Dr. Bbosa Science

Sponsored by
The Science Foundation College
Uganda East Africa
Senior one to sinior six
+256 778 633 682, 753 802709
Based On, best for science

digitalteachers.co.ug
Nurture your dreams

S4 New Curriculum chemistry

Theme: REDOX Reactions

Chapter 2 – Industrial process

Uganda is rich in natural resources such as minerals, stones, plants and animals. These are used in Chemical industries to make useful products in our daily life such as chairs, tables, fertilisers, drugs, cement, cooking oil, soaps and detergents.

Extraction of metals

Occurrence of elements in nature

Elements occur in two state

1. Native or free especially less reactive, Au, Ag, Cu, Pt.
2. Combined state: generally, the reactive metals occur as oxides, sulphide, phosphates, silicates, carbonates, phosphates, chlorides and nitrates

Minerals and ores

Minerals are compound of metals which are found in the earth.

Ores are those minerals from which the metals can be extracted economically and conveniently. Thus, all minerals are not ores but all ores are minerals.

Methods of concentrating ores from earth materials

Concentration of ores is the process of removing impurities (gangue) from raw earth materials to obtain a higher percentage of the desired metal. There are several methods used depending on the type of ore and its properties:

(i) **Hand picking/sorting method** is used when the impurities present in the ore are quite different from the ore. E.g. removal of extraneous matter present as impurity in haematite ore, Fe_2O_3 (ore of Fe)

(ii) **Gravity Separation** is used for ores with different densities from impurities. The ore is washed with water or separated using shaking tables.

(iii) **Magnetic Separation** is applied when the ore is magnetic (e.g., magnetite Fe_3O_4). A magnetic field is used to pull the ore from impurities.

(iv) **Froth Flotation** is used for sulfide ores (e.g., copper and zinc ores). The ore is mixed with water and chemicals; air bubbles help lift the desired minerals to the surface while impurities sink.

(v) **Leaching** involves dissolving the ore in a suitable solvent. Examples: Cyanide leaching for gold, acid leaching for bauxite.

(vi) **Electrostatic Separation** is used for ores with different electrical conductivity. A charged plate or drum separates the ore from impurities.

(vii) **Hydraulic Washing** is based on differences in particle size and density. Water is used to wash away lighter impurities.

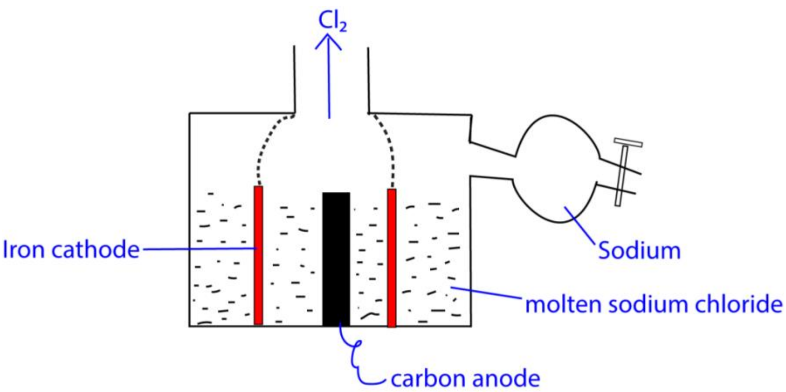
Methods of extraction of metals

The method of extraction of metals depends on metal's position in electrochemical series.

i.e. Potassium, sodium, calcium, magnesium, aluminium, carbon, zinc, iron, copper

Elements above carbon are extractions are extracted by electrolysis while those below carbon are extracted by reduction with carbon or carbon monoxide.

Extraction of Sodium



It is manufactured by electrolysis of fused sodium chloride in the Downs' cell) (MPt. 800^0C)

At first there were four difficulties

(i) It was expensive to keep the electrolyte over 800^0C

(ii) The molten sodium chloride was corrosive

(iii) Sodium is fairly soluble in its molten chloride at 800^0C

(iv) The vapour pressure of sodium at 800^0C is very high, about ½ atmosphere of 400mmHg.

The difficulties were all overcome by adding calcium chloride to sodium chloride to form a mixture that melts below 600^0C. It is cheaper to maintain this temperature, the mixture is non-corrosive, sodium is almost insoluble and the vapor pressure is about 15mmHg.

The iron gauze cylinder between anode and cathode prevent the sodium and chlorine from mixing.

Liquid sodium leaves the cell in a raised pipe high enough for the low density metal but not high enough for the higher density chloride mixture to overflow continuously into the receiver

The reactions are

At cathode: $Na^+ (l) + e \rightarrow Na(l)$

Anode; $2Cl^- - 2e \rightarrow Cl_2 (g)$

Sodium is collected in dry nitrogen to protect it from reacting with air.

