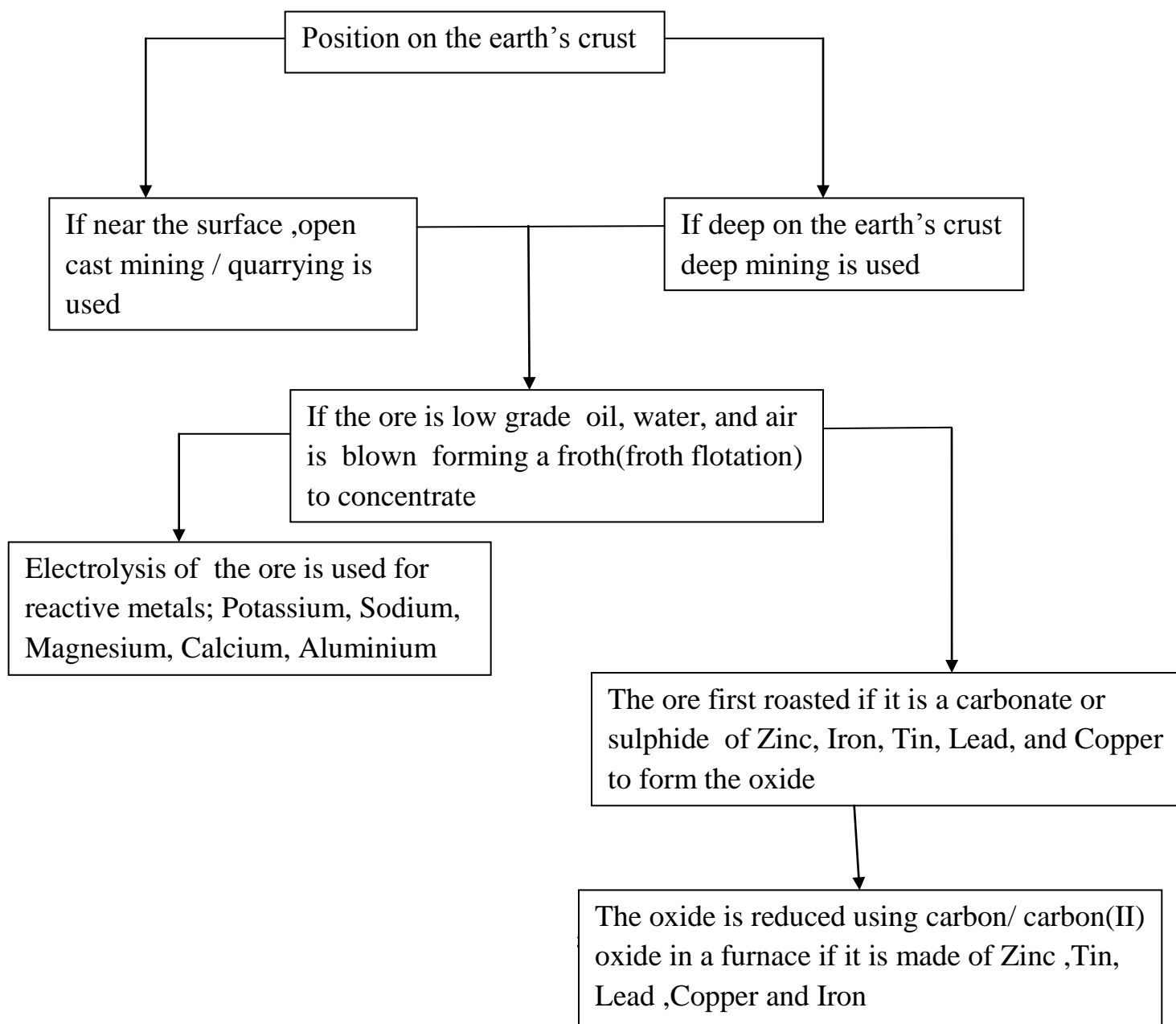# Chemistry of
# METALS

### a)Introduction to metals

The rationale of studying metals cannot be emphasized.Since ages, the world over, metals like gold and silver have been used for commercial purposes.

The periodicity of alkali and alkaline earth metals was discussed in year 2 of secondary school education. This topic generally deals with:

(**a**)Natural occurrence of the chief ores of the most useful metals for industrial /commercial purposes.

(**b**)Extraction of these metals from their ores for industrial/ commercial purposes.

(**c**)industrial/ commercial uses of these metals.

(**d**)main physical and chemical properties /characteristic of the metals.

The metals given detailed emphasis here are; **Sodium, Aluminium, Iron, Zinc, Lead** and **Copper.**

The main criteria used in extraction of metals is based on its position in the electrochemical/reactivity series and its occurrence on the earth's crust.

```
┌──────────────────────────────────┐
│   Position on the earth's crust   │
└──────────────────────────────────┘
```

| If near the surface ,open cast mining / quarrying is used |
|---|

| If deep on the earth's crust deep mining is used |
|---|

| If the ore is low grade  oil, water, and air is  blown  forming a froth(froth flotation) to concentrate |
|---|

| Electrolysis of  the ore is used for reactive metals; Potassium, Sodium, Magnesium, Calcium, Aluminium |
|---|

| The ore first roasted if it is a carbonate or sulphide  of Zinc, Iron, Tin, Lead, and Copper to form the oxide |
|---|

| The oxide is reduced using carbon/ carbon(II) oxide in a furnace if it is made of Zinc ,Tin, Lead ,Copper and Iron |
|---|

# 1.SODIUM

## a) Natural occurrence

Sodium naturally occurs as:

(i)Brine-a concentrated solution of sodium chloride(NaCl(**aq**)) in salty seas and oceans.

(ii)Rock salt-solid sodium chloride(NaCl(**s**)

(iii)Trona-sodium sesquicarbonate($NaHCO_3.Na_2CO_3.2H_2O$) especially in lake Magadi in Kenya.

(iv)Chile saltpeter-sodium nitrate($NaNO_3$)

## b)(i)

## Extraction of Sodium from brine/Manufacture of Sodium hydroxide/The flowing mercury cathode cell/ TheCaster-Keller process

### I.Raw materials

(**i**) Brine-concentrated solution of sodium chloride (NaCl (**aq**)) from salty seas and oceans.

(**ii**)Mercury

(**iii**)Water from river/lakes

### II. Chemical processes

Salty lakes, seas and oceans contain large amount of dissolved sodium chloride (NaCl (aq)) solution.

This solution is concentrated to form brine which is fed into an electrolytic chamber made of **suspended** Carbon **graphite**/titanium as the **anode** and a **continuous** flow of Mercury as the **cathode**.Note

Mercury is the only naturally occurring known liquid metal at room temperature and pressure

**Questions**

I. Write the equation for the decomposition of the electrolyte during the electrolytic process.

$$H_2O(l) \longrightarrow H^+(aq) + OH^-(aq)$$
$$NaCl(aq) \longrightarrow Na^+(aq) + Cl^-(aq)$$
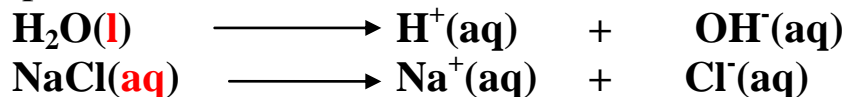
II. Name the ions present in brine that moves to the:

    (i)Mercury cathode; **$H^+(aq)$ , $Na^+(aq)$**

    (ii)Titanium/graphite; **$OH^-(aq)$, $Cl^-(aq)$**

III. Write the equation for the reaction that take place during the electrolytic process at the;

    Cathode;   **$2Na^+(aq)$ +   2e $\longrightarrow$   $2Na(s)$**

    Anode;    **$2Cl^-(aq)$ $\longrightarrow$ $Cl_2(g)$  +  2e**

**Note**

**(i)** Concentration of $2Cl^-(aq)$ ions is higher than $OH^-$ ions causing **overvoltage** thus **block**ing $OH^-$ ions from being discharged at the anode.

**(ii)** Concentration of $Na^+(aq)$ ions is higher than $H^+$ ions causing **overvoltage** thus **block**ing $H^+$ ions from being discharged at the cathode.

IV. Name the products of electrolysis in the flowing mercury-cathode cell.

    (i)Mercury cathode; **Sodium metal as grey soft metal/solid**

    (ii)Titanium/graphite; **Chlorine gas as a pale green gas that turns moist blue/red litmus papers red then bleaches both.** Chlorine gas is a very useful by-product in;

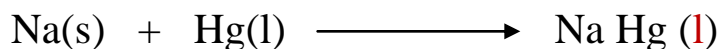        (i)making (PVC)polyvinylchloride(polychloroethene) pipes.
        (ii)chlorination/sterilization of water to kill germs.
        (iii)bleaching agent
        (iv)manufacture of hydrochloric acid.

Sodium produced at the cathode immediately reacts with the mercury at the cathode forming **sodium amalgam**(**NaHg**) liquid that flow out of the chamber.

$$Na(s) \; + \; Hg(l) \longrightarrow Na\,Hg\,(l)$$

Sodium amalgam is added distilled water and reacts to form sodium hydroxide solution, free mercury and Hydrogen gas.

$$2Na\,Hg\,(l) \; + 2H_2O(l) \longrightarrow 2NaOH\,(aq) \; + \; 2Hg(l) \; + \; H_2(g)$$
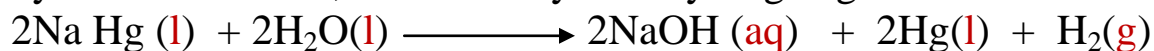
Hydrogen gas is a very useful by-product in;

        (i)making ammonia gas in the Haber process
        (ii)manufacture of hydrochloric acid

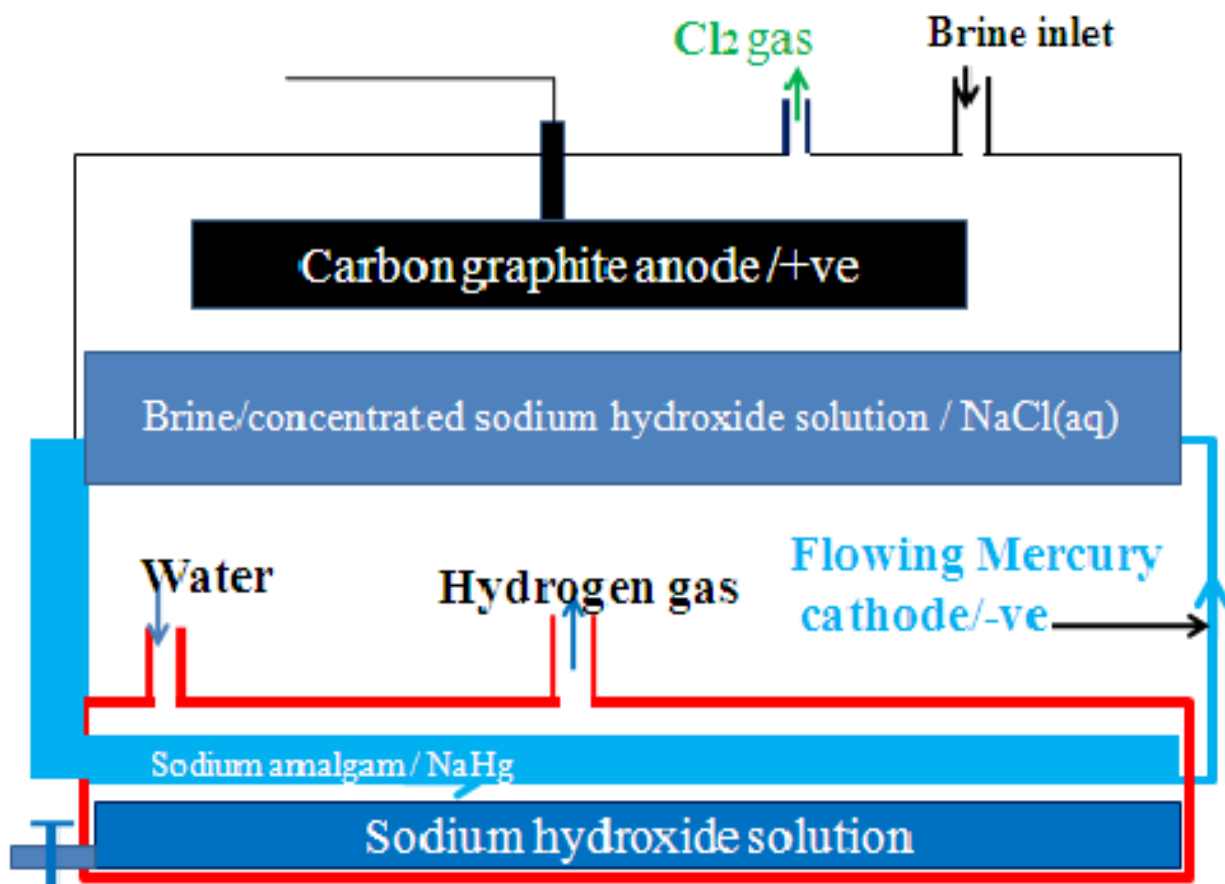(iii)in weather balloons to forecast weather

(iv)as rocket fuel

As the electrolysis of brine continues, the concentration of Cl-ions decreases and oxygen gas start being liberated. **Continuous** feeding of the electrolyte is therefore very necessary.

### III.Uses of sodium hydroxide

The sodium hydroxide produced is very pure and is used mainly in:

(i)Making soapy and soapless detergents.

(ii)making cellulose acetate/rayon

### IV. Diagram showing the Manufacture of Sodium hydroxide from the flowing Mercury-cathode cell.

Cl₂ gas    Brine inlet

Carbon graphite anode /+ve

Brine/concentrated sodium hydroxide solution / NaCl(aq)

Water    Hydrogen gas    Flowing Mercury cathode/-ve

Sodium amalgam / NaHg

Sodium hydroxide solution

**Flowing mercury cathode cell**

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### V. Environmental effects of Manufacture of Sodium hydroxide from the flowing Mercury-cathode cell.

1.Most of the Mercury used at the cathode is recycled ;
      (i)to reduce the cost because mercury is expensive
      (ii)to reduce pollution because mercury kills marine life.
      (iii)because it causes chromosomal/genetic mutation to human beings.

2.Chlorine produced at the anode;
      (i)has a pungent irritating smell that causes headache to human beings.
      (ii)bleaches any wet substance.
      (iii)dissolves water to form both hydrochloric acid and chloric(I)acid
      Both cause marine pollution and stomach upsets.

### b)(ii)
### Extraction of sodium from rock salt/The Downs cell/process

### I. Raw materials
      (i)Rock salt/solid sodium chloride
      (ii)calcium(II)chloride

### II. Chemical processes.
Rock salt/ solid sodium chloride is heated to molten state in a chamber lined with fire bricks on the outside.
Sodium chloride has a melting point of about $800^{o}$C. A little calcium (II) chloride is added to lower the melting point of the electrolyte to about $600^{o}$C. The molten electrolyte is the electrolyzed in a carbon graphite anode suspended at the centre and surrounded by steel cathode.

