

**SUBJECT:** CHEMISTRY  
**TOPIC:** ALKANOIC ACIDS  
**CLASS:** SS 3  
**ABILITY:** MIXED

**OBJECTIVES:** *At the end of the topic, the students should be able to:*

- Identify the functional group presents in alkanolic acid:
- Give the general formula of alkanolic acids:
- Write names and structures of some alkanolic acids:
- State some physical properties of alkanolic acids:
- Write reactions for chemical properties of alkanolic acids:
- Give some uses of alkanolic acids.

**PREVIOUS KNOWLEDGE:** Students have knowledge of homologous series, isomerism in alkanols.

### DEVELOPMENT

All alkanolic acids contains the carboxyl group – COOH as their functional group. Hence they are called carboxylic acids. They form homologous series with the general formula  $C_nH_{2n+1}COOH$ , when  $n \geq 0$ .

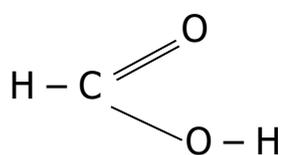
They are sometimes called fatty acids because some of them are found in natural fats and oils

### IUPAC NOMENCLATURE

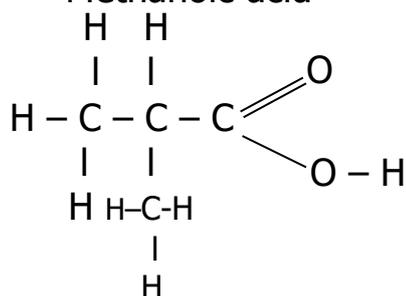
The IUPAC nomenclature for alkanolic acids involve changing the ending 'e' of the alkane and adding – OIC acid.

FORMULA	IUPAC NAME	COMMON NAME
HCOOH	Methanoic acid	Formic acid (art-fornica)
CH <sub>3</sub> CH <sub>2</sub> COOH	Ethanoic acid	Acetic acid (vinegar)
CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> COOH	Butanoic acid	Butyric acid (spoilt butter)

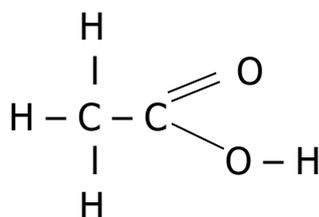
### STRUCTURE OF ALKANOIC ACIDS



Methanoic acid



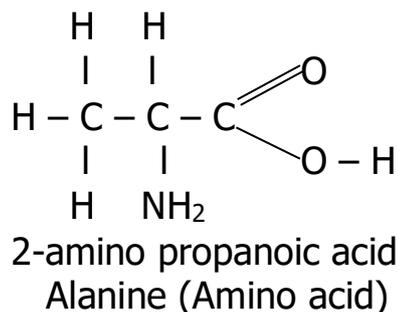
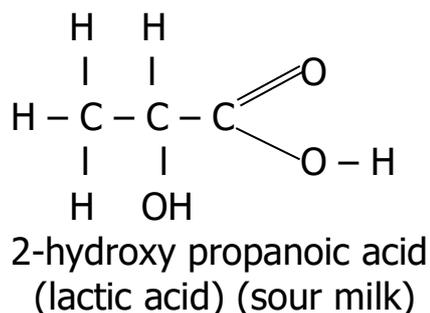
2-methyl Propanoic Acid.



Ethanoic acid.

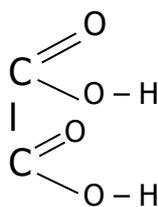


Some monocarboxylic acids have other additional functional groups e.g. OH and NH<sub>2</sub> groups.

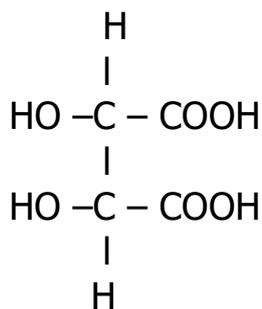
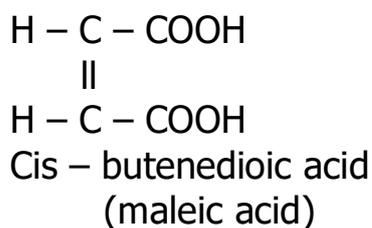


### DICARBOXYLIC ACIDS

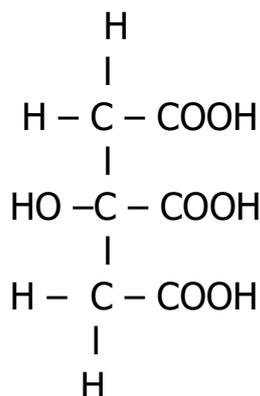
Some acids contain more than one carboxylic acid group e.g.



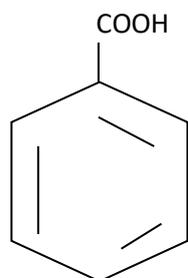
ethanedioic acid (oxalic)



2,3-dihydroxybutanedioic acid  
Tartaric acid (grape fruit)

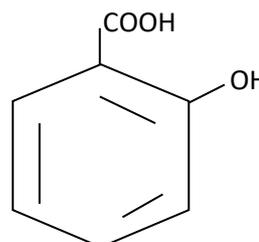


2-dihydroxypropane-  
1,2,3-tricarboxylic acid  
citric acid (lemon)



Benzoic acid

### ORGANIC ACIDS (AROMATIC)

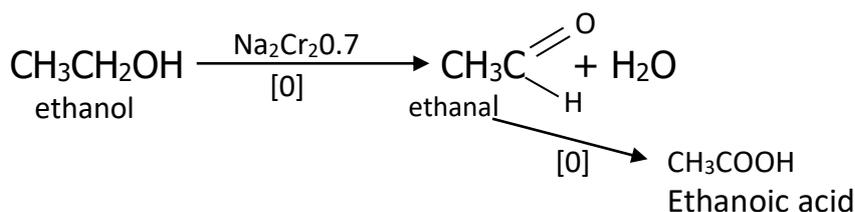


2-hydroxy benzoic acid  
(salicylic acid)  
Aspirin.

## PREPARATION OF ETHANOIC ACID

Ethanoic acid can be prepared by the complete oxidation of ethanol by acidified sodium dichromate (vi), ( $\text{Na}_2\text{Cr}_2\text{O}_7$ )

- Ethanol undergoes oxidation first to ethanal



The ethanal is oxidised further to ethanoic acid.

*Note:* The ethanol is dropped into a large excess of the oxidizing agent and distilled under reflux so that the reactants are brought into close and prolonged contact.