Uses of sodium

- Molten sodium is used as a coolant in some types of nuclear reactor because of its good thermal conductivity, low melting point and its higher boiling point than that of water
- Sodium wire is used in electrical circuit for special application
- Sodium vapor lamps are used for street lighting
- Sodium cyanide is used in extraction of silver and gold

Iron and its compounds

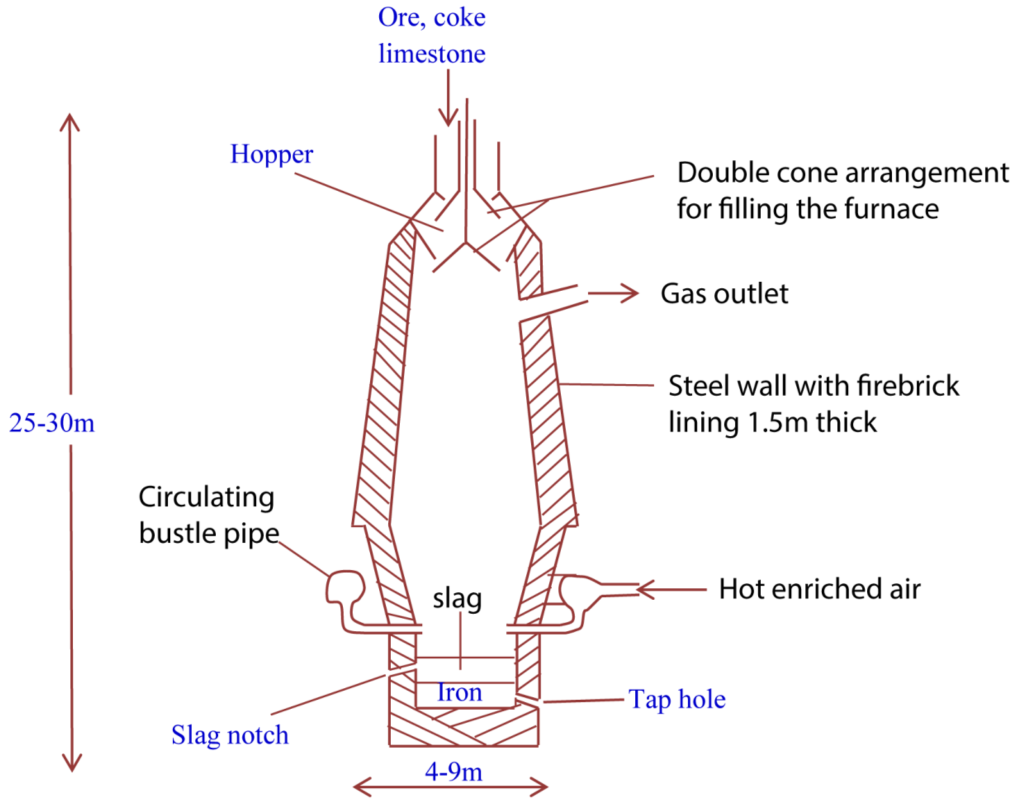
Iron, which is the second most abundant metal occurring in the earth crust, is extracted from its oxides, haematite, Fe_2O_3 and magnetite, Fe_3O_4, and from the siderite, $FeCO_3$.

The extraction of iron is carried out in a blast furnace that can vary in size between 2 and 600 metres high and up to 10 meters in diameter.

It is constructed from steel with the inner region lined with bricks. Iron ore, lime stone and coke in the correct proportions are fed into the top of the furnace through a cone and hopper arrangement.

Preheated air at a temperature of about 600^0C is injected into the furnace through a number of pipes called tyères (pronounced "Tweers"). The tuyères are fed from a "bustle" pipe encircling the blast furnace. The blast furnace is provided with two holes which are plugged with clay; molten iron is tapped from the lower one and molten slag from the upper one.

The production of iron is continuous process and depending on its size, a blast furnace can be producing from 1000 to 1800 tons of iron every 24 hours.



The Blast Furnace

The energy and reducing agent required for the smelting of iron are obtained by the combustion of coke, the temperature of the charge increasing steadily as it falls through the ascending combustion gases:

$$2C (s) + O_2 (g) \rightarrow 2CO (g)$$

At a temperature of about 700 ^{0}C the iron ore is reduced to spongy iron by the carbon monoxide.