### Questions
I. Write the equation for the decomposition of the electrolyte during the electrolytic process.
      $NaCl(l) \longrightarrow Na^{+}(l) + Cl^{-}(l)$
      **Note:** In absence of water, the ions are in liquid state.
II. Name the ions present in molten rock salt that move to the;
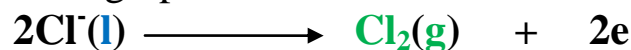      (i)Steel cathode -$Na^{+}(l)$
      (ii)Carbon graphite anode- $Cl^{-}(l)$
III. Write the equation for the reaction that take place during the electrolytic process at the;

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(i)Steel cathode

$$2Na^+(l) \quad + \quad 2e \longrightarrow 2Na(l)$$

(ii)Carbon graphite anode

$$2Cl^-(l) \longrightarrow Cl_2(g) \quad + \quad 2e$$

IV. Name the products of electrolysis in the Downs cell at;

(i)Cathode:

**Grey solid Sodium metal is <u>less dense</u> than the molten electrolyte and therefore <u>float</u> on top of the cathode to be periodically tapped off.**

(ii)Anode:

Pale green chlorine gas that turns moist/damp/wet blue/red litmus papers red then <u>bleaches/decolorizes</u> both. Chlorine gas is again a very useful by-product in;

(i)making (PVC)polyvinylchloride(polychloroethene) pipes.
(ii)chlorination/sterilization of water to kill germs.
(iii)bleaching agent
(iv)manufacture of hydrochloric acid.

A **steel diaphragm/gauze** is suspended between the electrodes to **prevent recombination** of sodium at the cathode and chlorine gas at the anode **back** to sodium chloride.

**III.** <u>Diagram showing the **Downs cell/process for extraction of sodium**</u>

**The Downs process for extraction of Sodium from Rock salt**
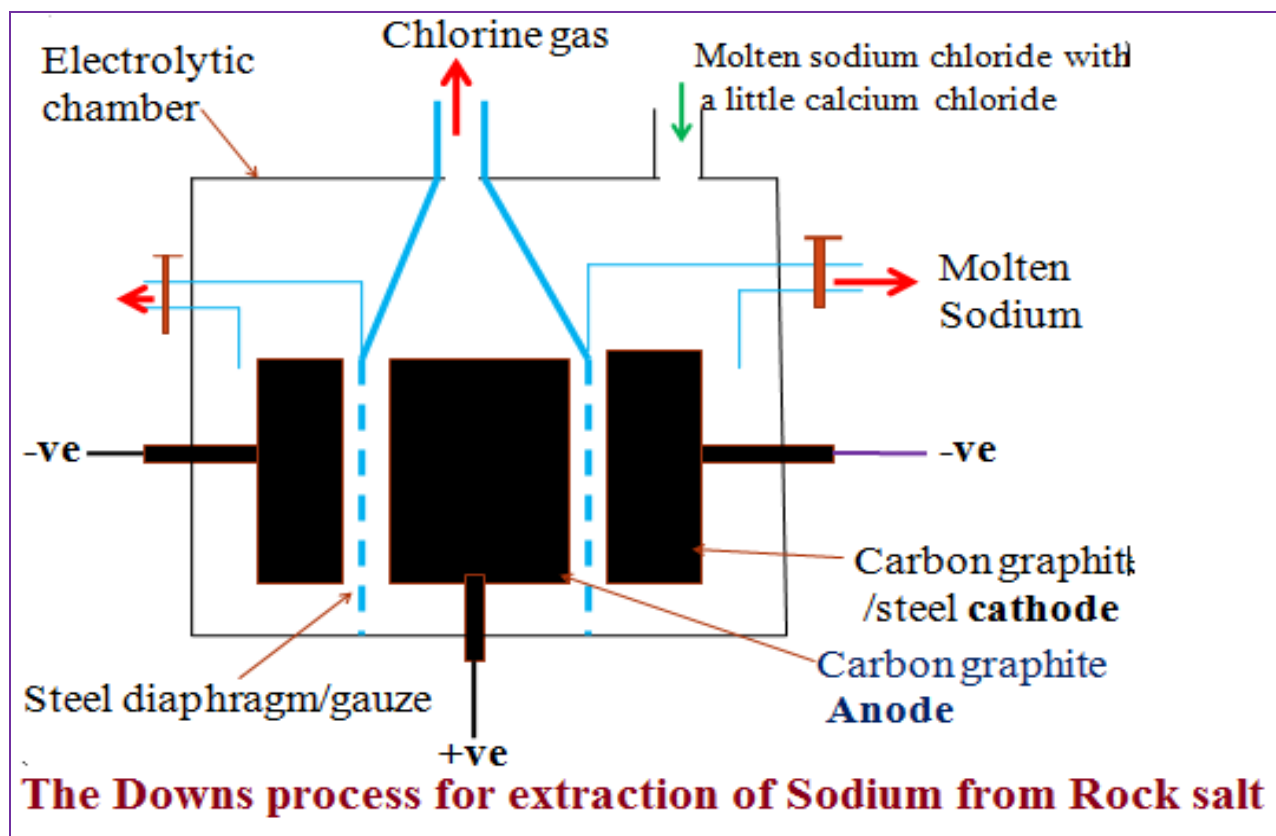
## IV. Uses of sodium.

1. Sodium vapour is used as sodium lamps to give a yellow light in street lighting.
2. Sodium is used in making very useful sodium compounds like;
    (i) Sodium hydroxide(NaOH)
    (ii) Sodium cyanide(NaCN)
    (iii) Sodium peroxide($Na_2O_2$)
    (iv) Sodamide($NaNH_2$)
3. An alloy of Potassium and Sodium is used as **coolant** in nuclear reactors.

## V. Environmental effects of Downs cell.

1. Chlorine produced at the anode;
    (i) has a pungent irritating smell that causes headache to human beings.
    (ii) bleaches any wet substance.
    (iii) dissolves water to form both hydrochloric acid and chloric(I)acid
    Both cause marine pollution and stomach upsets.

2.Sodium metal rapidly react with traces of water to form alkaline Sodium hydroxide(NaOH(aq))solution. This raises the pH of rivers/lakes killing aquatic lifein case of leakages.

### VI. Test for presence of Na.

If a compound has **Na$^+$** ions in solid/molten/aqueous state then it changes a non-luminous clear/colourless flame to a **yellow coloration** but does not burn
**Experiment**

Scoop a portion of sodium chloride crystals/solution in a clean metallic spatula. Introduce it to a clear /colourless Bunsen flame.

| Observation | Inference |
|---|---|
| Yellow coloration | Na$^+$ |

### Practice

**(i)Calculate the time taken in hours for 230kg of sodium to be produced in the Downs cell when a current of 120kA is used.**
**(ii)Determine the volume of chlorine released to the atmosphere.**
**(Na=23.0),Faraday constant=96500C.I mole of a gas =24dm3 at r.t.p)**
Working:

Equation at the cathode:

$$2Na^+ (l) + 2e \rightarrow 2Na(l)$$

2 mole of electrons = 2 Faradays = 2 x 96500 C  deposits a mass = molar mass of  Na = 23.0g  thus;

23.0 g      ->   2 x 96500 C

(230 **x 1000**)g    ->    $\dfrac{230 \times 1000 \times 2 \times 96500}{23}$

= **1,930,000,000 / 1.93 x 10$^9$C**

Time(**t**) in seconds    = **Quantity of electricity**
                          Current(**I**) in amperes

Substituting

= $\dfrac{1,930,000,000 / 1.93 \times 10^9 C}{120 \times 1000A}$

$$= \underline{16,083.3333 seconds} / 268.0556 \text{ minutes}$$
$$= \textbf{4.4676 hours}$$

Volume of Chlorine
Method 1
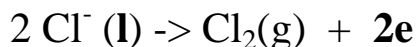
Equation at the anode:
$$2 \text{ Cl}^- \text{ (l)} \rightarrow Cl_2(g) + \textbf{2e}$$
From the equation:
2 moles of electrons = 2 Faradays  = 2 x 96500C
  2 x 96500C  -> 24dm3
 1,930,000,000 / 1.93 x $10^9$C-> $\underline{1,930,000,000 / 1.93 \times 10^9 C \times 24}$
                                         2 x 96500C
Volume of Chlorine = **240,000dm3** /**2.4 x $10^5$dm3**

Method 2
Equation at the anode:        Cl⁻ (l) -> $Cl_2$(g)  +  **2e**
Mole ratio of products at Cathode: anode = 1:1
Moles of  sodium  at cathode =$\underline{(230 \times 1000 )}$g= **10,000moles**
                                              23
10,000moles of  Na    =    **10,000moles** moles of Chlorine
1 moles of Chlorine gas    =   24000cm3
10,000moles of Chlorine-  >  10000 x 24
                              =**240,000dm3 / 2.4x $10^5$dm3**

Method 3
Equation at the anode: Cl⁻ (l) -> $Cl_2$(g)  +  **2e**
Ratio of Faradays of products at Cathode: anode = 2:2
 =>  2 x 96500C produce 24000cm3 of chlorine gas  Then: $\underline{1,930,000,000 /}$
$\underline{1.93 \times 10^9 C}$ ->
         $\underline{1,930,000,000 / 1.93 \times 10^9 C \times 24}$  = **240,000dm3**
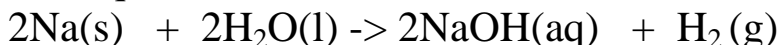                  2 x 96500

**(iij)The sodium metal produced was reacted with water to form 25000dm3  solution in a Caster-Keller tank.**
**(a)Calculate the concentration of the resulting solution in moles per litre.**

**(b)The volume of gaseous products formed at s.t.p(1 mole of gas =22.4 dm3 at s.t.p)**

Chemical equation at Caster-Keller tank

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

Mole ratio Na:NaOH = 2 : 2 => 1:1

Moles Na =10000moles=10000moles of NaOH

25000dm3 ->10000moles of NaOH

$1dm3 \rightarrow \dfrac{10000 \ x \ 1}{25000} = $ **0.4M / 0.4 moles/dm3**

Mole ratio Na: $H_2(g)$ = 2 : 1

Moles Na = 10000moles = **5000moles of $H_2(g)$**

Volume of $H_2(g)$ = moles x molar gas volume at s.t.p

=> 5000moles x 22.4 dm3

=**120,000dm3**

**(iv)The solution formed was further diluted with water for a titration experiment. 25.0 cm3 of the diluted solution required 20.0cm3 of 0.2M sulphuric(VI)acid for complete neutralization. Calculate the volume of water added to the diluted solution before titration.**

Chemical equation

$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$
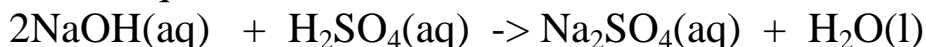
Moles ratio NaOH : $H_2SO_4$ = 2 : 1

Moles ratio $H_2SO_4$ = $\dfrac{molarity \ x \ volume}{1000}$ => $\dfrac{0.2M \ x \ 20}{1000}$

=**4.0 x $10^{-3}$ moles**

Moles NaOH = 2 x 4.0 x $10^{-3}$ moles= **8.0 x $10^{-3}$ moles**

Molarity of NaOH= $\dfrac{Moles \ x \ 1000}{volume}$=> $\dfrac{8.0 \ x \ 10^{-3} \ moles \ x \ 1000}{25}$

=**0.16 molesdm$^{-3}$ /M**

**Volume used during dilution**

$C_1V_1 = C_2V_2$ => 0.4M x $V_1$ = 0.16 M x 25

$$= \underline{0.16 \text{ M x } 25} \quad = \textbf{\textcolor{red}{10cm3}}$$
$$0.4$$

**(a) Below is a simplified diagram of the Downs Cell used for the manufacture of sodium. Study it and answer the questions that follow**
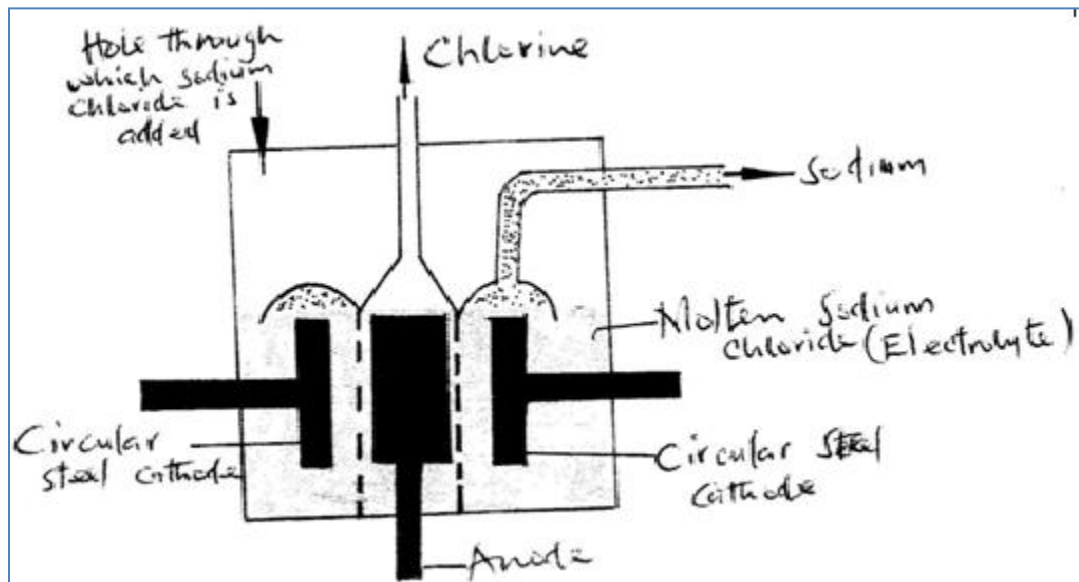


**(i)What material is the anode made of? Give a reason (2 mks)**
    Carbon graphite/Titanium
    This because they are cheap and inert/do not influence/affect the products
    of electrolysis

**(ii) What precaution is taken to prevent chlorine and sodium from re-combination? ( 1 mks)**
Using a steel gauze/diaphragm separating the cathode from anode

**(iii) Write an ionic equation for the reaction in which chlorine gas is formed ( 1mk)**

$$2Cl^-(l) \quad \rightarrow \quad Cl_2(g) \quad + \quad 2e$$

**(b) In the Downs process, (used for manufacture of sodium), a certain salt is added to lower the melting point of sodium chloride from about $800^0C$ to about $600^0C$.**
    **(i) Name the salt that is added          (1mk)**
            Calcium chloride
    **(ii) State why it is necessary to lower the temperature(1mk)**

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To reduce the cost of production

**(c) Explain why aqueous sodium chloride is not suitable as an electrolyte for the manufacture of sodium in the Downs process( 2mk)**
The sodium produced react explosively/vigorously with water in the aqueous sodium chloride

**(d) Sodium metal reacts with air to form two oxide. Give the formulae of two oxides( 1mk)**
$Na_2O$   Sodium oxide(in limited air)
$Na_2O_2$  Sodium peroxide(in excess air)

## 2.ALUMINIUM
### a)Natural occurrence
Aluminium is the most common naturally occurring metal. It makes 7% of the earths crust as:

(i)Bauxite ore- Hydrated aluminium oxide($Al_2O_3.2H_2O$)
(ii)Mica ore-Potassium aluminium silicate($K_2Al_2Si_6O_{16}$)
(iii)China clay ore- aluminium silicate ($Al_2Si_6O_{16}$)
(iv)Corrundum-Anhydrous aluminium oxide($Al_2O_3$)

### b)Extraction of aluminium from Bauxite/Halls cell/process)
The main ore from which aluminium is extracted is **Bauxite** ore- hydrated aluminium oxide($Al_2O_3.2H_2O$).
The ore is mined by open-caste mining method/quarrying where it is scooped together with silica/sand/silicon(IV)oxide (**$SiO_2$**) and soil/ iron(III)oxide (**$Fe_2O_3$**) as **impurities**.
The mixture is first dissolved in hot concentrated sodium/potassium hydroxide solution.
The alkalis dissolve both bauxite and silicon(IV)oxide.
This is because bauxite is **amphotellic** while silicon(IV)oxide is **acidic**.
Iron(III)oxide (**$Fe_2O_3$**) is filtered of /removed as a residue.
Carbon(IV)oxide is bubbled into the filtrate to precipitate aluminium (III) hydroxide (Al(OH)**₃**) as residue.