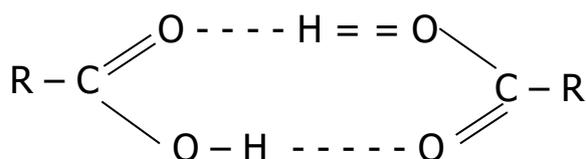
*Assignment:* Students to write the procedure for the process.

## PHYSICAL PROPERTIES OF ETHANOIC ACID

1. Ethanoic acid is a colourless liquid with a characteristic sharp and pungent smell.
2. The dilute solution has a sour taste.
3. It is very soluble in water.
4. The pure anhydrous ethanoic acid is called glacial ethanoic acids because it freezes into ice-like crystals at temperatures below  $17^\circ\text{C}$ .
5. It has a boiling point of  $118^\circ\text{C}$ .
6. It turns blue litmus paper red.

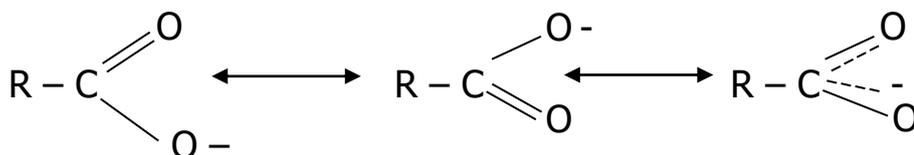
## DIMERISATION

The boiling point of ethanoic acid is higher than expected due to formation of hydrogen bonds. They form dimers

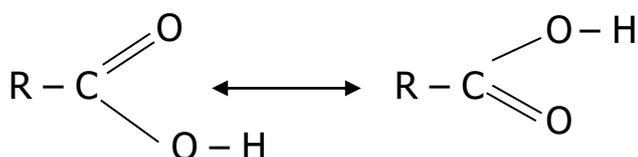


## CHEMICAL PROPERTIES

The carboxyl group is a resonance structure.



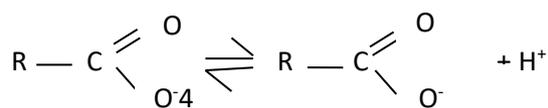
OR



The 2 C – O bonds are of equal length and identical. The double bond character is equally distributed.

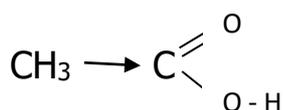
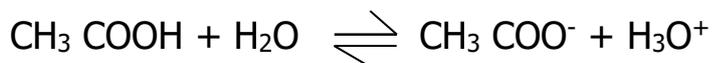
## ACID STRENGTH

They are weak acids. They turn blue litmus paper faintly red.

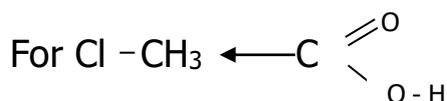


That is

Alkanoate ion



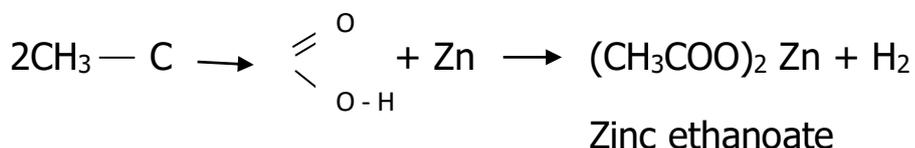
Very weak as  $CH_3$  pushes in electron to the group and  $O-H$  bond get stronger. Hydrogen cannot leave easily.



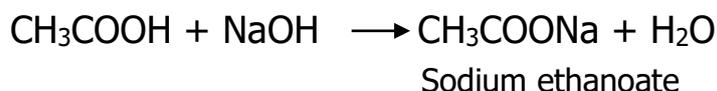
$Cl^-$  withdraws electrons to itself and weakens the  $OH$  group. Chloroethanoic acid is a strong acid.

## OTHER REACTIONS

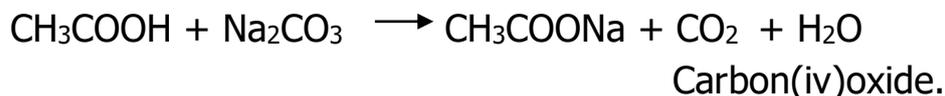
1. Reaction with Metals: Ethanoic acid reacts with highly electropositive metals to liberate hydrogen gas.



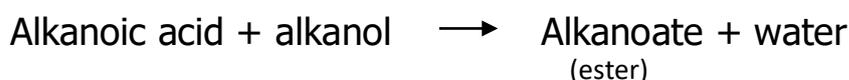
2. Neutralization: Ethanoic acid reacts with alkali to give organic salt and water.



3. Reaction with Trioxcarbonates (iv) to give carbon(iv) oxide.



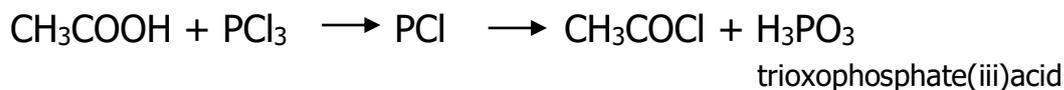
4. Esterification: This is the reaction between an alkanol and an alkanolic acid to give an alkanoate and water only.



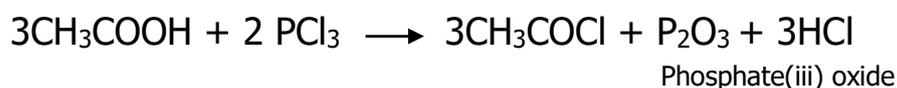
## 5. Formation of Acyl chloride



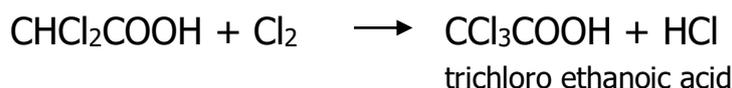
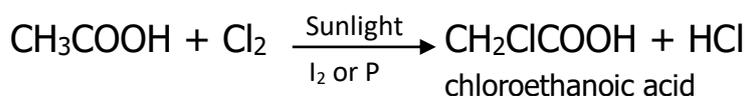
Using Phosphorus III chloride



or

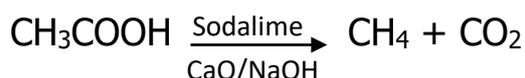


## 6. Formation of chloro alkanolic acid. (substitution reaction)

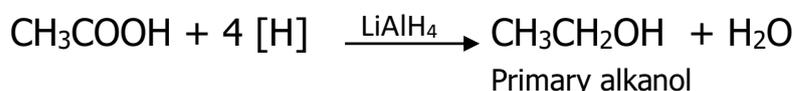


Note that the hydrogen of the methyl group is gradually replaced.

