzerchelaat EDTA
Polski	Chelat EDTA żelaza
Português	Quelato EDTA de ferro
Română	Chelat EDTA de fier
Slovenčina	Chelát EDTA železa
Slovenščina	Železov EDTA kelat
Srpski	Helat EDTA gvožđa
Türkçe	Şelasyon demir EDTA

acturer/Fabbricante:

A fertilizer or fertiliser is any substance of natural or synthetic origin that is applied to soil or to plant tissues to supply plant nutrients. Fertilizers may be distinct from liming substances or other non-nutrient soil amendments. Many sources of fertilizer exist, both natural and industrially produced. Fertilizers may be organic or inorganic. Organic fertilizers are found in nature as animal or plant remains or animal or plant excreta eg cow dung, chicken droppings, banana peelings, food remains etc.

Inorganic fertilizers are the synthetic type and they are manufactured industrially.

Activity

In your groups

- **a)** List as many industrial fertilizers that you know
- **b)** What companies in Uganda manufacture the fertilizers you have listed?

NITROGENOUS FERTILIZERS

These are fertilizers which contain nitrogen as the major element.

They include nitrates, eg ammonium nitrate, potassium nitrate

and sulphate or chloride or phosphate of ammonia.

Activity

- a) Write names and chemical formulae of at least five nitrogenous fertilizers used in Uganda
- b) Calculate the percentage composition by mass of nitrogen in each fertilizer you have named.

The Role of Nitrogen in Crop Production

Nitrogen is an essential macronutrient for plant function and is a key component of amino acids, which form the building blocks of plant proteins and enzymes. Proteins make up the structural materials of all living matters and enzymes facilitate the vast array of biochemical reactions within a plant. Nitrogen is also a component of the chlorophyll molecule, which enables the plant to capture sunlight energy by photosynthesis, driving plant growth and grain yield.

Nitrogen plays a critical role within the plant to ensure energy is available when and where the plant needs it to optimize yield. This crucial nutrient is even present in the roots as proteins and enzymes help regulate water and nutrient uptake.

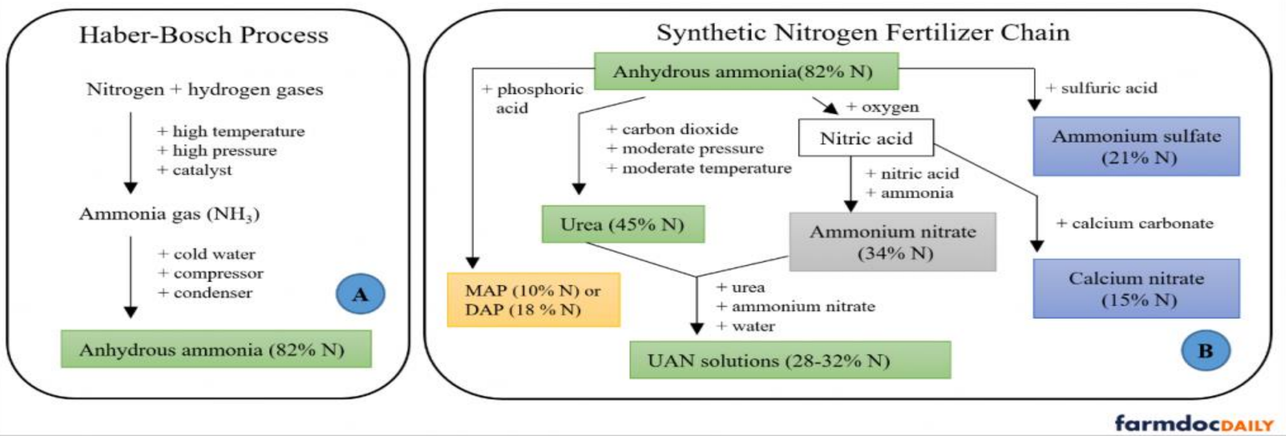
MANUFACTURE OF NITROGENOUS FERTILIZERS

For nitrogen-based fertilizers, the largest product group, the process starts by **mixing nitrogen from the air with hydrogen from natural gas at high temperature and pressure to create ammonia**. Approximately 60% of the natural gas is used as a source of hydrogen, with the remainder employed to power the synthesis process.

Nitrogen is obtained from air mainly by fractional distillation of liquefied air after removing dust, water vapour and carbon dioxide (Refer to preparation of nitrogen by fractional distillation of liquefied air).

Ammonia obtained by the Haber process is then treated with different acids to obtain sulphate, nitrate, phosphate etc. Nitrogenous fertilizers of metals such as calcium nitrate can be obtained by treating an oxide or hydroxide of the metal with dilute nitric acid

Figure 1. Diagram of the Haber-Bosch process (A) and a simplified scheme showing different nitrogen fertilizers and products obtained from anhydrous ammonia (B). N: nitrogen; MAP: monoammonium phosphate; DAP: diammonium phosphate; UAN: urea-ammonium nitrate.