The aluminium (III) hydroxide (**Al(OH)₃**) residue is filtered off. Silicon (IV)oxide remain in the solution as filtrate. Aluminium (III) hydroxide (Al(OH)**₃**) residue is then heated to form pure aluminium (III)oxide(**$Al_2O_3$**)

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$$2Al(OH)_3 \text{ (s)} \longrightarrow Al_2O_3 \text{ (s)} + 3H_2O(l)$$
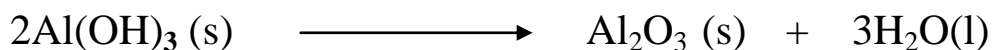
Pure aluminium (III)oxide (**$Al_2O_3$**) has a very high melting point of **$2015^oC$**.
Alot of energy is required to melt the oxide.
It is therefore dissolved first in molten **cryolite** /sodium hexafluoroaluminate
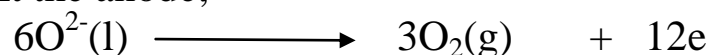(III)/$Na_3AlF_6$ to **lower** the melting point to about **$800^oC$**.

The molten electrolyte is put in the Hall cell made up of a steel tank lined with
carbon graphite and an anode suspended into the electrolyte.
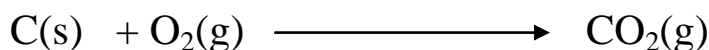During the electrolysis:

   (**i**)At the cathode;
$$4Al^{3+}(l) + 12e \longrightarrow 4Al(l)$$
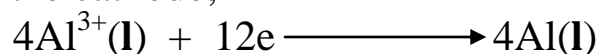
   (**ii**) At the anode;
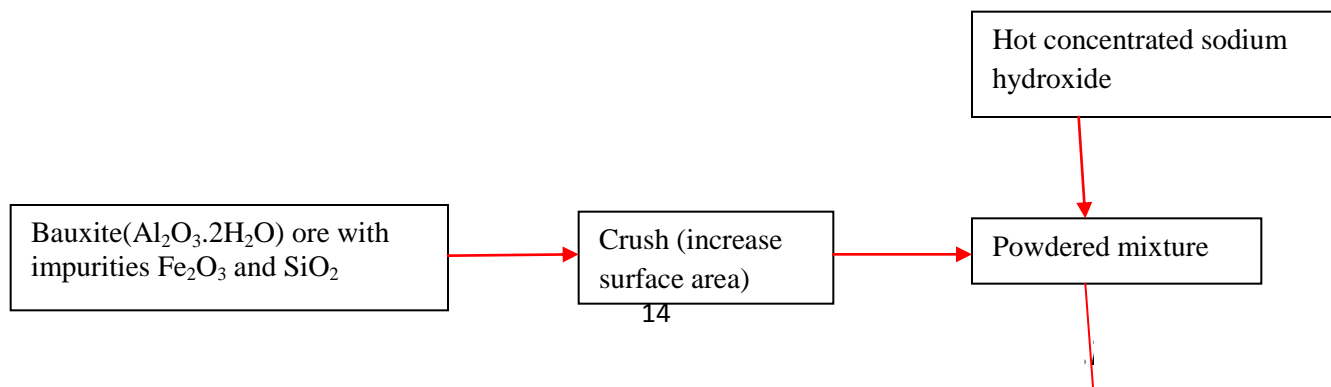$$6O^{2-}(l) \longrightarrow 3O_2(g) + 12e$$

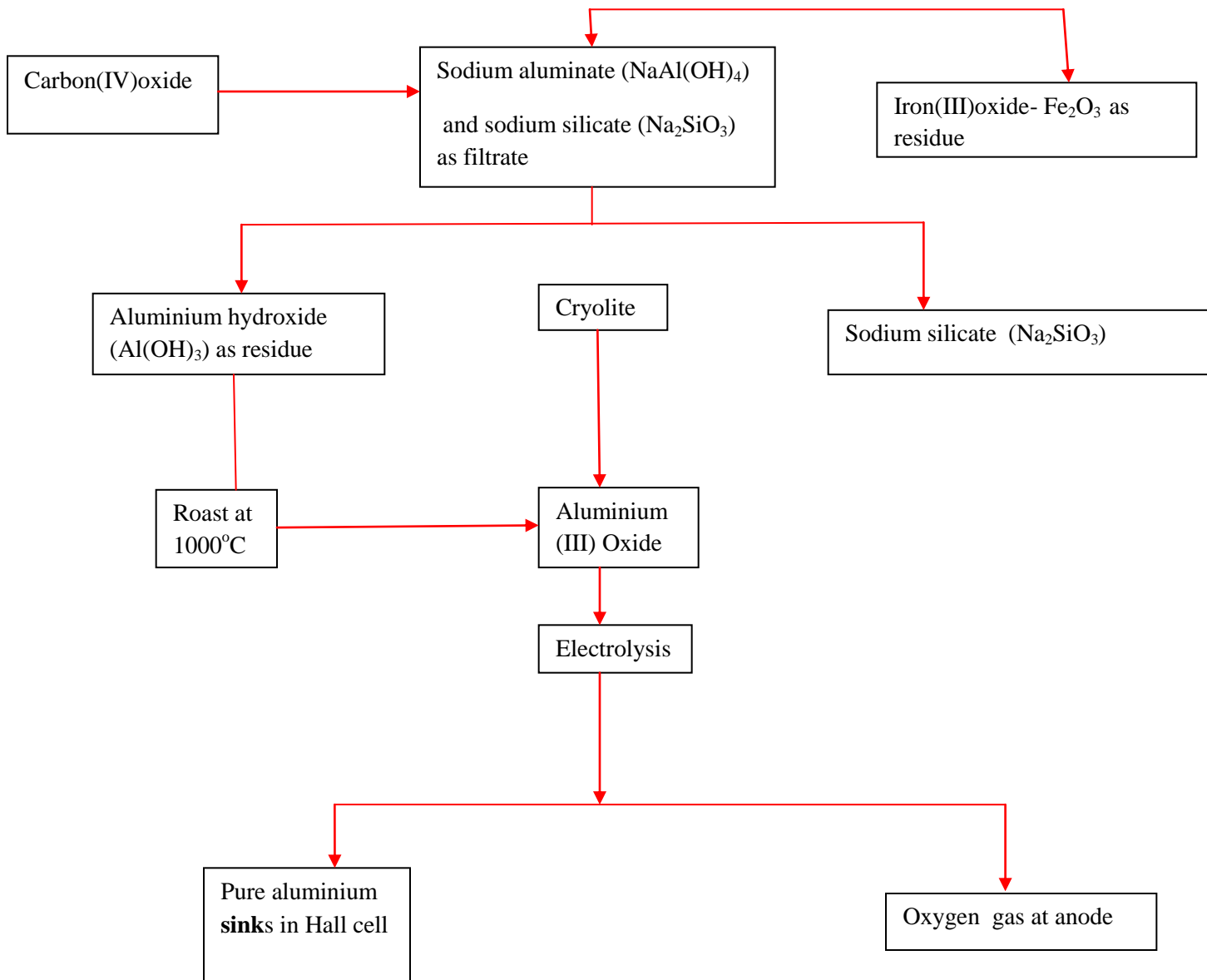Aluminium is denser than the electrolyte therefore sink to the bottom of the
Hall cell.
At this temperature ,the Oxygen evolved/produced at the anode **reacts** with
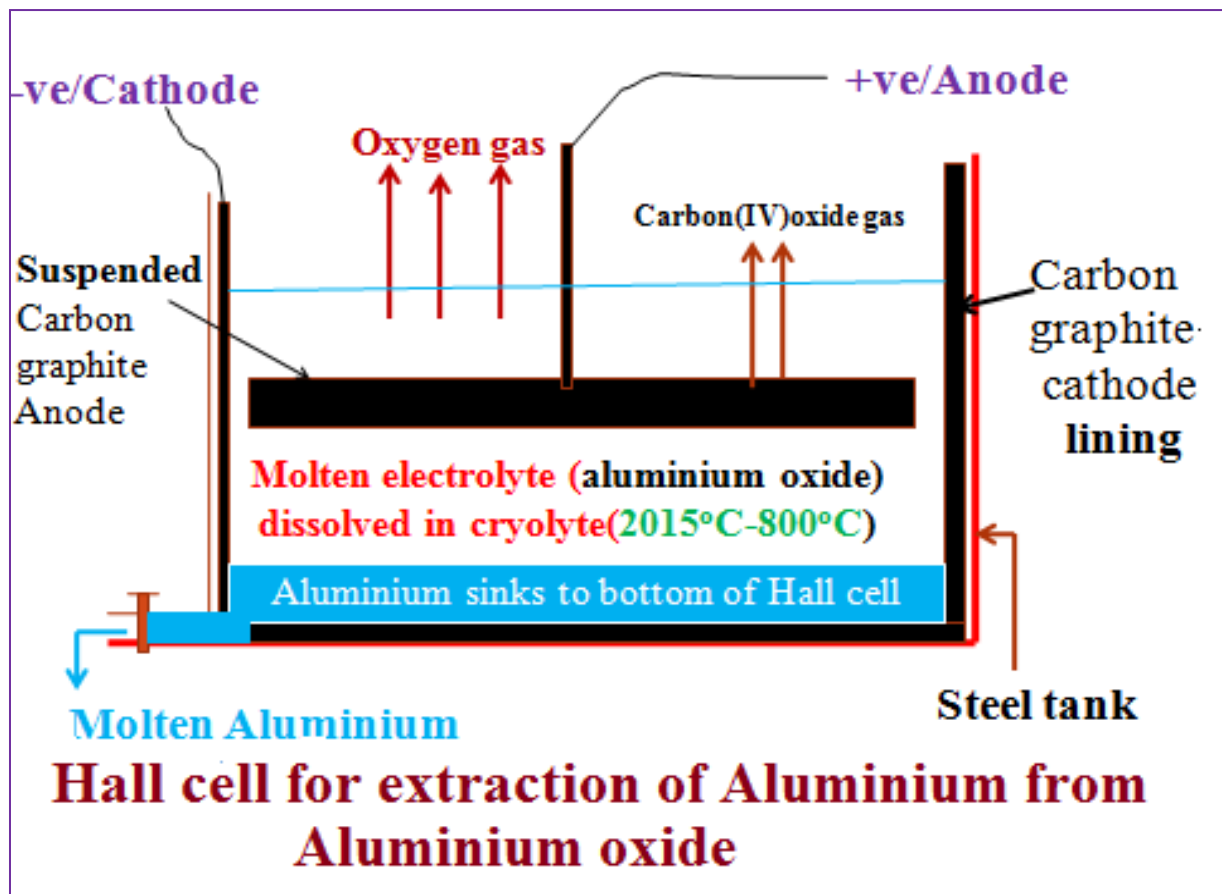carbon anode to form carbon(IV)oxide gas that **escape** to the atmosphere.

$$C(s) + O_2(g) \longrightarrow CO_2(g)$$
The anode thus should be continuously **replaced** from time to time.

Flow chart summary of extraction of aluminium from Bauxite

| Hot concentrated sodium hydroxide |
|---|

| Bauxite($Al_2O_3.2H_2O$) ore with impurities $Fe_2O_3$ and $SiO_2$ | Crush (increase surface area) | Powdered mixture |
|---|---|---|

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Carbon(IV)oxide

Sodium aluminate (NaAl(OH)$_4$)

and sodium silicate (Na$_2$SiO$_3$) as filtrate

Iron(III)oxide- Fe$_2$O$_3$ as residue

Aluminium hydroxide (Al(OH)$_3$) as residue

Cryolite

Sodium silicate (Na$_2$SiO$_3$)

Roast at 1000$^o$C

Aluminium (III) Oxide

Electrolysis

Pure aluminium **sink**s in Hall cell

Oxygen gas at anode

**c)** Diagram showing the **Hall cell / process for extraction of Bauxite**

**-ve/Cathode**  **+ve/Anode**

Oxygen gas

Carbon(IV)oxide gas

**Suspended Carbon graphite Anode**

Carbon graphite cathode lining

Molten electrolyte (aluminium oxide) dissolved in cryolyte($2015^{\circ}C$-$800^{\circ}C$)

Aluminium sinks to bottom of Hall cell

**Molten Aluminium**

**Steel tank**

**Hall cell for extraction of Aluminium from Aluminium oxide**

### d)Uses of aluminium

(i) In making aeroplane parts, buses, tankers, furniture because aluminium is very light.

(ii)Making duralumin-an alloy which is harder and has a higher tensile strength

(iii)Making utensils,sauce pans,spoons because it is light and good conductor of electricity.

(iv)Making overhead electric cables because it is light,ductile and good conductor of electricity.

(iv)Used in the thermite process for production of Manganese, Chromium amd Titanium.

### e) Environmental effects of extracting aluminium from Bauxite.

Carbon(IV)oxide gas that **escape** to the atmosphere is a green house gas that causes global warming.

Bauxite is extracted by open caste mining that causes soil/environmental degradation.

### f) Test for presence of $Al^{3+}$

If an ore is suspected to contain $Al^{3+}$ it is;

(i)added hot concentrated sulphuric(VI)/Nitric(V)acid to free the ions present.