## 7. De Carboxylation: if acid is heated strongly with sodalime, methane will be produced.



## 8. Reduction: Ethanoic acid can be reduced to primary alkanol using lithium tetrahydride aluminate(iii)



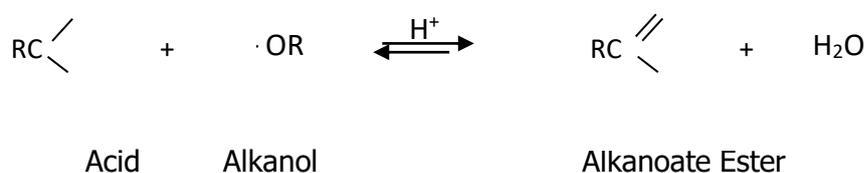
### USES OF ETHANOIC ACID

- Ethanoic acid is used in making compounds like:
  - Ethanoic anhydride which is used in making aspirin
  - Cellulose ethanoate which is used for packing cigarette filters etc.
  - For producing dyes.
- Ethanoic acid is an important organic solvent
- It is used in the food industry as vinegar for preserving food.
- It can be used for coagulating rubber latex.

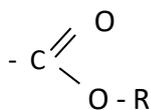
## ALKANOATES (ESTERS)

Alkanoates are formed by the reaction between alkanolic acids and alkanols. The alkanoates are usually referred to as esters and the reaction for their formation is known as Esterification. Esters are the main constituents of many naturally occurring fats and oils. Many of them have pleasant smells and are largely responsible for the fragrance of flowers and the flavor of fruits. Eg.

HCOOC <sub>2</sub> H <sub>5</sub>	used as	Rum flavouring
CH <sub>3</sub> COOC <sub>2</sub> H <sub>5</sub>		Perfume
CH <sub>3</sub> COOC <sub>5</sub> H <sub>11</sub>		Odour of banana (banana oil)
CH <sub>3</sub> COOC <sub>2</sub> H <sub>17</sub>		Smell of oranges
C <sub>3</sub> H <sub>7</sub> COOC <sub>2</sub> H <sub>5</sub>		Pineapple flavouring



Alkanoates have the general formula C<sub>n</sub>H<sub>2n+1</sub>COO C<sub>m</sub>H<sub>2m</sub> + 1 or R COOR<sup>1</sup> where R and R<sup>1</sup> where R and R<sup>1</sup> are whole numbers. The functional group in alkanoate is – COOR or



### PREPARATION OF ETHYL ETHANOATE

In a dry round bottomed flask add a mixture of ethanol (25)cm<sup>3</sup> and 25cm<sup>3</sup> of tetraoxosulphate (vi) acid. Setup a distilling flask. Add an equal volume of ethanoic acid through a dropping funnel.

As the oil bath gets to 150<sup>o</sup>c the ethyl ethanoate distills over. The distillate contains impurities like ethanol, acids, water and ethoxy ethane, apart from ethyl ethanoate.

### PURIFICATION OF THE ETHYL ETHANOATE

1. Shake the distillate in a separating funnel with ConC Na<sub>2</sub>CO<sub>3</sub> to remove the acidic impurities.
2. Na<sub>2</sub>CO<sub>3</sub> + 2CH<sub>3</sub>COOH → 2CH<sub>3</sub>COONa + H<sub>2</sub>O + CO<sub>2</sub>.
3. Discard the lower aqueous layer and shake with ConC CaCl<sub>2</sub> solution to remove the ethanol
4. Add anhydrous Calcium chloride to remove water
5. Finally, filter the mixture, distill it over a water bath and collect the fraction which over between 74 to 79<sup>o</sup>c

## DIAGRAM FOR PREPARATION OF ETHYL ETHANOATE

### Fifteen lines for diagram

#### PHYSICAL PROPERTIES

1. Ethyl Ethanoate is a colourless volatile liquid with a pleasant smell.
2. It is slightly soluble in water but readily soluble in organic solvent examples benzene, ethanol, etc.
3. It has a boiling point of about 76<sup>o</sup>C

#### CHEMICAL PROPERTIES

1. HYDROLYSIS  
 $\text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH}$   
With Alkali,  
 $\text{CH}_3\text{COOC}_2\text{H}_5 + \text{NaOH} \rightleftharpoons \text{CH}_3\text{COONa} + \text{C}_2\text{H}_5\text{OH}$
2. With Ammonia  
 $\text{CH}_3\text{COOC}_2\text{H}_5 + \text{NH}_3 \rightarrow \text{C}_2\text{H}_5\text{OH} + \text{CH}_3\text{CONH}_2$   
ethanamide
3. Reduction (using tetrahydrido Aluminide (iii))  
 $\text{CH}_3\text{COOC}_2\text{H}_5 + 4(\text{H}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}$

#### NAMING OF ALKANOATES

Note convention used in writing the formula of Alkanoates. The alkyl group on the right of the formula indicates the alkanol end, while the Alkyl group on the left of the formula indicates the acid from which it is derived. In naming, name the alkanol end first.

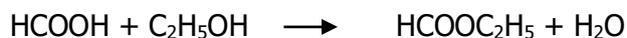
$\text{HCOOC}_2\text{H}_5$  — Ethyl methanoate

$\text{C}_2\text{H}_5\text{COOC}_2\text{H}_3$  — Methyl Propanoate

Acid end    Alkanol end

$\text{C}_3\text{H}_7\text{COOC}_2\text{H}_5$             Ethyl butanoate

Pairs of this compound yield different products on hydrolysis



Acid end    Alkanol end



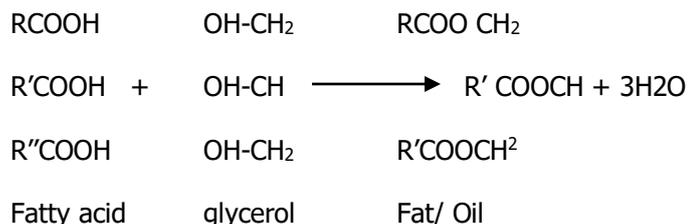
Alkanoates may be Isomeric with Alkanoic acids e.g.