Effects of agrochemicals on the Environment

Agrochemicals, as the name suggests, are used in agriculture to facilitate plant growth and protection. They are also called agricultural chemicals.

These chemicals were initially used to improve crop production, however, their overuse has now affected the environment. Agrochemicals seep into the surrounding land and water bodies, entering the food chain which leads to bioaccumulation.

Regarding their impact on crops, excessive use of such chemicals generates a significant amount of residues. These residues cause nutrient imbalance and quality-reduction of agricultural produce. Consumption of these residues has been linked to various illnesses. For example, pesticide residues in food can increase the risk of asthma in humans.

Effect on Soil

- They may kill bacteria and other organisms beneficial to the soil
- Increase nitrate content in the soil
- Alter pH levels
- Unnatural growth effects

- Residual effects
- Can bioaccumulate; thereby entering the food chain

Effect on Water

- Make water unfit for consumption.
- Agrochemicals in water diffuse with larger water bodies to promote the growth of algae – which can cause organisms such as fish to die. (This phenomenon is widely called Fish kills)
- Excess chemicals lead to eutrophication.
- Leads to water pollution.
- Alters the chemical properties of water.

Read More: Eutrophication.

Effect on Air

- Pesticide particles diffuse in air, altering the composition of air
- Winds disperse polluted air across large areas, spreading their ill effects.
- Increases risk of respiratory illnesses.

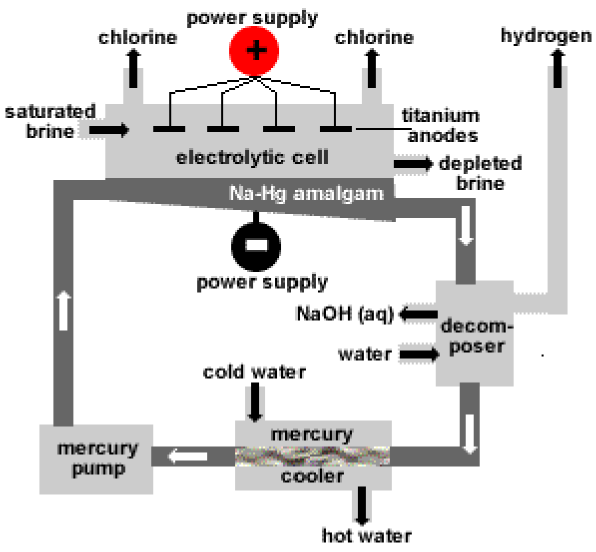
In your groups, discuss the mitigation steps for the danger posed by these agrochemicals

ALKALI INDUSTRY

MANUFACTURE OF SODIUM HYDROXIDE AND INDUSTRIAL CHLORINE

Electrolytic Cells for the Production of Sodium Hydroxide

Castner-Kellner Cell (Mercury Process)



- Anode (positive electrode): titanium

  Anode reaction (oxidation):
  $2Cl^{-}_{(aq)} \rightarrow Cl_{2(g)} + 2e^{-}$

- Cathode (negative electrode): mercury flowing along bottom of cell

  Cathode reaction (reduction):
  $Na^{+}_{(aq)} + e^{-} \rightarrow Na_{(s)}$

- $Na_{(s)}$ dissolves in the liquid mercury to form an amalgam which is removed to the decomposer.
- In the decomposer the amalgam reacts with water to form sodium hydroxide, hydrogen gas and mercury.

  $2Na/Hg + 2H_2O_{(l)} \rightarrow 2Na^{+} + 2OH^{-} + H_{2(g)} + 2Hg_{(l)}$
  Sodium hydroxide solution and hydrogen gas are collected.
  Mercury is recycled through the electrolytic cell.

- Mercury is toxic so care must be taken to prevent mercury from escaping.

NOTE: The sodium hydroxide solution is concentrated by evaporation until pellets begin to form

USES OF SODIUM HYDROXIDE

Manufacturers may use sodium hydroxide to **produce soaps, rayon, paper, products that explode, dyes, and petroleum products**. Other tasks that may use sodium hydroxide include processing cotton fabric, metal cleaning and processing, oxide coating, electroplating, and electrolytic extraction.

USES OF CHLORINE

Chlorine has a variety of uses. It is used **to disinfect water and is part of the sanitation process for sewage and industrial waste**. During the production of paper and cloth, chlorine is used as a bleaching agent. It is also used in cleaning products, including household bleach which is chlorine dissolved in water.

TASK

Make research on the environmental effects of the alkali industry and how these effects can be mitigated.

POLYMERS

1. a) What do you understand by a polymer?

b) Name any five polymers that you know and state their monomer(s)

c) Distinguish between natural and synthetic polymers

d) Draw a table categorizing some addition and some condensation polymers

2. How are synthetic polymers different from natural polymers structurally and behaviorally?

3.What are the dangers of poor disposal of synthetic polymers? How can these be mitigated?

4. Discuss the benefits and negative impact of chemical industries in Uganda and suggest how the negative impact can be addressed or mitigated.