(ii)the free ions are then added a precipitating reagent like 2M sodium hydroxide /2M aqueous ammonia.

| Observation | Inference |
|---|---|
| White precipitate in excess 2M NaOH(aq) | $Pb^{2+}$, $Al^{3+}$, $Zn^{2+}$ |
| White precipitate in excess 2M $NH_3$(aq) | $Pb^{2+}$, $Al^{3+}$ |
| No black precipitate on adding $Na_2S$(aq) | $Al^{3+}$ |
| No white precipitate on adding either NaCl(aq),HCl(aq),$H_2SO_4$(aq),$Na_2SO_4$(aq) | $Al^{3+}$ |

## Practice

1.An unknown rock X was discovered in Ukraine. Test with dilute sulphuric (VI)acid shows rapid effervescence with production of a colourless gas A that forms a white precipitate with lime water and colourless solution B. On adding 3cm3 of 2M sodium hydroxide, a white precipitate C is formed that dissolves to form a colourless solution D on adding more sodium hydroxide. On adding 2M aqueous ammonia, a white precipitate E is formed which persist in excess aqueous ammonia.On which on adding 5cm3 of 1M Lead(II)nitrate(V) to F  a white precipitate G is formed which remains on heating.
Identify:
A
**Hydrogen/$H_2$**
B
**Aluminium sulphate(VI)/$Al_2(SO_4)_3$**
C
**Aluminium hydroxide/ $Al(OH_4)_3$**
D
**Tetrahydroxoaluminate(III)/ $[Al(OH_4)_3]^-$**
E
**Aluminium hydroxide/ $Al(OH)_3$**

F

## Aluminium chloride/ $AlCl_3$

2.Aluminium is obtained from the ore with the formula $Al_2O_3$. $2H_2O$. The ore is first heated and refined to obtain pure aluminium oxide ($Al_2O_3$).  The oxide is then electrolysed to get Aluminium and oxygen gas using carbon anodes and carbon as cathode. Give the common name of the ore from where aluminium is extracted from ½ mark

What would be the importance of heating the ore first before refining it?1 mark
**To remove the water of crystallization**
The refined ore has to be dissolved in cryolite first before electrolysis. Why is this necessary? 1½  mark
**To  lower the melting point of aluminium oxide from  about $2015^{o}C$ to $900^{o}C$ so as to lower /reduce cost of production**

Why are the carbon anodes replaced every now and then in the cell for electrolysing aluminium oxide?                              1 mark
**Oxygen produced at anode react with carbon to form carbon(IV)oxide gas that escape**
State two uses of aluminium
**In making aeroplane parts, buses, tankers, utensils,     sauce pans,spoons**
         **Making overhead electric cables**
         **Making duralumin**

# 3. IRON

## a)Natural occurrence

Iron is the second most common naturally occurring metal. It makes 4% of the earths crust as:

(i)Haematite($Fe_2O_3$)
(ii)Magnetite($Fe_3O_4$)
(iii)Siderite($FeCO_3$)

## b)The blast furnace for extraction of iron from Haematite and Magnetite

### a)Raw materials:

(i)Haematite($Fe_2O_3$)
(ii)Magnetite($Fe_3O_4$)
(iii)Siderite($FeCO_3$)
(iv)Coke/charcoal/ carbon
(v)Limestone

### b)Chemical processes:

Iron is usually extracted from Haematite ($Fe_2O_3$), Magnetite($Fe_3O_4$) Siderite ($FeCO_3$).These ores contain silicon(IV)oxide($SiO_2$) and aluminium(III)oxide ($Al_2O_3$) as impurities.

When extracted from siderite, the ore must first be roasted in air to decompose the iron(II)Carbonate to Iron(II)oxide with production of carbon(IV)oxide gas:

$$FeCO_3(s) \longrightarrow FeO(s) \quad + \quad CO_2(g)$$
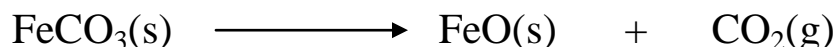
Iron(II)oxide is then rapidly oxidized by air to iron(III)oxide(Haematite).

$$4FeO(s) \quad + \quad O_2(g) \longrightarrow 2Fe_2O_3(s)$$
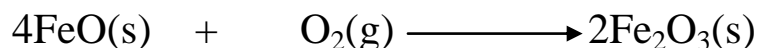
Haematite ($Fe_2O_3$), Magnetite($Fe_3O_4$), coke and limestone are all then fed from top into a tall (about 30metres in height) tapered steel chamber lined with refractory bricks called a blast furnace.

The furnace is covered with **inverted** double cap to prevent/reduce amount of any gases escaping .

Near the base/bottom, blast of hot air at about 1000K ($827^{\circ}C$) is driven/forced into the furnace through small holes called **Tuyeres**.
As the air enters ,it reacts with coke/charcoal/carbon to form carbon(IV)oxide gas. This reaction is highly exothermic.
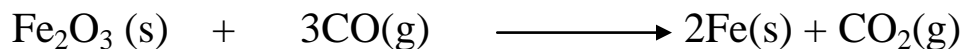
$$C(s) + O_2(g) \longrightarrow CO_2(g) \quad \Delta H = -394kJ$$
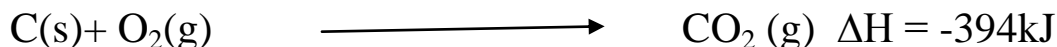
This raises the temperature at the bottom of the furnace to about 2000K($1650^{\circ}C$).As Carbon(IV)oxide gas rises up the furnace it reacts with more coke to form carbon(II)oxide gas.This reaction is endothermic.

$$CO_2(g) + C(s) \longrightarrow 2CO(g) \quad \Delta H = +173kJ$$
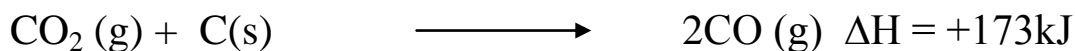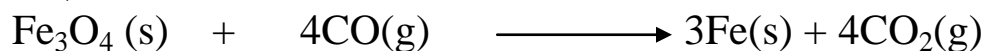
Carbon(II)oxide gas is a strong reducing agent that reduces the ores at the upper parts of the furnace where temperatures are about 750K($500^{\circ}C$) i.e.
For Haematite;

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + CO_2(g)$$

For Magnetite;

$$Fe_3O_4(s) + 4CO(g) \longrightarrow 3Fe(s) + 4CO_2(g)$$
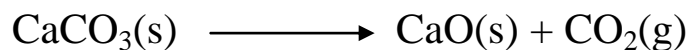
Iron is denser than iron ore. As it falls to the hotter base of the furnace it melts and can easily be tapped off.
Limestone fed into the furnace decomposes to quicklime/calcium oxide and produce more carbon(IV)oxide gas.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

Quicklime/calcium oxide reacts with the impurities silicon(IV)oxide($SiO_2$) and aluminium(III)oxide($Al_2O_3$)in the ore to form calcium silicate and calcium aluminate.

$$CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(l)$$
$$CaO(s) + Al_2O_3(s) \longrightarrow Ca\,Al_2O_4(l)$$
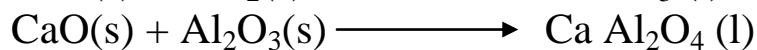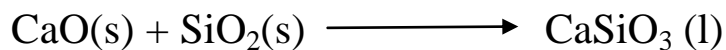
Calcium silicate and calcium aluminate mixture is called **slag**.Slag is **denser** than iron ore but **less dense** than iron therefore **float** on the pure iron. It is tapped at different levels to be tapped off for use in:
    (i)tarmacing roads
    (ii) cement manufacture
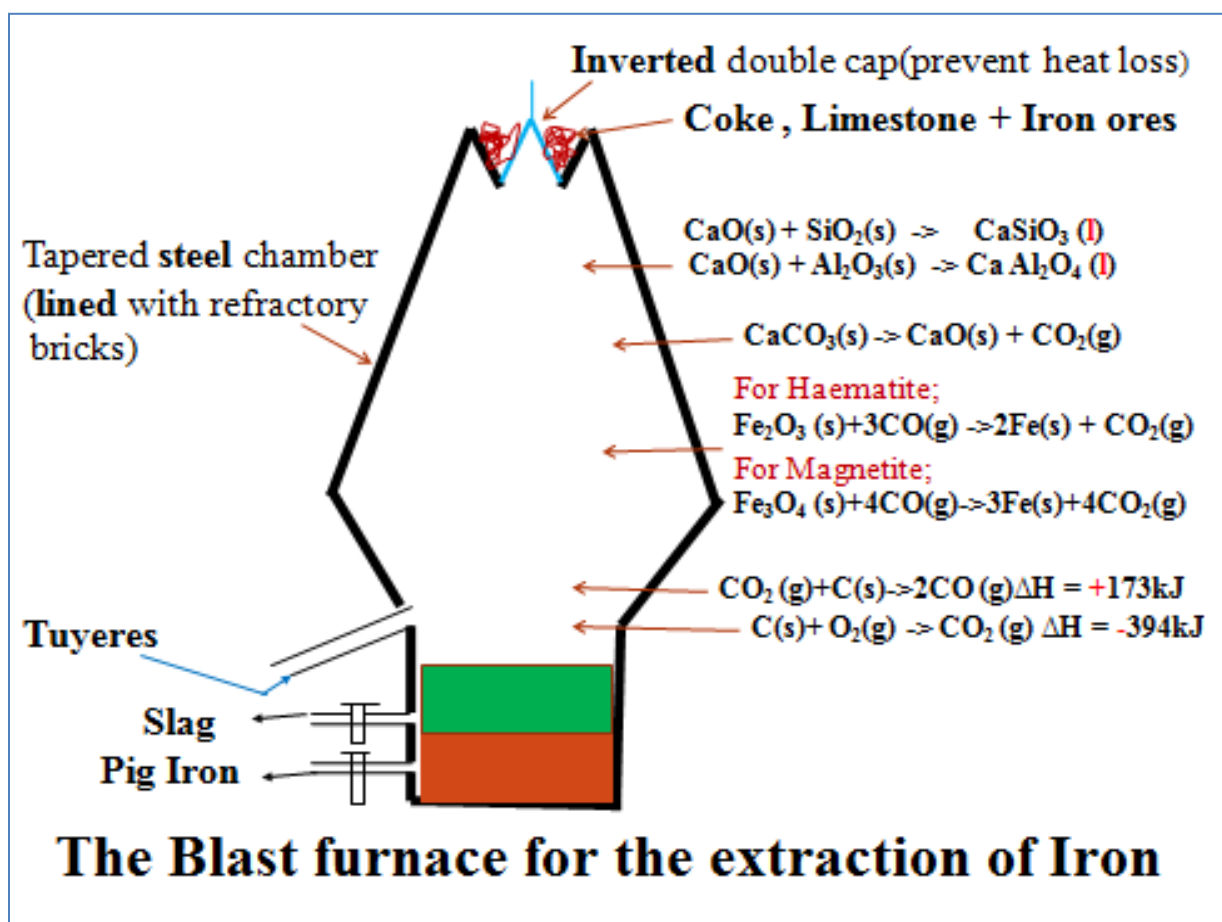    (iii)as building construction material

**(c)Uses of Iron**

Iron obtained from the blast furnace is hard and brittle. It is called **Pig iron.** It is remelted, added scrap steel then cooled. This iron is called cast iron.

Iron is mainly used to make:

(i)gates ,pipes, engine blocks, rails, charcoal iron boxes,lamp posts because it is cheap.

(ii)nails, cutlery, scissors, sinks, vats, spanners,steel rods, and railway points from steel.

Steel is an alloy of iron with carbon, and/or Vanadium, Manganese, Tungsten, Nickel ,Chromium. It does **not rust**/corrode like iron.

Inverted double cap(prevent heat loss)

Coke , Limestone + Iron ores

Tapered **steel** chamber (**lined** with refractory bricks)

$$CaO(s) + SiO_2(s) \rightarrow CaSiO_3 (l)$$
$$CaO(s) + Al_2O_3(s) \rightarrow Ca Al_2O_4 (l)$$

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

For Haematite;
$$Fe_2O_3 (s) + 3CO(g) \rightarrow 2Fe(s) + CO_2(g)$$
For Magnetite;
$$Fe_3O_4 (s) + 4CO(g) \rightarrow 3Fe(s) + 4CO_2(g)$$

$$CO_2 (g) + C(s) \rightarrow 2CO (g) \Delta H = +173kJ$$
$$C(s) + O_2(g) \rightarrow CO_2 (g) \Delta H = -394kJ$$

Tuyeres

Slag

Pig Iron

**The Blast furnace for the extraction of Iron**

**e) Environmental effects of extracting Iron from Blast furnace**

(i)Carbon(IV)oxide($CO_2$) gas is a green house gas that causes/increases global warming if allowed to escape/leak from the furnace.

(ii)Carbon(II)oxide(CO)gas is a highly poisonous/toxic odourless gas that can kill on leakage.

It is **preferentially** absorbed by the haemoglobin in mammals instead of Oxygen to form a **stable** compound that reduce free hemoglobin in the blood.

(iii) Haematite ($Fe_2O_3$), Magnetite($Fe_3O_4$) and Siderite ($FeCO_3$) are extracted through quarrying /open cast mining that cause soil / environmental degradation .

### f) Test for the presence of Iron

Iron naturally exist in its compound as $Fe^{2+}$ /$Fe^{3+}$

If an ore is suspected to contain $Fe^{2+}$ /$Fe^{3+}$ it is;

    (i)added hot concentrated sulphuric(VI)/Nitric(V)acid to free the ions present.

    (ii)the free ions are then added a precipitating reagent like 2M sodium hydroxide /2M aqueous ammonia which forms;

        I) an insoluble green precipitate in excess of 2M sodium hydroxide /2M aqueous ammonia if $Fe^{2+}$ ions are present.