$\text{CH}_3\text{COOCH}_3$  is isomeric with  $\text{C}_2\text{H}_5\text{COOH}$  and both are isomeric with  $\text{HCOOC}_2\text{H}_5$

## FATS AND OILS

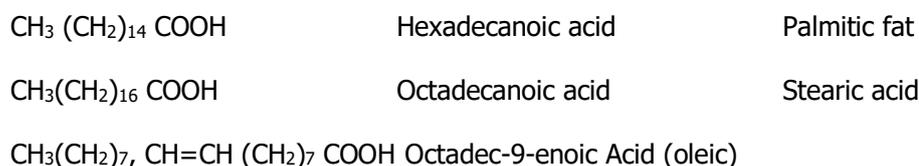
Animals fats, vegetables oils like palm oil, G.N oil, palm kernel oil are esters (alkanoates) occurring naturally in plants and animals. They are derived from

Propan -1,2,3- trio and a fatty acid



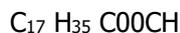
## FATTY ACIDS

The fatty acids commonly found in fats and oil are the higher fatty acids



In case of solid fat, the fatty acid is a straight chain saturated fatty acid

E.G



PROPAN-1,2,3 trioctadecanoate



A typical liquid fact or oil is derived from glycerol but the acid contains 2hydrogen atoms fewer per molecule ( $\text{C}_n \text{H}_{2n-1} \text{COOH}$ ). This normally contains the unsaturated grouping  $-\text{CH}=\text{CH}-$ . Taking oliec acid



Triolein



Propan-1,2,3- trioctadec-9-enoate

Fats are solids whereas oils are liquid under the same condition. If the esterification product of fatty acids and glycerol contain a high proportion of low MP unsaturated fatty acids they are generally liquids at room temperature, and called oils. If the esterification product contains a high percentage of saturated fatty acids they are severally solid or semi solid at room temperature and are classified as fats. Generally fats are glycerides of saturated fatty acids and oils are glycerides of unsaturated fatty acid.

## HYDROGENATION OF OILS

An oil can be changed into fat by hydrogenation. E.g margarine

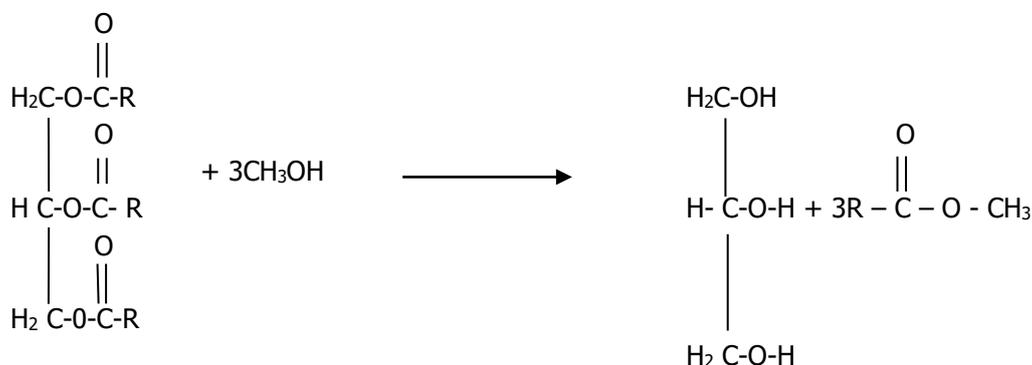
Oil  $\xrightarrow[\text{H}_2 \text{ 5at}]{\text{Ni 180}}$  fats. The hydrogen is added across the double bond in the unsaturated chain. The hardened oils are then mixed with salt, vitamin, skimmed milk and other fats to form margarine.

### PHYSICAL PROPERTIES OF FATS AND OILS

- (a) They are insoluble in water
- (b) They have low densities. They float in water
- (c) They have lubricating properties.

### CHEMICAL PROPERTIES

**REDUCTION:** For reduction to occur, fats and oils are first converted to simpler alkanoates by reaction with methanol

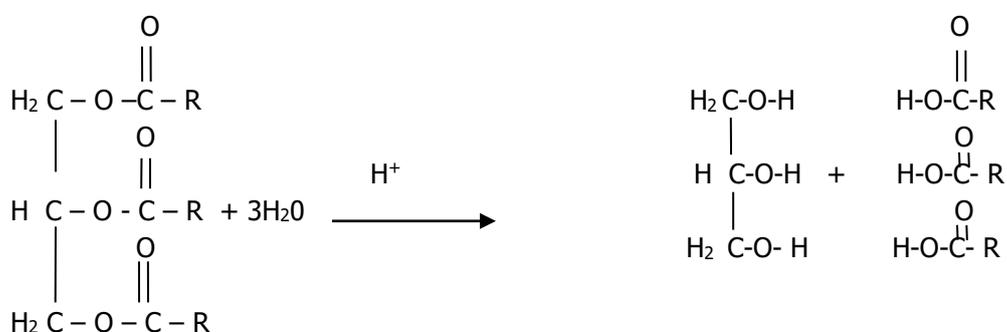


These alkanoate are then reduced to alkanols under high pressure with copper(II) pentaoxochromate(III) as catalyst



### HYDROLYSIS

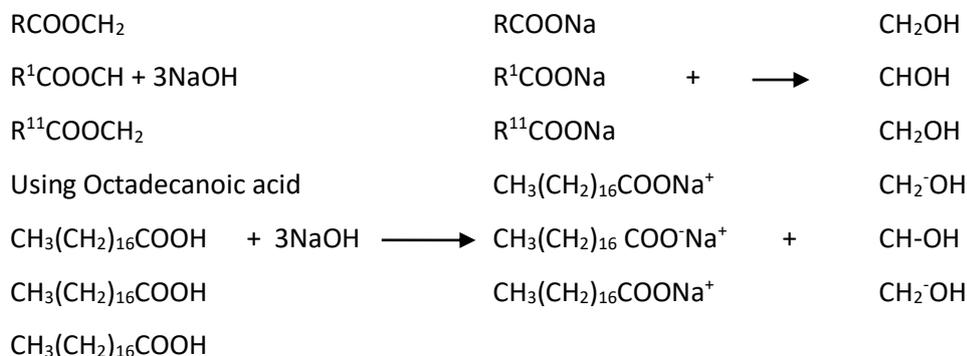
Fats and oils can be hydrolysed by water to form glycerol and corresponding fatty acids. Reaction is the reverse of esterification. A dilute acid is used to catalyse the reaction.



## SAPONIFICATION

Hydrolysis of fats and oils with caustic soda/potash yields propane-1,2, 3-triol and the corresponding sodium and potassium salts of component fatty acid. These salts are the principal constituent of soap. The process is called saponification.

Fat oil + caustic alkali  $\longrightarrow$  soap + propane-1, 2, 3-triol

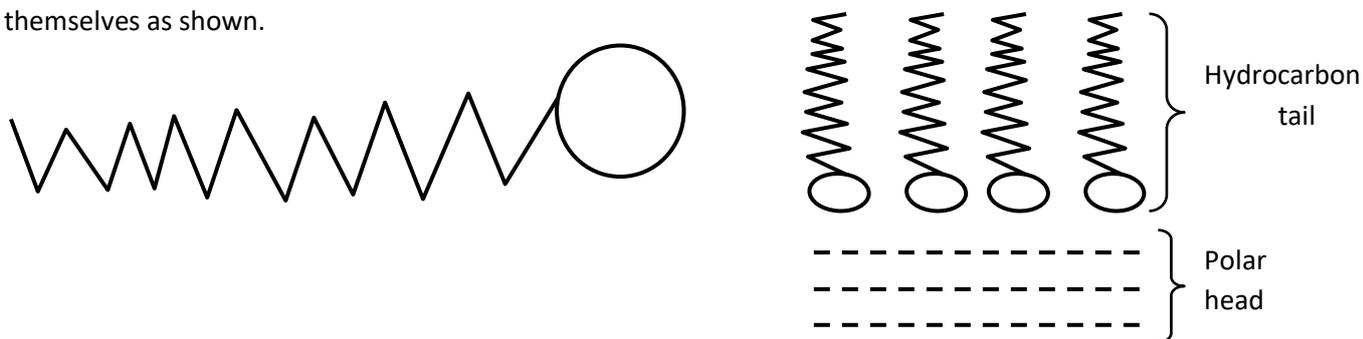


## MANUFACTURE OF SOAP

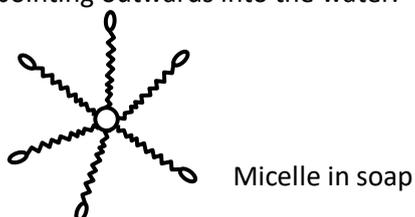
Heat fat/oil to a high temperature and add NaOH and stir until saponification is complete. Add concentrated NaCl to decrease the solubility of the soap and the soap separates out as a hard cake. This is called salting out. Purify the soap with steam and water. Dyes or perfumes are added.

## PROPERTY OF SOAP

The properties of soap produced depend mainly on the alkali and the fat/oil used. Hard soaps used for laundering are chiefly composed of the sodium salts of saturated acids, while softer toilet soaps are composed of the potassium salts of unsaturated acids. Each soap molecule possesses a long hydrocarbon chain, R attached to an ionic head which is either  $\text{COO-Na}^+$  or  $\text{COO-K}^+$ . The hydrocarbon tail is hydrophobic. It is insoluble in water but soluble in organic solvent or oil. The ionic head is hydrophilic and hence soluble in water. Due to this dual nature at the interphase of an aqueous – oil layer, soap molecules arrange themselves as shown.



When soap dissolves in water the molecules form spherical clusters called micelles. Each micelle may contain hundreds of molecules which are arranged with the hydrocarbon tails pointing inwards and the hydrophilic heads pointing outwards into the water.



## CLEANING ACTION OF SOAP

When soap solution is applied to a grease coated piece of fabric, the soap molecule first approach the grease spot. At the interphase of grease and water, the hydrophobic tail of the particles dissolve in grease while the hydrophobic head dissolve in water. The water molecules attract the polar ionic heads of the soap molecules. This action helps to lift the grease spot upwards, enabling soap particles to dissolve in the grease. Eventually with mechanical scrubbing, the grease patch is emulsified. On rinsing the fabric the grease is removed.

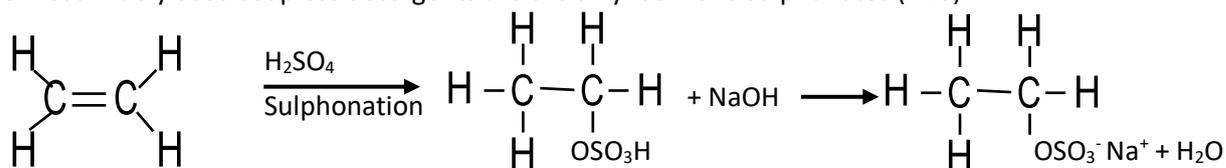
## ADVANTAGE AND DISADVANTAGE OF SOAP

**DISADVANTAGE:** Soap forms scum in hard water. In acidic water it reacts with the excess acid to form unionized fatty acids. This lowers the cleaning effect of the soap. Since it is the ionic head (polar) of soap molecules that are chiefly responsible for its solubility in water.

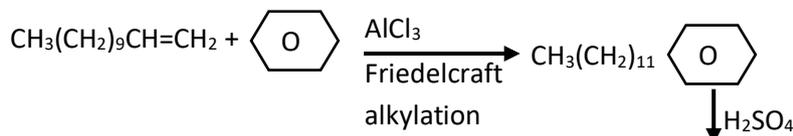
**ADVANTAGE:** soap is biodegradable. It can easily be decomposed by bacteria into simple inorganic substances hence it does not cause water pollution. It is made from natural sources – fats and oil.

## SOAPLESS DETERGENT.

Soapless detergent are the more favoured all purpose cleansing agent. They are available as liquids or solids. The most widely used soapless detergents are the alkyl benzene sulphanates (ABS).



Detergents can also be made from alkyl benzene sukphonate.



The detergent molecule has a hydrophobic tail and a hydrophilic head. The hydrophilic head can be positively/negatively charged or even neutral ( $\text{OSO}_3^-/\text{SO}_3 \text{Na}^+$ ).

## ADVANTAGE OF DETERGENT

- They can be designed for specific purposes – for oil slick, etc.
- Useful in hardwater containing  $\text{Ca}^{2+}/\text{Mg}^{2+}$  as less detergent is used.
- Does not form scum in hard water

## Disadvantage of detergent

- Many are not biodegradable. Hence can cause pollution.
- Some are made from phosphates which may become fertilizers and increase growth of see weeds.

## ALUMINIUM

It is the third most abundant element in the earth's crust. It is found abundantly as trioxosilicates(iv) in rocks and clays. The main source of aluminium is the mineral bauxite,  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ . Others are kaolin  $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot 2\text{H}_2\text{O}$ , cryolite  $\text{Na}_3\text{AlF}_6$ , corundum  $\text{Al}_2\text{O}_3$  and mica,  $\text{K}_2 \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ .

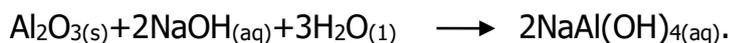
## EXTRACTION

Aluminium is extracted from bauxite by electrolysis. The extraction proceeds in two stages:

1. The crude bauxite is purified to yield pure anhydrous aluminium oxide, which is then purified by electrolysis in the second stage.

## PURIFICATION OF BAUXITE

The bauxite is first heated with caustic soda solution under pressure to form soluble sodium aluminate(III)  $\text{NaAl}(\text{OH})_4$ .