        I) an insoluble brown precipitate in excess of 2M sodium hydroxide /2M aqueous ammonia if $Fe^{2+}$ ions are present.

| Observation | Inference |
|---|---|
| green precipitate in excess 2M NaOH(aq) | $Fe^{2+}$ |
| green precipitate in excess 2M $NH_3$(aq) | $Fe^{2+}$ |
| brown precipitate in excess 2M NaOH(aq) | $Fe^{3+}$ |
| brown precipitate in excess 2M $NH_3$(aq) | $Fe^{3+}$ |

**Practice questions**

### 4.COPPER

**a)Natural occurrence**

Copper is found as uncombined element/metal on the earths crust in Zambia, Tanzania, USA and Canada .The chief ores of copper are:

(i)Copper pyrites($CuFeS_2$)
(ii)Malachite($CuCO_3.Cu(OH)_2$)
(iii)Cuprite($Cu_2O$)

**b)Extraction of copper from copper pyrites.**

Copper pyrites are first crushed into fine powder. The powdered ore is the added water and oil. The purpose of water is to dissolve hydrophilic substances/particle. The purpose of oil is to make cover copper ore particle so as to make it hydrophobic

Air is blown through the mixture. Air creates bubbles that stick around hydrophobic copper ore. The air bubbles raise through buoyancy small hydrophobic copper ore particles to the surface. A concentrated ore floats at the top as froth. This is called froth flotation. The concentrated ore is then skimmed off.The ore is then roasted in air to form copper(I)sulphide ,sulphur(IV)oxide and iron (II) oxide.

$$2CuFeS_2(s) + 4O_2(g) \longrightarrow Cu_2S(s) + 3SO_2(g) + 2FeO(s)$$
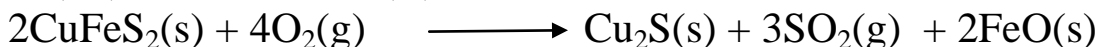
Limestone ($CaCO_3$) and silicon(IV)oxide ($SiO_2$) are added and the mixture heated in absence of air.Silicon(IV)oxide ($SiO_2$) reacts with iron (II) oxide to form Iron silicate which constitutes the slag and is removed.

$$FeO(s) + SiO_2(s) \longrightarrow FeSiO_3(s)$$
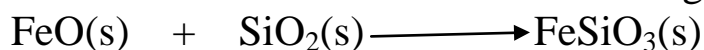
The slag separates off from the copper(I)sulphide. Copper(I)sulphide is then heated in a regulated supply of air where some of it is converted to copper (I) oxide.

$$2Cu_2S \text{ (s)} + 3O_2(g) \longrightarrow 2Cu_2S(s) + 2SO_2(g)$$
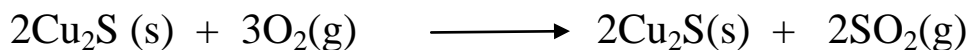
The mixture then undergo self reduction in which copper(I)oxide is reduced by copper(I)sulphide to copper metal.

$$Cu_2S \text{ (s)} + 2Cu_2O \text{ (s)} \longrightarrow 6Cu \text{ (s)} + SO_2(g)$$
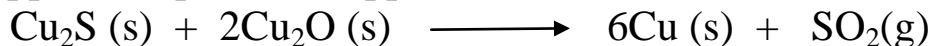
The copper obtained has Iron, sulphur and traces of silver and gold as impurities.It is therefore about 97.5% pure. It is refined by electrolysis/electrolytic method.

During the electrolysis of refining copper, the impure copper is made the anode and a small pure strip is made the cathode.

Electrode ionization takes place where:

At the anode;

$$Cu(s) \longrightarrow Cu^{2+} \text{ (aq)} + 2e$$

Note: Impure copper anode dissolves/erodes into solution and decreases in size.

At the Cathode;

$$Cu^{2+} \text{ (aq)} + 2e \longrightarrow Cu(s)$$
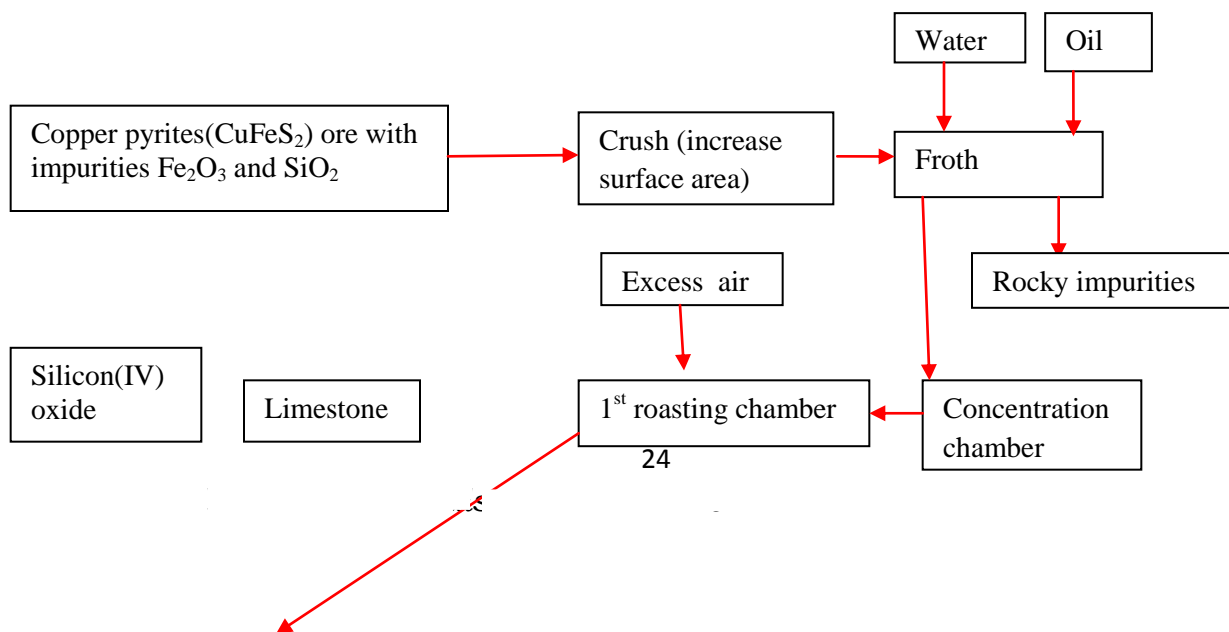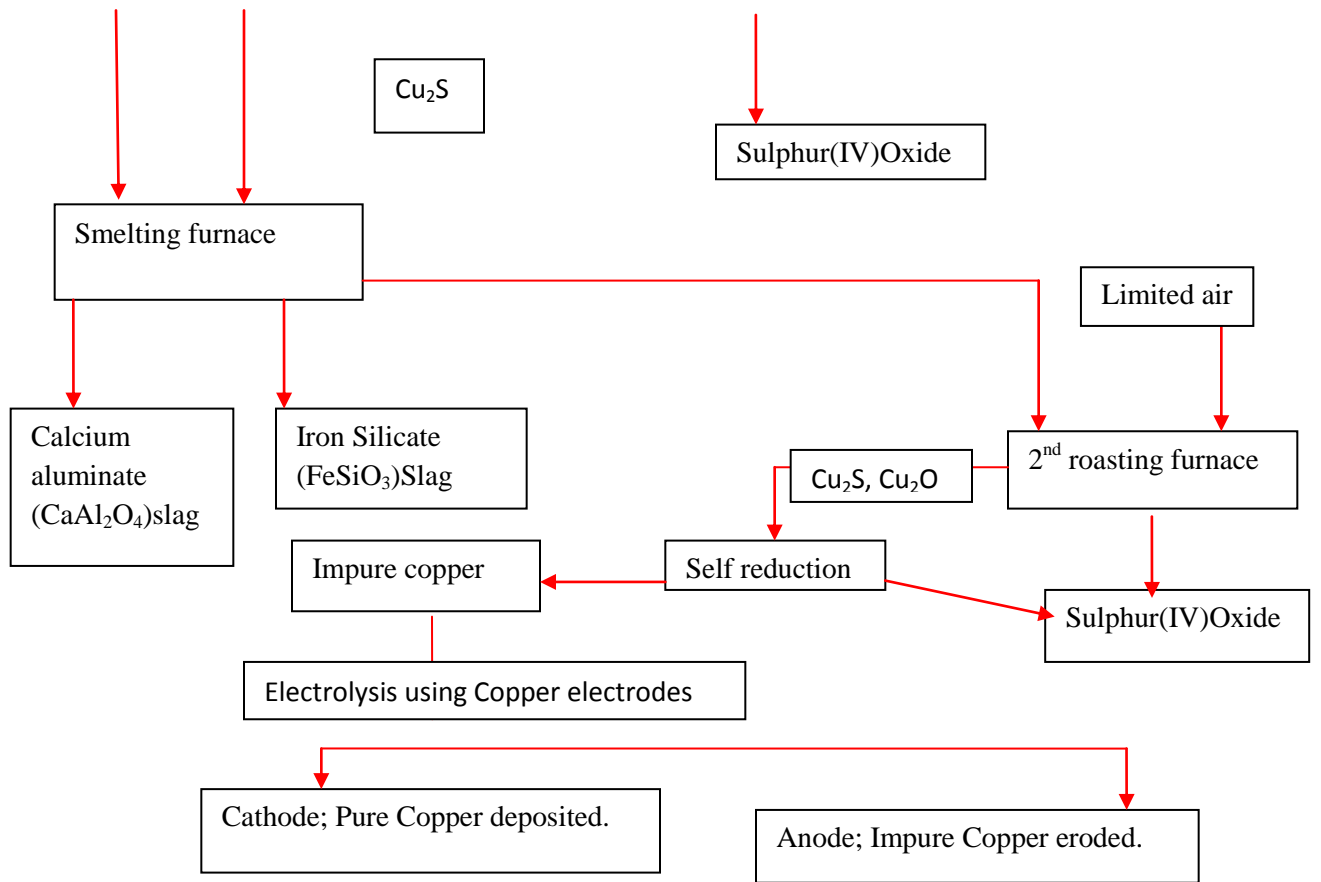
Note: The copper ions in the electrolyte($CuSO_4$) are reduced and deposited as copper metal at the cathode. The copper obtained is 99.98% pure.

Valuable traces of silver and gold collect at the bottom of the electrolytic cell as sludge. It is used to finance the extraction of copper pyrites.

### (c)Flow chart summary of extraction of copper from Copper pyrites

| | Water | Oil |
|---|---|---|

| Copper pyrites($CuFeS_2$) ore with impurities $Fe_2O_3$ and $SiO_2$ | → | Crush (increase surface area) | → | Froth |

| | Excess air | | Rocky impurities |

| Silicon(IV) oxide | Limestone | | 1st roasting chamber | ← | Concentration chamber |

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Cu$_2$S

Sulphur(IV)Oxide

Smelting furnace

Limited air

Calcium aluminate (CaAl$_2$O$_4$)slag

Iron Silicate (FeSiO$_3$)Slag

Cu$_2$S, Cu$_2$O

2$^{nd}$ roasting furnace

Impure copper

Self reduction

Sulphur(IV)Oxide

Electrolysis using Copper electrodes

Cathode; Pure Copper deposited.

Anode; Impure Copper eroded.

Electrolytic purification of impure copper

**d) Uses of copper**
Copper is mainly used in:

(i)making low voltage electric cables,contact switches, cockets and plugs because it is a good conductor of electricity.
(ii)Making solder  because it is a good thermal conductor.
(iii)Making useful alloys e.g.
      -Brass is an alloy of copper and Zinc(Cu/Zn)
      -Bronze is an alloy of copper and Tin(Cu/Sn)
      -German silver is an alloy of copper ,Zinc and Nickel(Cu/Zn/Ni)
(iv)Making coins and ornaments.

### e) Environmental effects of extracting copper from Copper pyrites
(i)Sulphur(IV)oxide is a gas that has a pungent poisonous smell that causes head ache to human in high concentration.
(ii)Sulphur(IV)oxide  gas if allowed to escape dissolves in water /rivers/rain to form weak sulphuric(IV)acid lowering the pH of the water leading to marine pollution, accelerated corrosion/rusting of metals/roofs and breathing problems to human beings.
(iii)Copper is extracted by open caste mining leading to land /environmental /soil degradation.

### f) Test for the presence of copper in an ore
Copper naturally exist in its compound as $Cu^{2+}$ /$Cu^{+}$
Copper (I) / $Cu^{+}$ is readily oxidized to copper(II)/ $Cu^{2+}$
If an ore is suspected to contain $Cu^{2+}$ /$Cu^{+}$ it is;
      (i)added hot concentrated sulphuric(VI)/Nitric(V)acid to free the ions present.
      (ii)the free ions are then added a precipitating reagent; 2M sodium hydroxide /2M aqueous ammonia which forms;
         I) an insoluble blue precipitate in excess of 2M sodium hydroxide if $Cu^{2+}$ ions are present.
         I) an insoluble blue precipitate in 2M aqueous ammonia that dissolve to **royal/deep blue solution** in excess if **$Cu^{2+}$** ions are present.

| Observation | Inference |
| --- | --- |
| blue precipitate in excess 2M NaOH(aq) | $Cu^{2+}$ |
| **blue** precipitate,dissolve to **royal/deep blue solution** in excess 2M NH$_3$(aq) | **$Cu^{2+}$** |

**g)Sample questions**

Copper is extracted from copper pyrites as in the flow chart outlined below. Study it and answer the questions that follow

### 5.ZINC and LEAD

**a)Natural occurrence**

Zinc occurs mainly as:

(i)Calamine-Zinc carbonate($ZnCO_3$)

(ii)Zinc blende-Zinc sulphide(ZnS)

Lead occurs mainly as Galena-Lead(II)Sulphide mixed with Zinc blende:

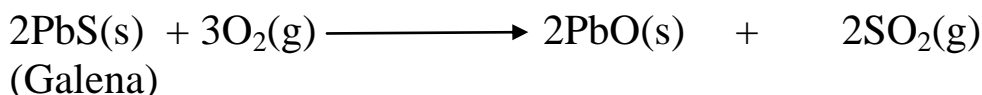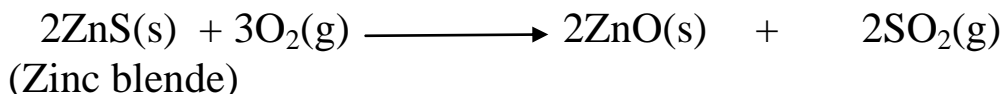**b)Extraction of Zinc/Lead  from Calamine ,Zinc blende and Galena.**

During extraction of Zinc , the ore is first roasted in air:

For Calamine Zinc carbonate decompose to Zinc oxide and carbon(IV) oxide gas.

$ZnCO_3(s) \longrightarrow ZnO(s) \quad + \quad CO_2(g)$
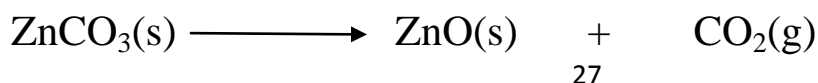
Zinc blende does not decompose but reacts with air to form Zinc oxide and sulphur(IV) oxide gas.

Galena as a useful impurity also reacts with air to form Lead(II) oxide and sulphur(IV) oxide gas.

$$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$$
(Zinc blende)

$$2PbS(s) + 3O_2(g) \longrightarrow 2PbO(s) + 2SO_2(g)$$
(Galena)

The oxides are mixed with coke and limestone/Iron(II)oxide/ Aluminium (III) oxide and heated in a blast furnace.