Other impurities like Iron(III)oxide and other silicates are filtered off.

The filtrate which contains the  $\text{NaAl}(\text{OH})_4$  is then seeded with Aluminium hydroxide crystals to induce more precipitation of aluminium hydroxide.

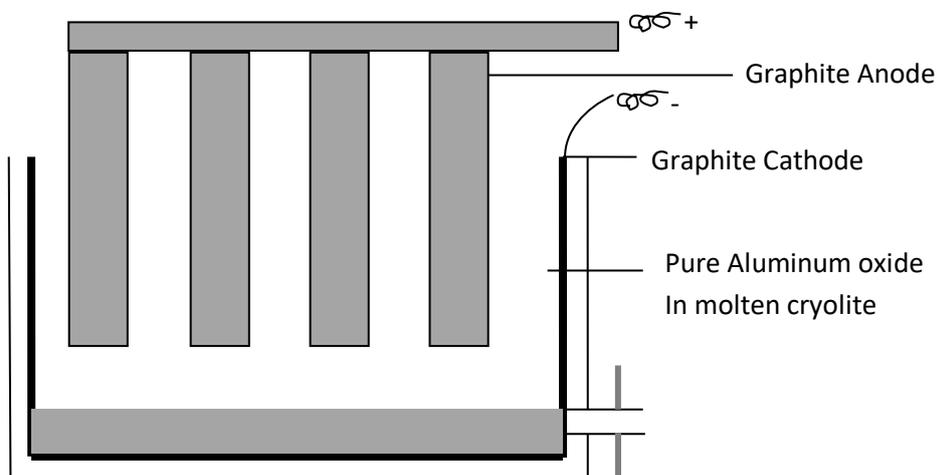


The  $\text{Al}(\text{OH})_3$  is then filtered off, washed, dried and strongly heated to yield pure Aluminium oxide or Alumina,  $\text{Al}_2\text{O}_3$  while the  $\text{NaOH}$  is concentrated and used again.



## ELECTROLYTIC PROCESS

The electrolytic cell is an iron container lined with graphite. The graphite lining serves as the cathode while the anode consists of graphite rods dipping into the electrolyte, which is a solution of pure alumina in molten cryolite;  $\text{Na}_3\text{AlF}_6$

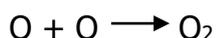


The electrolyte is maintained at  $950^{\circ}\text{C}$  by the heating effect of the large current (process is expensive). Oxygen is given off at the anode. The anodes are slowly burnt away as carbon(iv)oxide. (This adds to the cost of the whole process).

### CHEMISTRY OF THE PROCESS

**CATHODE:-**  $\text{Al}^{3+} + 3\text{e}^{-} \longrightarrow \text{Al}_{(\text{s})}$ . Reduction

**ANODE:-**  $\text{O}^{2-} \longrightarrow \text{O} + 2\text{e}^{-}$  Oxidation



**OVER ALL:-**  $4\text{Al} + 6\text{O}^{2-} \longrightarrow 4\text{Al}_{(\text{s})} + 3\text{O}_2$ .

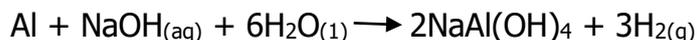
### PHYSICAL PROPERTIES OF ALUMINUM

1. Aluminum is a white silvery solid
2. It has relative density of 2.7 (low)
3. It is ductile and malleable
4. It has a moderate tensile strength
5. It has a melting point of  $660^{\circ}\text{C}$
6. It is a very good conductor of heat and electricity.

### CHEMICAL PROPERTIES

1. **With Air:-** Forms aluminum oxide and this coating prevents further reaction by metal with oxygen or moisture. Hence aluminum is corrosion free at normal temperature. At about  $800^{\circ}\text{C}$  Aluminum metal will react with air to give the oxide and nitride.  $4\text{Al} + 3\text{O}_2 \longrightarrow 2\text{Al}_2\text{O}_{3(\text{s})}$ ,  
 $2\text{Al} + \text{N}_2 \longrightarrow 2\text{AlN}_{(\text{s})}$ .
2. **With Non Metals:-** Heated aluminum reacts with halogens, sulphur with the evolution of heat.  $2\text{Al}_{(\text{s})} + 3\text{Cl}_{2(\text{g})} \longrightarrow 2\text{AlCl}_{3(\text{s})}$ .
3. **With Acids:-**  $2\text{Al}_{(\text{s})} + 6\text{HCl} \longrightarrow 2\text{AlCl}_{3(\text{aq})} + 3\text{H}_{2(\text{g})}$   
 Reaction is faster with conc Hcl. With dilute  $\text{H}_2\text{SO}_4$ , there is no reaction. With conc  $\text{H}_2\text{SO}_4$  liberates  $\text{SO}_2$ .  
 $2\text{Al}_{(\text{s})} + 6\text{H}_2\text{SO}_{4(\text{aq})} \longrightarrow \text{Al}_2(\text{SO}_4)_3 + 6\text{H}_2\text{O} + 3\text{SO}_{2(\text{g})}$ .  
 Aluminum will not react with  $\text{HNO}_3$  (conc or dilute) due to the formation of  $\text{Al}_2\text{O}_3$ . Hence Aluminum containers are used to transport  $\text{HNO}_3$ .

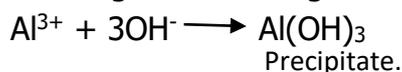
4. **With Alkali:-** (Al dissolves in NaOH/KOH).



5. **With Iron(III) Oxide:-**  $2\text{Al}_{(\text{s})} + \text{Fe}_2\text{O}_{3(\text{s})} \longrightarrow 2\text{Fe} + \text{Al}_2\text{O}_{3(\text{s})}$  (reduction).

6. **With Aqueous Ammonia:-** Aqueous Ammonia + Aluminum Salt.

Solution gives a white gelatinous precipitate which is insoluble in excess Ammonia.



## USES OF ALUMINUM

1. **Cooking Materials:-** Used in making cooking materials. It is cheap, light and a good conductor of heat.
2. **Overhead Cables:-** It is used in making overhead cables because it is light and has good electrical conductivity.
3. **Aluminum Power For Mirror:-** Used in making paints for mirrors because of its high reflectivity.
4. **Making Alloys:-** (homogenous mixture of metals) Duralumin (Al, Cu, Mg, Mn) Aluminum Bronze (Cu, Al), Aluminum (Al, Mg).
5. **Thermit Process:-** Used in thermit process for welding together metallic part of machines. Eg. To weld together broken ends of iron rods:  $2\text{Al} + \text{Fe}_2\text{O}_3 \longrightarrow \text{Al}_2\text{O}_3 + 2\text{Fe}$ . The heat melts the iron formed which welds together the broken rods. (If a chromium article is involved, then chromium(II) oxide is used in place of iron(II)oxide.
6. Aluminum foils are used as packaging material
7. Aluminum ions are used as coagulants in water treatment.

## IRON

Iron is the fourth most abundant element in the earth's crust and the second most abundant metal after aluminum. It is not found in the free metallic state.

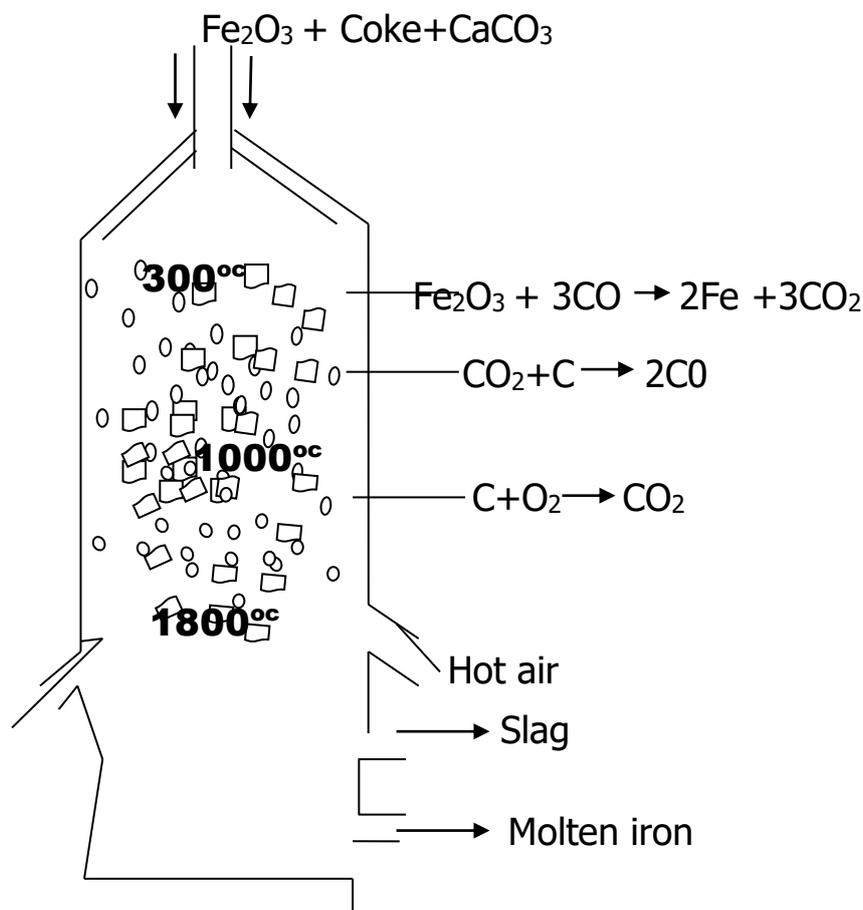
The most common iron ores are haematite  $\text{Fe}_2\text{O}_3$ . Others are magnetite  $\text{Fe}_3\text{O}_4$ , iron pyrite,  $\text{FeS}_2$ . Siderite or spathic iron ore  $\text{FeCO}_3$  and limonite  $\text{Fe}_2\text{O}_3$ . It is also present as trioxosilicates in clay soils.

## AVAILABILITY IN NIGERIA

Iron ores are available in commercial quantities in Itakpe, Ajaokuta, Jebba and Lokoja in Kogi State.

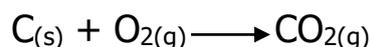
## EXTRACTION

Iron is extracted from its ore (haematite)  $\text{Fe}_2\text{O}_3$ . It is first roasted in air. The roasted haematite with coke and limestone are introduced into the blast furnace. Hot air ( $600^\circ\text{C}$ ) is introduced from the bottom

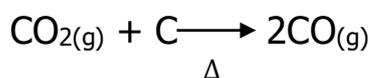


### CHEMISTRY OF THE ACTION

1. **Production of Carbon(IV):-** The carbon in coke burns in a blast of hot air to produce carbon(IV)oxide.



2. **Production of Carbon(II)oxide:-** As carbon(IV)oxide rises up the furnace and reacts with more coke to produce carbon(II)oxide.



3. **Reduction of Iron:-** The carbon(II)oxide reduces the Iron(III)oxide to give the raw iron.



The iron formed is molten and runs to the bottom of the furnace.

### REMOVAL OF IMPURITIES

Iron ore contains the impurities clay and sand which are silicon(iv)oxides. The limestone added removes the impurities. The limestone is decomposed by heat to give CaO.  
 $\text{CaCO}_{3(s)} \longrightarrow \text{CaO} + \text{CO}_2$ .

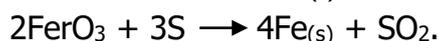
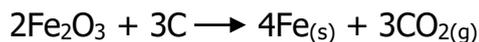
The CaO reacts with the SiO<sub>2</sub> to give CaSiO<sub>3</sub> (Slag).



The molten slag floats on the molten iron and it's tapped off. Solidified slag is used for road surfacing.

### TYPES OF IRON

- (a) **PIG IRON:-** This is obtained directly from the blast furnace, it is impure with up to 5% carbon, and other impurities, S, Si, P etc. it has a melting point of above 1200<sup>o</sup>c due to impurities. It is brittle and hard. Not very useful. For engine blocks, pipes.
- (b) **CAST IRON:-** Obtained from pig iron which has been remelted with some scrap iron and cooled in moulds. The percentage of impurities is reduced. It is used for making cookers, stoves, radiators, railings Bunsen burners, lampposts.
- (c) **WROUGHT IRON:-** This is the purest form of iron (99.5% pure). It is obtained by heating cast iron in a furnace with haematite. During the process, carbon and sulphur are oxidized and removed as gaseous oxides



It is soft but tough and malleable. It is used for making nails, chains, iron rods and organic implements and magnets.

### STEEL

Steel is an alloy of iron(pig iron) with about 0.1-1.5% carbon. Alloy steel contains varying proportions of other elements e.g. nickel and chromium etc.

Steel is hard, tough and strong. Its properties depend on its carbon content, the treatment it receives and the presence of other metals hardness increase with as carbon content increase.

There is hard steel (0.6-1.5) medium steel (0.25-0.6) and mild steel (0.1-0.25) They are used for engineering purpose,

### STEEL MAKING PROCESS

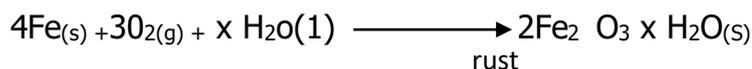
-Bessemer, open hearth and electric are processes.