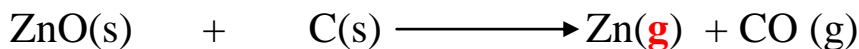At the furnace temperatures limestone decomposes to quicklime/CaO and produce Carbon(IV)oxide gas.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2 (g)$$
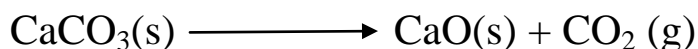
Carbon(IV)oxide gas reacts with more coke to form the Carbon(II)oxide gas.

$$C(s) + CO_2 (g) \longrightarrow 2CO (g)$$
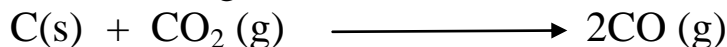
Both Carbon(II)oxide and carbon/coke/carbon are reducing agents.
The oxides are reduced to the metals by either coke or carbon (II)oxide.

$$ZnO(s) + C(s) \longrightarrow Zn(\textbf{g}) + CO (g)$$
$$PbO(s) + C(s) \longrightarrow Pb(\textbf{l}) + CO (g)$$

$$PbO(s) + CO(s) \longrightarrow Pb(\textbf{l}) + CO_2 (g)$$
$$PbO(s) + CO(s) \longrightarrow Pb(\textbf{g}) + CO_2 (g)$$
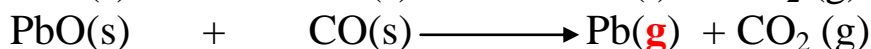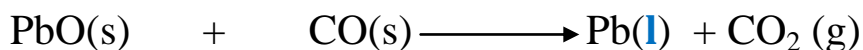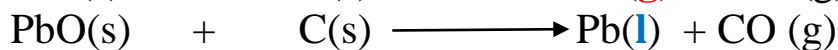
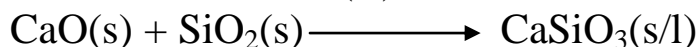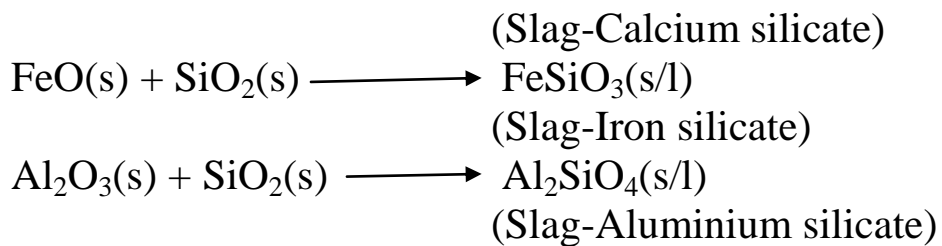At the furnace temperature:

(i)Zinc is a gas/vapour and is collected at the **top** of the furnace. It is condensed in a spray of molten lead to prevent reoxidation to Zinc oxide. On further cooling , Zinc collects on the surface from where it can be tapped off
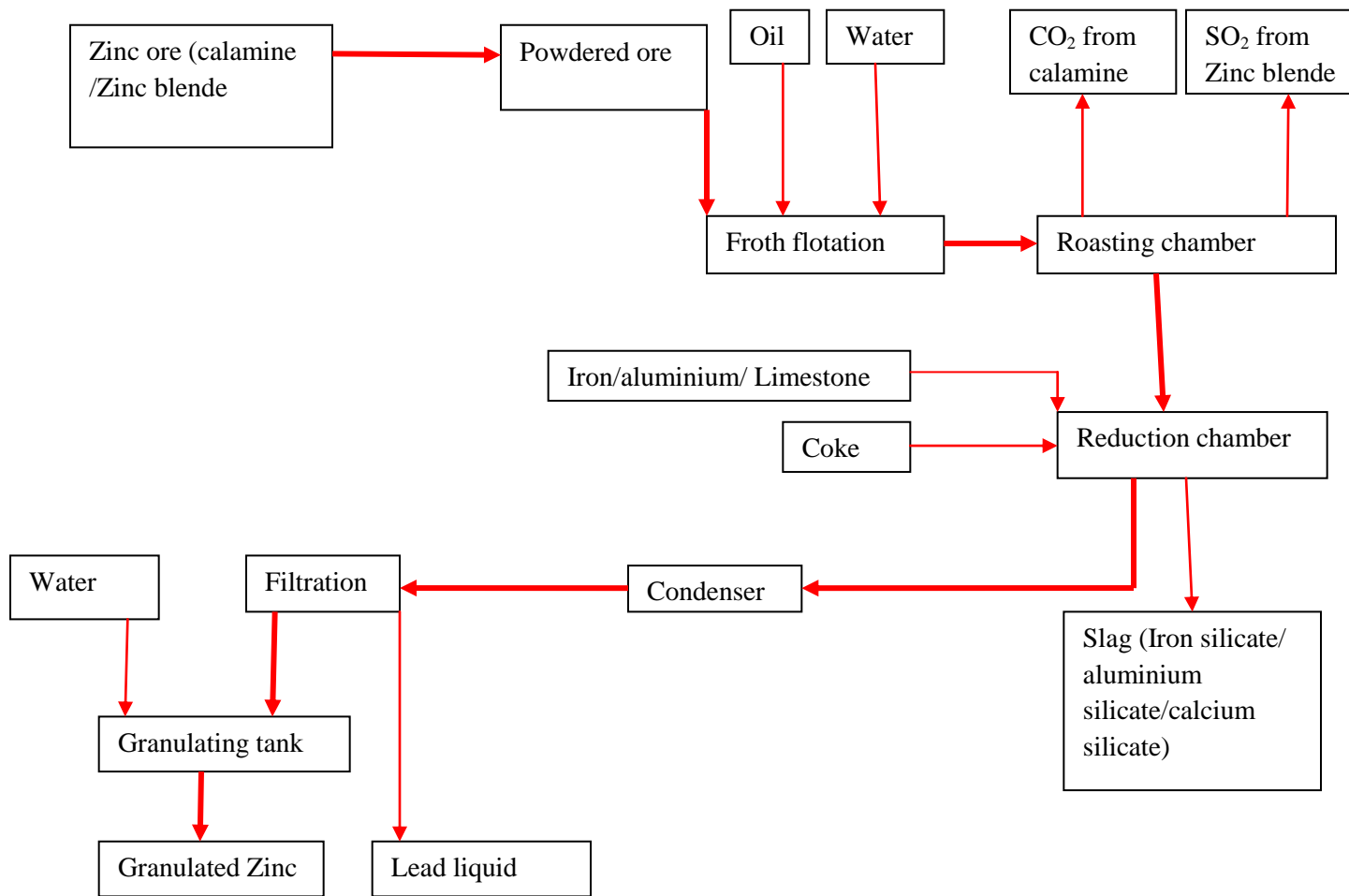
(ii)Lead is a liquid and is ale to trickle to the bottom of the furnace from where it is tapped off.

Quicklime/CaO, Iron(II)Oxide, Aluminium(III)oxide are used to remove silica/silicon(IV)oxide as silicates which float above Lead preventing its reoxidation back to Lead(II)Oxide.
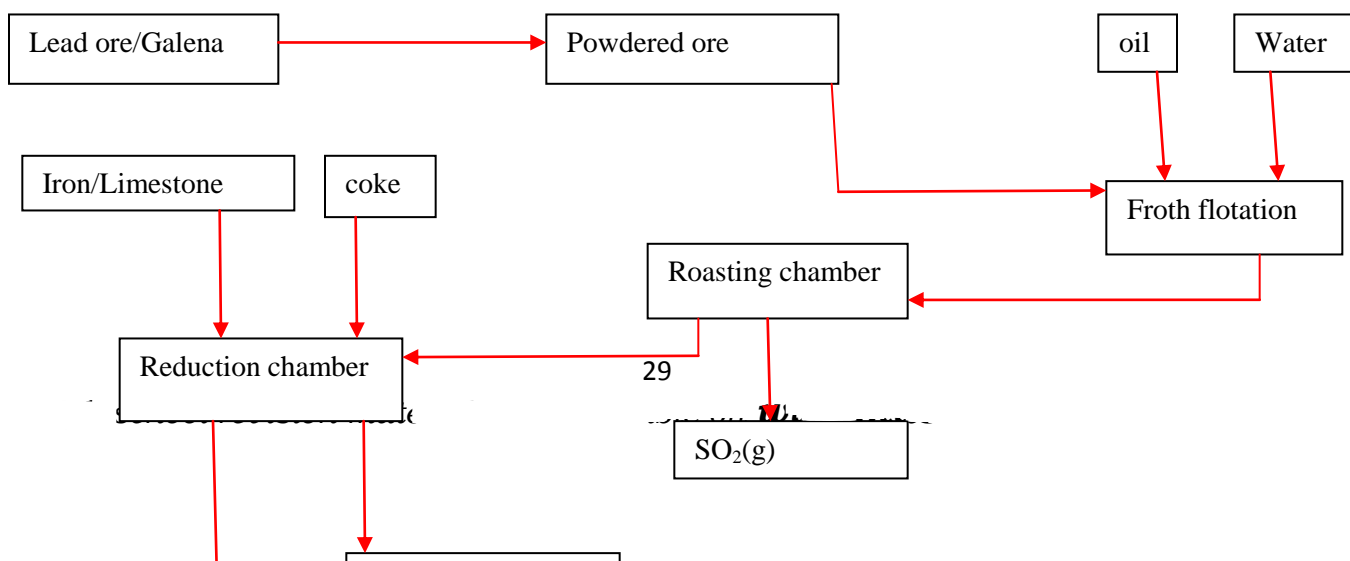
$$CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(s/l)$$

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(Slag-Calcium silicate)

$$FeO(s) + SiO_2(s) \longrightarrow FeSiO_3(s/l)$$

(Slag-Iron silicate)

$$Al_2O_3(s) + SiO_2(s) \longrightarrow Al_2SiO_4(s/l)$$

(Slag-Aluminium silicate)

## c)Flow chart on extraction of Zinc from Calamine ,Zinc blende.

| Zinc ore (calamine /Zinc blende |
| --- |

→ Powdered ore

| Oil | Water | | $CO_2$ from calamine | $SO_2$ from Zinc blende |

Froth flotation → Roasting chamber

Iron/aluminium/ Limestone

Coke → Reduction chamber

Water | Filtration ← Condenser ←

Slag (Iron silicate/ aluminium silicate/calcium silicate)

Granulating tank

Granulated Zinc | Lead liquid

## d) Flow chart on extraction of Lead from Galena

| Lead ore/Galena | → | Powdered ore | | oil | Water |

| Iron/Limestone | coke |

Froth flotation

Roasting chamber

Reduction chamber

29

$SO_2(g)$

## e) Uses of Lead

Lead is used in:

(i)making gun-burettes.

(ii)making protective clothes against nuclear (alpha rays/particle) radiation in a nuclear reactor.

(iii)Mixed with tin(Sn) to make **solder** alloy

## f) Uses of Zinc

Zinc is used in:

(i)Galvanization-when iron sheet is dipped in molten Zinc ,a thin layer of Zinc is formed on the surface.Since Zinc is more reactive than iron ,it reacts with elements of air($CO_2$/ $O_2$ / $H_2O$) to form basic Zinc carbonate($ZnCO_3.Zn(OH)_2$).This **sacrificial** method protects iron from corrosion/rusting.

(ii)As negative terminal and casing in dry/Laclanche cells.

(iii)Making brass alloy with copper(Cu/Zn)

## g) Environmental effects of extracting Zinc and Lead.

(i) Lead and Lead salts are carcinogenic/causes cancer

(ii)Carbon(IV)oxide is a green house gas that causes/accelerate global warming.

(iii)Carbon(II)oxide is a colourless odourless poisonous /toxic gas that combines with haemoglobin in the blood to form stable carboxyhaemoglobin reducing free haemoglobin leading to death.

(iv) Sulphur(IV)oxide is a gas that has a pungent poisonous smell that causes headache to human if in high concentration.

(v)Any leakages in Sulphur(IV)oxide gas escapes to the water bodies to form weak sulphuric(VI)acid lowering the pH of the water. This causes marine pollution /death of aquatic life, accelerated rusting/corrosion of metals/roofs and breathing problems to human beings.

## h) Test for presence of Zinc/ Lead.

If an ore is suspected to contain Zinc/Lead it is:

I.added hot concentrated Nitric(V)acid to free the ions present.

Note:

Concentrated Sulphuric(VI)acid forms insoluble $PbSO_4$ thus cannot be used to free the ions in Lead salts.

II.the free ions are then added a precipitating reagent mostly 2M sodium hydroxide or 2M aqueous ammonia with the formation of;

(i)a soluble precipitate in excess of 2M sodium hydroxide if $Zn^{2+}$, $Pb^{2+}$, $Al^{3+}$ions are present.

(ii)a white precipitate that dissolves to form a colorless solution in excess 2M aqueous ammonia if $Zn^{2+}$ions are present.

(iii)an insoluble white precipitate in excess 2M aqueous ammonia if $Pb^{2+}$, $Al^{3+}$ions are present.

(iv) $Pb^{2+}$ ions form a white precipitate when any soluble $SO_4^{2-}$, $SO_3^{2-}$, $CO_3^{2-}$, $Cl^-$, is added while $Al^{3+}$ ions do not form a white precipitate

(v) $Pb^{2+}$ ions form a yellow precipitate when any soluble $I^-$(e.g. Potassium/sodium Iodide) is added while $Al^{3+}$ ions do not form a yellow precipitate.

(vi) $Pb^{2+}$ ions form a black precipitate when any soluble $S^-$(e.g. Potassium/sodium sulphide) is added while $Al^{3+}$ ions do not form a black precipitate.i.e;

| Observation | Inference |
|---|---|
| White precipitate in excess 2M NaOH (aq) | $Zn^{2+}$, $Pb^{2+}$, $Al^{3+}$ ions |
| White precipitate that dissolves to form a colourless solution in excess 2M $NH_3$(aq) | $Zn^{2+}$ ions |
| White precipitate in excess 2M $NH_3$(aq) | $Pb^{2+}$, $Al^{3+}$ ions |

| | |
|---|---|
| White precipitate on adding about 4 drops of either $Na_2CO_3(aq)$, $Na_2SO_3(aq)$, $Na_2SO_4(aq)$, $H_2SO_4(aq)$, $HCl(aq)$, $NaCl(aq)$ | $Pb^{2+}$ions |
| Yellow precipitate on adding about 4 drops of of $KI(aq).NaI (aq)$ | $Pb^{2+}$ ions |
| Black precipitate on adding aout 4 drops of $Na_2S(aq)/K_2S(aq)$ | $Pb^{2+}$ ions |

# 6.GENERAL SUMMARY OF METALS

## a) Summary methods of extracting metal from their ore

The main criteria used in extraction of metals is based on its position in the electrochemical/reactivity series and its occurrence on the earth's crust.

Position on the earth's crust

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If near the surface use open
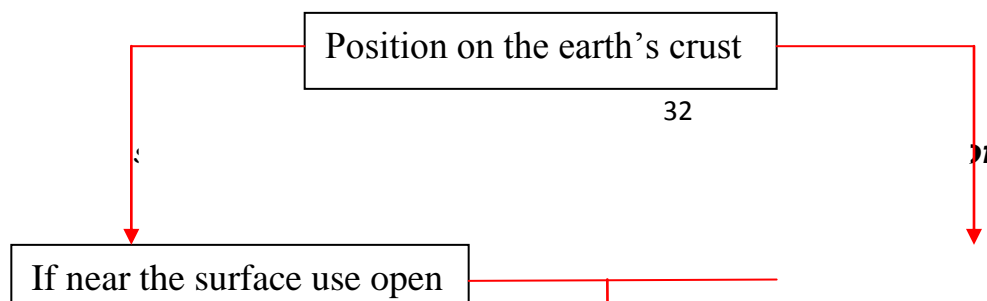
If deep on the earth's crust use deep mining

Electrolyse the ore if it is made of reactive metals; Potassium, Sodium, Magnesium, Calcium, Aluminium

Roast the ore first if it is a carbonate / sulphide of Zinc, Iron, Tin, Lead, and copper to form the oxide

Reduce the oxide using carbon in a furnace if it is made of Zinc ,Tin, Lead ,Copper and Iron

**b) Summary of extraction of common metal.**

| Metal | Chief ore/s | Chemical formula of ore | Method of extraction | Main equation during extraction |
|---|---|---|---|---|
| Sodium | Rock salt | NaCl(s) | **Downs process** | **Cathode:** |

| | | | Through electrolysis of molten NaCl ($CaCl_2$ lower m.pt from $800^{o}C$-> $600^{o}C$) | $2Na^{+}(l) + 2e -> 2Na(l)$ **Anode:** $2Cl^{-}(l) -> Cl_2(g) + 2e$ |
|---|---|---|---|---|
| Sodium/ sodium hydroxide | Brine | NaCl(aq) | **Flowing mercury cathode cell** Through electrolysis of concentrated NaCl(aq) | **Cathode:** $2Na^{+}(aq)+2e -> 2Na(aq)$ **Anode:** $2Cl^{-}(aq) -> Cl_2(g) + 2e$ |
| Aluminium | Bauxite | $Al_2O_3.2H_2O$ | **Halls process Through electrolysis of molten** $Al_2O_3$. (Cryolite lower m.pt from $2015^{o}C$ -> $800^{o}C$) | **Cathode:** $4Al^{3+}(l) + 12e -> 4Al(l)$ **Anode:** $6O^{2-}(l) -> 3O_2(g) + 12e$ |
| Iron | Haematite Magnetite | $Fe_2O_3$ $Fe_3O_4$ | **Blast furnace** Reduction of the ore by carbon(II)oxide | $Fe_2O_3(s)+ 3CO(g) \longrightarrow$ $2Fe(l) +3CO_2(g)$ $Fe_3O_4(s)+ 4CO(g) \longrightarrow$ $3Fe(l) +4CO_2(g)$ |
| Copper | Copper pyrites | $CuFeS_2$ | **Roasting** the ore in air to get $Cu_2S$. **Heating** $Cu_2S$ ore in regulated supply of air. **Reduction** of $Cu_2O$ by $Cu_2S$ | $2CuFeS_2 (s)+ 4O_2(g) ->$ $Cu_2S(s)+3SO_2(g)$ $+2FeO(s)$ $2Cu_2S (s)+ 3O_2(g) ->$ $2Cu_2O(s)+2SO_2(g)$ $Cu_2S (s)+ 2Cu_2O(s) ->$ $6Cu(s)+ SO_2(g)$ |
| Zinc | Calamine | $ZnCO_3$ | **Roasting** the ore in air to get ZnO **Blast furnace /reduction** of the oxide by Carbon(II)Oxide/Carbon | $ZnCO_3(s)-> ZnO(s) +$ $CO_2(g)$ $2ZnS(s) +3O_2(g) ->$ $2ZnO(s) + 2SO_2(g)$ $ZnO(s) + CO(g)->$ $Zn(s) + CO_2(g)$ |
| Lead | Galena | PbS | **Blast furnace- Reduction of the oxide** | $PbO(s) + CO(g)->$ $Pb(s) + CO_2(g)$ |

| | | | by carbon(II)oxide /Carbon | |
|---|---|---|---|---|
| | | | | |

## c) Common alloys of metal.

| Alloy name | Constituents of the alloy | Uses of the alloy |
|---|---|---|
| Brass | Copper and Zinc | Making scews and bulb caps |
| Bronze | Copper and Tin | Making clock springs,electrical contacts and copper coins |
| Soldier | Lead and Tin | Soldering, joining electrical contacts because of its low melting points and high thermal conductivity |
| Duralumin | Aluminium, Copper and Magnesium | Making aircraft , utensils ,windows frames because of its light weight and corrosion resistant. |
| Steel | Iron, Carbon ,Manganese and other metals | Railway lines , car bodies girders  and utensils. |
| Nichrome | Nichrome and Chromium | Provide resistance in electric heaters and ovens |
| German silver | Copper,Zinc and Nickel | Making coins |

## d) Physical properties of metal.

Metals form giant metallic structure joined by metallic bond from electrostatic attraction between the metallic cation and free delocalized electrons.

This makes metals to have the following physical properties:

### (i)High melting and boiling points

The giant metallic structure has a very close packed metallic lattice joined by strong electrostatic attraction between the metallic cation and free delocalized electrons.The more delocalized electrons the higher the melting/boiling points e.g.

Aluminium has a melting point of about $2015^oC$ while that of sodium is about $98^oC$.This is mainly because aluminium has more/three delocalized electrons than sodium/has one.

Aluminium has a boiling point of about $2470^oC$ while that of sodium is about $890^oC$.This is mainly because aluminium has more/three delocalized electrons than sodium/has one.

### (ii)High thermal and electrical conductivity

All metals are good thermal and electrical conductors as liquid or solids. The more delocalized electrons the higher the thermal and electrical conductivity. e.g.

Aluminium has an electrical conductivity of about $3.82 \times 19^{-9}$ ohms per metre. Sodium has an electrical conductivity of about $2.18 \times 19^{-9}$ ohms per metre.

### (iii)Shiny/Lustrous

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The free delocalized electrons on the surface of the metal absorb, vibrate and then scatter/re-emit/lose light energy. All metals are therefore usually shades of grey in colour except copper which is shiny brown.e.g.
Zinc is bluish grey while iron is silvery grey.

### (iv)High tensile strength
The free delocalized electrons on the surface of the metal atoms binds the surface immediately when the metal is coiled/folded preventing  it from breaking /being brittle.

### (v)Malleable.
Metals can be made into thin sheet. The metallic crystal lattice on being beaten/pressed/hammered on two sides extend its length and width/bredth and is then immediately bound by the delocalized electrons preventing it from breaking/being brittle.
### (vi)Ductile.
Metals can be made into thin wires. The metallic crystal lattice on being beaten/pressed/hammered on all sides extend its length is then immediately bound by the delocalized electrons preventing it from breaking/being brittle.

### Revision  questions
**1.Given some soil , dilute sulphuric(VI)acid,mortar,pestle,filter paper,filter funnel and 2M aqueous ammonia,describe with explanation,how you would show that the soil contain Zinc.**
Place the soil sample in the pestle. Crush using the mortar to reduce the particle size/increase its surface area.
Add dilute sulphuric(VI)acid to free the ions in soil sample.
Filter to separate insoluble residue from soluble filtrate
To filtrate,add three drops of aqueous ammonia as precipitating reagent. A white precipitate of  $Zn(OH)_2$, $Pb(OH)_2$ or $Al(OH)_3$ is formed
Add  excess aqueous ammonia to the white precipitate. If it dissolves the $Zn^{2+}$ ions are present. $Zn(OH)_2$ react with excess ammonia to form soluble $[Zn(OH)_4]^{2+}$ complex.

**2.In the extraction of aluminium,the oxide is dissolved in cryolite.**
**(i)What is the chemical name of cryolite?**
     Sodium hexafloroaluminate/$Na_3AlF_6$

**(ii)What is the purpose of cryolite?**
To lower the melting point of the electrolyte/Aluminium oxide from about $2015^{o}C$ to $900^{o}C$

**(iii)Name the substance used for similar purpose in the Down cell**
     Calcium chloride/$CaCl_2$
**(iv)An alloy of sodium and potassium is used as coolant in nuclear reactors.Explain.**

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Nuclear reactors generate a lot of heat energy. sodium and potassium alloy reduce/lower the high temperature in the reactors.

**(v)Aluminium metal is used to make cooking utensils in preference to other metals.Explain.**

Aluminium

(i) is a very good conductor of electricity because it has three delocalized electrons in its metallic structure

(ii)is cheap,malleable,ductile and has high tensile strength

(iii)on exposure to fire/heat form an impervious layer that prevent it from rapid corrosion.

3.Study the scheme below and use it to answer the questions that follow.
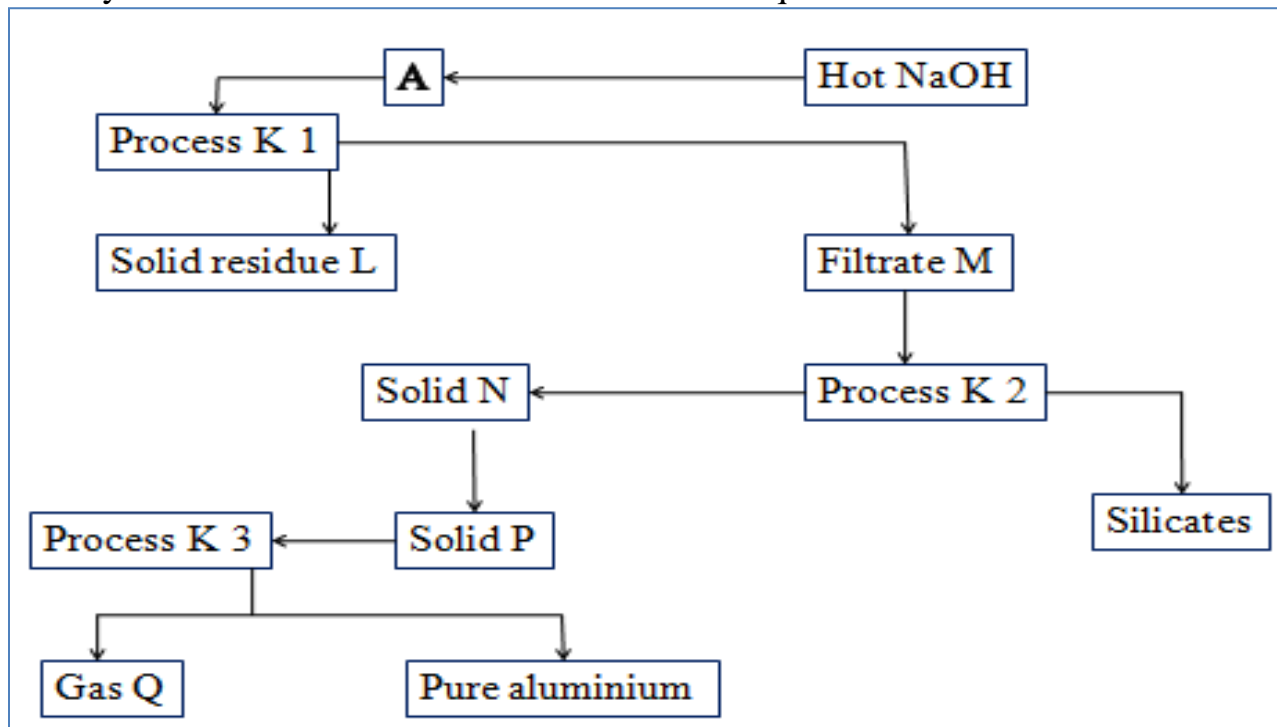


**(a)Identify:**

**(i)solid residue L**

Iron(III)Oxide/$Fe_2O_3$

**(ii)Solid N**

Aluminium hydroxide /$Al(OH)_3$

**(iii)Filtrate M**

Sodium tetrahydroxoaluminate/ $NaAl(OH)_4$ and sodium silicate/ $NaSiO_3$

**(iv)Solid P**

Aluminium oxide/ $Al_2O_3$

**(v)Gas Q**
Oxygen/$O_2$

**(vi)Process K1**
Filtration

**(vii)Process K2**
Electrolysis

**(b)Write the equation for the reaction taking place in the formation of solid P from solid N**
$2Al(OH)_3$   ->    $Al_2O_3$ (s)    +    $3H_2O$(l)
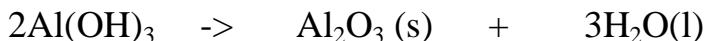
**(c)Name a substance  added to solid N before process Process K2 take place.**
Cryolite/Sodium tetrahydroxoaluminate/ $NaAl(OH)_4$

**(d)State the effect of evolution of gas Q on**

**(i)process K2**
Oxygen produced at the anode reacts with the carbon anode to form carbon(IV) oxide which escape. The electrolytic process needs continuous replacement of the carbon anode.

**(ii)the environment**
Oxygen produced at the anode reacts with the carbon anode to form carbon(IV) oxide which escape to the atmosphere.$CO_2$ is a green house gas that cause global warming.