### PHYSICAL PROPERTIES OF IRON

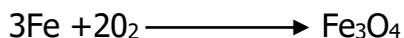
- a) Iron is a silvery white or greyish appearance
- b) It has a melting point of 1530<sup>o</sup>c
- c) It is ductile and malleable
- d) It has a high tensile strength
- e) It is a good conductor of heat and electricity.
- f) It is ferromagnetic and can be magnetized easily.

## CHEMICAL PROPERTIES

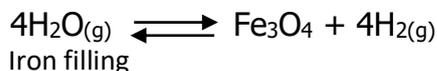
1. **With Air:-** Iron reacts with mulish air and generally rusts.



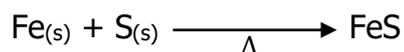
With freely divided iron, it forms iron(II) diiron(III) oxide



2. **With Stigma:-** When heated with steam, iron fillings give hydrogen gas  $3\text{Fe}_{(s)} +$



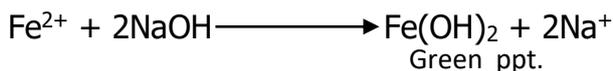
3. **With Non Metals:-**  $2\text{Fe}_{(s)} + 3\text{Cl}_{2(g)} \xrightarrow{\Delta} 2\text{FeCl}_{3(s)}$



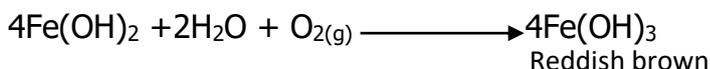
4. **With Acids:-**  $\text{Fe}_{(s)} + \text{H}_2\text{SO}_{4(aq)} \longrightarrow \text{FeSO}_{4(aq)} + \text{H}_{2(g)}$

With Dilute  $\text{HNO}_3$  serial products are obtained. No neutron exists with conc  $\text{HNO}_3$  as the  $\text{HNO}_3$  is a powerful oxidising agent.

## TEST FOR IRON



Same reaction with ammonia. Iron(II) hydroxide could be oxidized to iron(III)



With POTASSIUM HEXACYANOFERATE II



With POTASSIUM THIOCYANATE



## COPPER

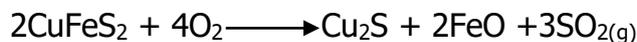
Copper is one of the least reactive metals and belongs to a group of elements known as the noble metals (Cu, Ag, Au).

## OCCURRENCE

Copper exists as copper pyrites  $\text{CuFeS}_2$ , as Cuprite  $\text{Cu}_2\text{O}$ , Malachite,  $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$  Chalcocite  $\text{Cu}_2\text{S}$ ; bornite ( $\text{Cu}_2\text{S} \cdot \text{CuSFeS}$ ).

## EXTRACTION

Copper is usually extracted from sulphide ores such as copper pyrites,  $\text{CuFeS}_2$ . The ore is concentrated by froth floatation. It is then roasted in a limited supply of air to oxide the iron and some sulphur in the ore to iron(II) oxide and sulphur(IV)oxide.



Heating with  $\text{CaCO}_3$  in a furnace will remove the silica and iron(II)oxides as slag which floats on top.



The  $\text{Cu}_2\text{S}$  is heated in controlled amount of air to copper.



The  $\text{SO}_2$  causes blisters on the copper (copper blisters).

### PURIFICATION

Where copper of high purity is required the crude copper is made into anodes in an electrolytic cell containing  $\text{CuSO}_4$  solution and pure copper cathodes.

At cathode  $\longrightarrow \text{Cu}^{2+} + 2\text{e}^- \longrightarrow \text{Cu}_{(s)}$  deposit at cathode.

At Anode, the impure copper dissolves, and goes into solution as  $\text{Cu}^{2+}$  and gains electrons to be deposited at the anode. The anode becomes depleted while the cathode increases in size.

### TIN

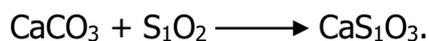
Tin does not occur naturally as free elements. The main source is the mineral cassiterite or tin stone  $\text{SnO}_2$ . It is found in Malaysia, Bolivia, Jos. It is found in granite rocks.

### EXTRACTION

Tin ore is washed / crushed and concentrated. It is roasted in air to remove impurities like sulphur, arsenic and antimony as volatile oxides.

The product is then mixed with provided charcoal and heated to  $1300^\circ\text{C}$  to reduce the oxide. Molten tin is then tapped of  $\text{SnO}_{2(s)} + 2\text{C} \longrightarrow \text{Sn}_{(l)} + 2\text{CO}_{(g)}$ .

Impurities such as  $\text{SiO}_2$  (sand) are removed from the mixture as slag, by the addition of limestone.



The tin obtained is impure. It is refined by heating it gently on a sloping surface. The impurities are exposed and become converted to the oxide.

### PROPERTIES

1. Silvery white solid with luster
2. Exists in different allotropes greytin  $\xrightleftharpoons[5.76\text{g/cm}^{-3}]{13.2^\circ\text{C}}$  white tin  $\xrightleftharpoons[7.2\text{g/cm}^{-3}]{161^\circ\text{C}^+}$  rhombic tin
3. Malleable, not ductile enough, good conductor of heat shekel.

## USES

It is used in coating iron against corrosion

It forms alloys – bronze (Sn, Cu) etc.

## ALLOYS

Alloys are mixtures of two or more metals to obtain more desirable properties like Tensile strength, lightness, corrosion resistance.

ALLOY	CONSTITUENTS	USES
Brass	Cu, 60-70% Zn	For ornaments, watches, nuts, musical instrument.
Bronze	Cu(90%) Sn	For coins, medals, sculptures
Duralumin	Al(90%), Cu, Mg, Mn	For aircraft, ships, cars
Coins	Cu, Sn, Zn, or Ag	For coins
Dentist amalgam	Hg, Cu	For dental filling
Gold dental	Au, Cu, Ag	For dental filling
Gunmetal	Cu, Sn	For making guns
Magnalium	Al Mg, Cu, Mn	
Soft solder	Pb, Sn, Pb, Cu	For welding, plumbing
Type metal	Pb, Sn, Pb, Cu	For typing, printing
Stainless Steel	Fe, Cr, Ni	Cutlery, surgical equipment, Tools
Steel	Fe, (93%) C	Bridges, ships, cars
Alnico	Fe, Al, Ni, Co	For making permanent magnets
Permallyory	Fe, Ni	For making electromagnets
Pewter	Sn, Pb	For making dishes, mugs.