(e)An aluminium manufacturing factory runs for  24 hours. If the total mass of aluminium produced is  27000kg,
(i)Calculate the current used. (Faraday constant=96500Coulombs, Al=27.0).
(ii)assuming  all the gas produced  react with 200kg of anode ,calculate the loss in mass of the electrode.(Molar gas volume at room temperature = 24dm3,C=12.0)

Working
Equation at Cathode
$Al^{3+}$(l)        +     3e    ->     Al(l)
27g  Al   -> 3 Faradays  =   3   x   96500C
(27000kg x 1000) g  -> (27000kg x 1000) g x 3   x   96500C
                                                              27g
=**289500000000 Coulombs**

Current  =   Quantity of electricity    =>289500000000 Coulombs
                    Time in seconds                    24 x 60 x 60
                 **3350690Ampheres**

Working

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Equation at Anode

$2O^{2-}(l)$ + 4e -> $O_2(g)$

      4 Faradays            -> 4 x 96500C24dm3 $O_2(g)$ -

    289500000000 Coulombs -> $\dfrac{289500000000 \text{ Coulombs x 24dm3}}{4 \text{ x } 96500C}$

**18,000,000dm3**

**Chemical equation at anode**

    $O_2(g)$ + C (s) -> $CO_2(g)$
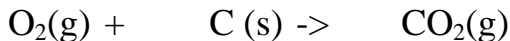
<u>Method 1</u>

24dm3 of $O_2(g)$       ->      12.0g Carbon

18,000,000dm3 of $O_2(g)$ ->    $\dfrac{18{,}000{,}000\text{dm3 x 12}}{24\text{dm3}}$ = $\dfrac{9000000g}{1000g}$ = **9000kg**

Loss in mass of the carbon graphite anode = **9000kg**

**NB:**Mass of the carbon graphite anode remaining =27000kg - 9000kg =**18000kg**

The flow chart below shows the extraction of iron metal.Use it to answer the questions that follow.
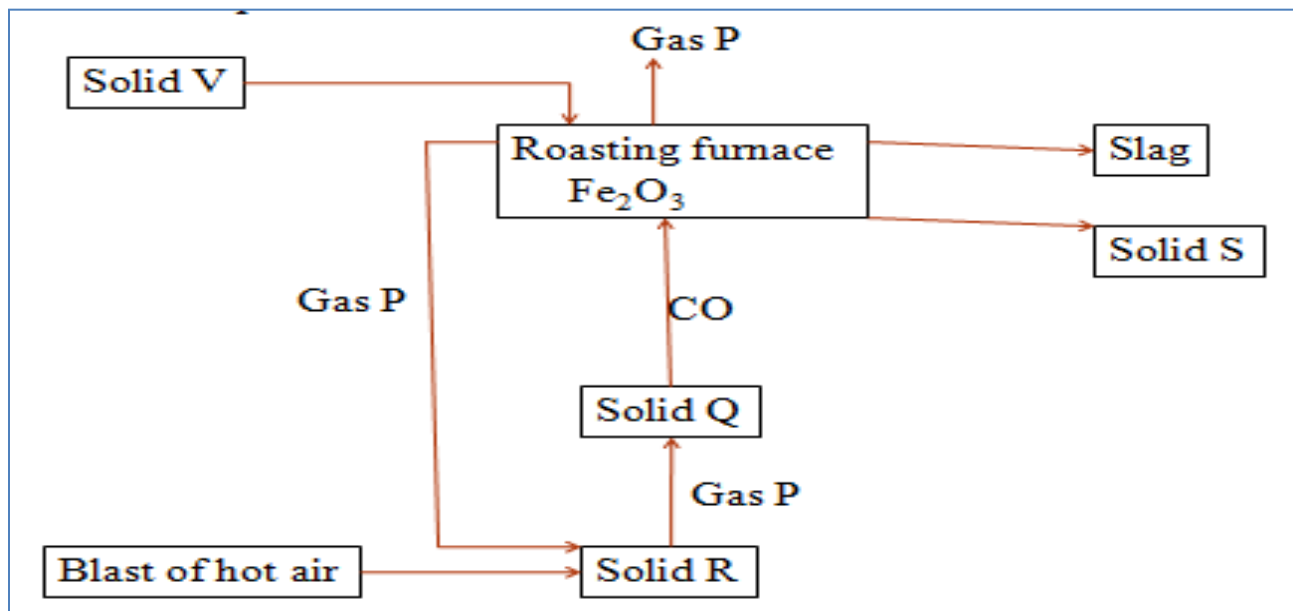


**(a)Identify:**
**(i)gas P**
    Carbon(IV)oxide/$CO_2$

**(ii)Solid Q**
    Carbon/coke/charcoal
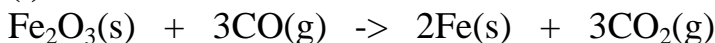
**(iii)Solid R**

Carbon/coke/charcoal

**(iv)Solid V**
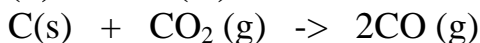
Limestone/calcium carbonate/$CaCO_3$

**(v)Solid S**

Iron/Fe

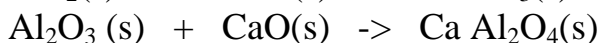**(b)Write the chemical equation for the reaction for the formation of:**

**(i)Solid S**

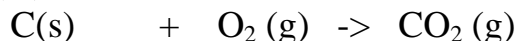$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

**(ii)Carbon(II)oxide**

$C(s) + CO_2(g) \rightarrow 2CO(g)$

**(iii)Slag**

$SiO_2(s) + CaO(s) \rightarrow CaSiO_3(s)$

$Al_2O_3(s) + CaO(s) \rightarrow Ca\,Al_2O_4(s)$

**(iv)Gas P**

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

**(c)State two uses of:**

**(i)Solid S**

Iron is used in making:

(i)gates ,pipes, engine blocks, rails, charcoal iron boxes, lamp posts because it is **cheap**.

(ii)nails, cutlery, scissors, sinks, vats, spanners, steel rods, and railway points from steel.

Steel is an alloy of iron with carbon, and/or Vanadium, Manganese, Tungsten, Nickel ,Chromium.

It does **not rust**/corrode like iron.

**(ii)Slag**

(i) tarmacing roads

(ii) cement manufacture

(iii) as building construction material

3.You are provided with sulphuric(VI)acid ,2M aqueous ammonia and two ores suspected to contain copper and iron. Describe with explanation how you would differentiate the two ores.

Crush the two ores separately in using a mortar and pestle to reduce the particle size/increase the surface area.

Add sulphuric(VI)acid to separate portion of the ore. Filter.

To a portion of the filtrate,add three drops of 2M aqueous ammonia then axcess

Results

A green precipitate insoluble in excess 2M aqueous ammonia confirms the ore contain $Fe^{2+}$ ion.

A brown precipitate insoluble in excess 2M aqueous ammonia confirms the ore contain $Fe^{3+}$ ion.

A blue precipitate that dissolve in excess 2M aqueous ammonia to form a deep/royal blue solution confirms the ore contain $Cu^{2+}$ ion.

**4. Use the flow chart below showing the extraction of Zinc metal to answer the questions that follow**
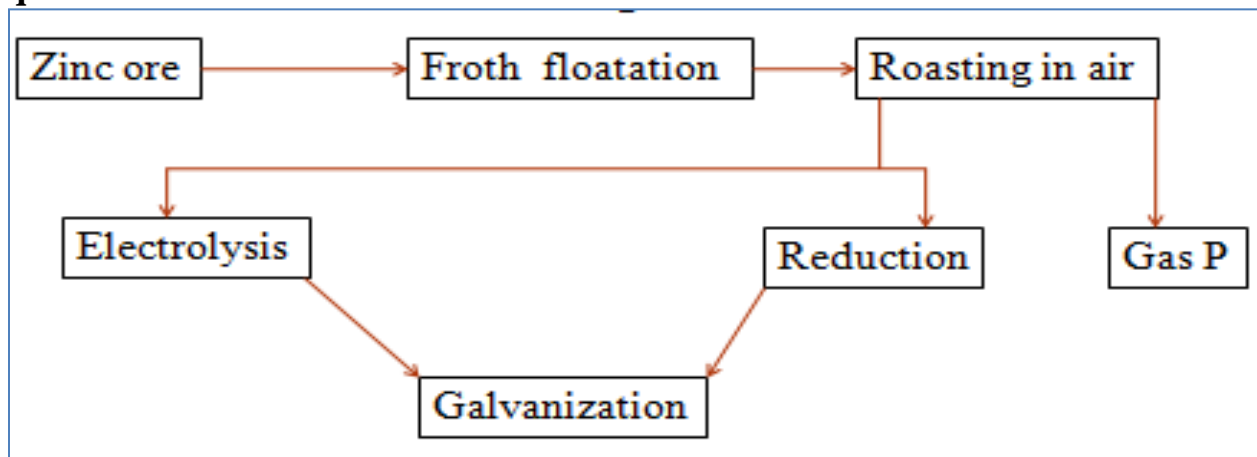


**(a)Name:**

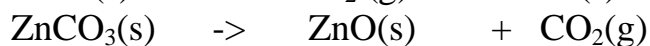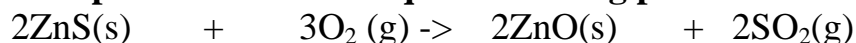**(i)two ores from which Zinc can be extracted**

Calamine($ZnCO_3$)

Zinc blende(ZnS)

**(ii)two possible identity of gas P**

Sulphur(IV)oxide($SO_2$) from roasting Zinc blende

Carbon(IV)oxide($CO_2$) from decomposition of Calamine.

**(b)Write a possible chemical equation taking place in the roasting chamber.**

$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$

$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$

**(c)Explain the effect of the by-product of the roating on the environment.**

Sulphur (IV)oxide from roasting Zinc blende is an acidic gas that causes "acid rain" on dissolving in rain water.

Carbon(IV)oxide($CO_2$) from decomposition of Calamine is a green house gas that causes global warming.

**(d)(i)Name a suitable reducing agent used in the furnace during extraction of Zinc.**

Carbon(II)oxide

**(ii)Write a chemical equation  for the reduction process**

$ZnO(s)$    +       $CO(g)$ ->     $Zn(s)$           +   $CO_2(g)$
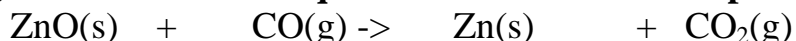
**(e)(i)Before electrolysis, the products from roasting is added dilute sulphuric (VI)acid. Write the equation for the reaction with dilute sulphuric(VI)acid.**

$ZnO(s) +$  $H_2SO_4$ (aq)  ->  $Zn$ $SO_4(aq) +$  $H_2(g)$
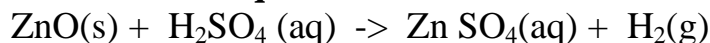
**(ii)During the electrolysis for extraction of Zinc,state the**
**I. Anode used**
Aluminium sheet
**II. Cathode used**
Lead plate coated with silver
**(ii)Write the equation for  the electrolysis for extraction of Zinc at the:**
**I.Cathode;**
$Zn^{2+}(aq)$       +       $2e$  ->  $Zn(s)$

**II.Anode;**
$4OH^-(aq)$    ->  $2H_2O(l)$   +  $O_2(s) +$    $4e$

**(f)(i)What is galvanization**
Dipping Iron in molten Zinc to form a thin layer of Zinc to prevent iron  from rusting.

**(ii)Galvanized iron sheet rust after some time. Explain**
 The thin layer of  Zinc protect Iron from rusting through sacrificial protection. When all the Zinc has reacted with elements of air, Iron start rusting.

**(g)State two uses of Zinc other than galvanization.**
Making brass(Zinc/copper alloy)
Making  german silver(Zinc/copper/nickel alloy)
As casing for dry cells/battery

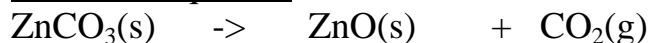**(h)Calculate the mass of Zinc that is produced from the reduction chamber if 6400kg of Calamine ore is fed into the roaster. Assume the process is 80% efficient in each stage(Zn=64.0,C=12.0,O=16.0)**

Molar mass $ZnCO_3(s)$     =124g
Molar mass Zn                = 64g
Molar mass ZnO              = 80g

Chemical equation
$ZnCO_3(s)$      ->      $ZnO(s)$        +   $CO_2(g)$
Method 1

124g $ZnCO_3$                  => 80g ZnO
(6400kg x1000)g $ZnCO_3$   => $\frac{(6400 \ x1000) \ x \ 80}{124}$ = **512,000,000** g of ZnO

100%       =>  512,000,000 g of ZnO
80%        =>  $\frac{80 \ x \ 512,000,000 \ g}{100}$       = **409600000**g of ZnO

Chemical equation
ZnO(s)      +      CO(g) ->      Zn(s)        +   $CO_2$(g)
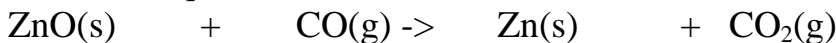
80g ZnO(s)                 =>     64g Zn(s)
409600000g of ZnO       =>     $\frac{409600000g \ \ x \ \ 64}{80}$ =    **327680000 g Zn**

100%       =>  327680000 g Zn
80%        =>  $\frac{80 \ x \ 327680000 \ g \ Zn}{100}$     = **262144000**g of Zn

Mass of Zinc produced = **262144000g of Zn**


## 5.An ore is suspected to bauxite. Describe the process that can be used to confirm the presence of aluminium in the ore.

Crush the ore to fine powder to increase surface area/reduce particle size.
Add hot concentrated sulphuric(VI)/nitric(V) acid to free the ions.
Filter. Retain the filtrate
Add excess aqueous ammonia to a sample of filtrate.
A white precipitate confirms presence of either $Al^{3+}$ or $Pb^{2+}$.
Add sodium sulphate,dilute sulphuric(VI)to another portion of filtrate.
No white precipitate confirms presence of $Al^{3+}$
 **Or** Add potassium iodide to another portion of filtrate.
No yellow precipitate confirms presence of $Al^{3+}$


## 6.The flow chart below illustrate the industrial extraction of Lead metal

Hot air    SO₂(g)    Fe    Coke    CaO    Gas P

Ore → Roasting furnace → Smelting furnace → Slag → Lead
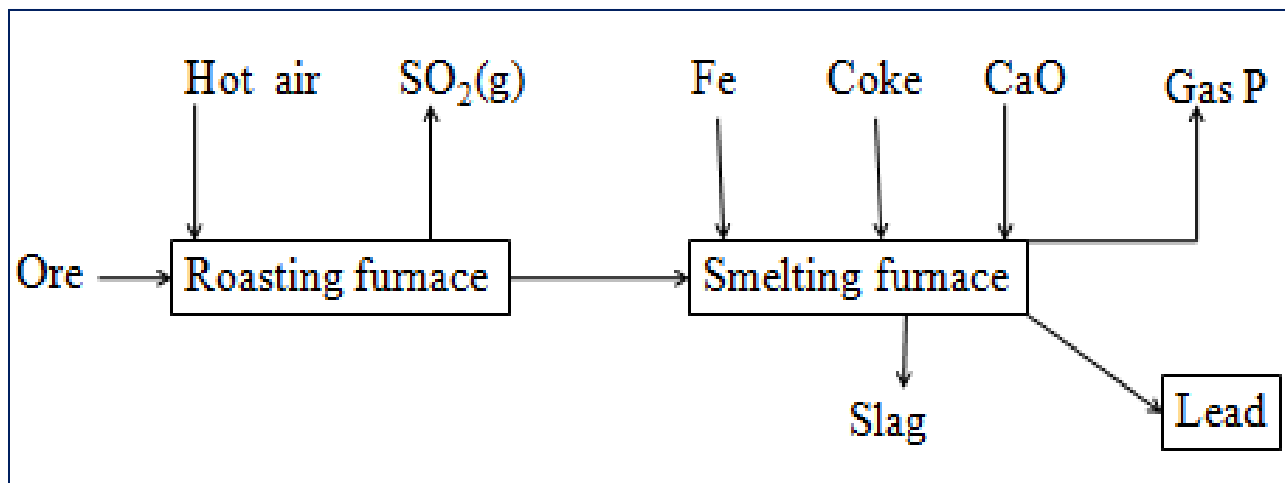
**(a)(i)Name the chief ore that is commonly used in this process**

Galena(PbS)

**(ii)Explain what take place in the roasting furnace**

******************END*********************

❖  *All secondary school schemes of work.*

❖ *Form 1-form 4 revision papers in all subjects.*

❖ *Marking schemes to most of the revision papers.*

❖ *K.C.S.E past papers.*

- *University past papers.*

- *K.A.S.N.E.B past papers e.g. C.P.A*

- *Primary school schemes of work.*

- *Primary school revision papers to all classes.*

- *Marking schemes to primary school past papers.*

- *K.C.P.E past papers.*