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

Removal of impurities

The limestone decomposes at 500 ^{0}C and the calcium oxide reacts with sandy impurities to form a slag of calcium silicate. More carbon monoxide is produced by the reduction of carbon dioxide:

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

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

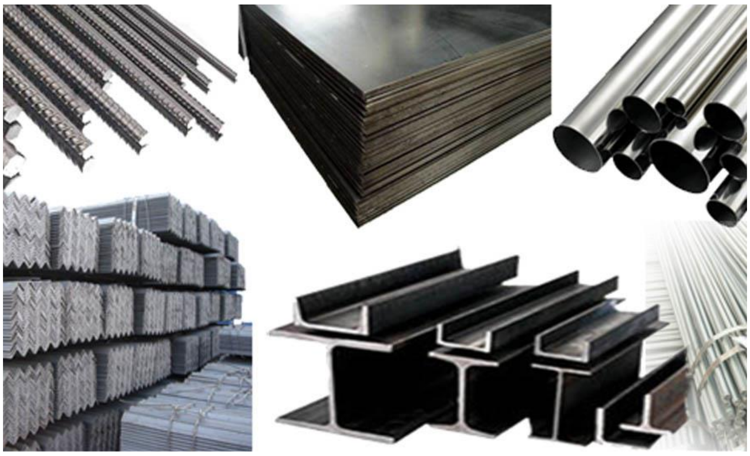
impurity slag

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

Uses of iron

In form of steel it used to make bridges, doors and window flame, cutlery and so on

Examples of construction materials made of iron and steel



Properties of iron

1. It reacts with oxygen to form iron (III) oxide.
   $2Fe (s) + 2O_2(g) \rightarrow 2Fe_2O_3(s)$
2. It reacts with sulphur to form black iron (II) sulphide
   $Fe(s) + S(s) \rightarrow FeS(s)$
3. It reacts with chlorine to form iron (III) chloride
   $2Fe(s) + 3Cl_2 (g) \rightarrow FeCl_3(s)$
4. It reacts with hydrogen chloride gas to form iron (II) chloride
   $Fe(s) + 2 HCl(g) \rightarrow FeCl_2(s)$
5. Reacts reversibly with steam to form hydrogen and triirontetroxide
   $3Fe (s) + H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$
6. It reacts with dilute acid to liberate hydrogen
   $Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$

Recycling of metal wastes

Recycling metal waste is an essential process that helps conserve natural resources, reduce energy consumption, and minimize environmental pollution. Here’s how it’s done:

Types of Metals Recycled

- **Ferrous Metals** (contain iron): Steel, cast iron
- **Non-Ferrous Metals** (do not contain iron): Aluminum, copper, brass, silver, gold

Steps in Metal Recycling

1. **Collection** – Scrap metal is collected from industries, households, and demolition sites.
2. **Sorting** – Metals are sorted based on type (ferrous vs. non-ferrous) and purity.
3. **Cleaning** – Impurities like plastic, paint, and rust are removed.
4. **Shredding** – Metals are broken down into smaller pieces for easier processing.
5. **Melting** – The shredded metal is melted in furnaces at high temperatures.
6. **Purification** – The molten metal is purified to remove any remaining contaminants.
7. **Solidification** – The purified metal is cooled and formed into bars, sheets, or new products.
8. **Reuse** – The recycled metal is sent to manufacturers for use in new products.

Benefits of Metal Recycling

- **Saves Energy** – Recycling aluminum saves up to **95%** of the energy needed to produce new aluminum.
- **Reduces Pollution** – Cuts down emissions from mining and processing.
- **Conserves Natural Resources** – Limits the need for extracting new ore.
- **Economic Benefits** – Creates jobs in recycling industries and lowers production costs.

Industrial chemical

Industrial chemicals are substances used in large-scale manufacturing, processing, and production across various industries. They serve as raw materials, catalysts, solvents, or additives in industrial operations. Examples of industrial chemicals include**:**

(a) **Nitrogen** is obtained by fractional distillation of air and is used for

- (i) production of ammonia;
- (ii) preservation of food, animal semen for artificial insemination and biological samples in hospitals;
- (iii) **Metal Processing** – Provides an inert atmosphere for welding and metal production,
- (iv) **Electronics** – Used in semiconductor manufacturing to prevent oxidation.

(b) **Ammonia** is manufactured by reacting nitrogen and hydrogen in Haber process and it is used for

- (i) Production of fertilizers, plastics, pesticides
- (ii) It used as a coolant in refrigerators
- (iii) It is used for production of explosives.

(c) Sulphuric acid is produced by contact process and used for

- (i) Manufacture of fertilizer, explosives, dyes,
- (ii) Help to remove impurities during oil refinery.
- (iii) Acidifying agent in laboratories
- (iv) Car batteries
- (v) Drying agent in laboratores

Manufacture of fertilizers for crop production
Fertilizers are substances added to soil or plants to supply essential nutrients that enhance growth and productivity.

Steps in production of nitrate fertilizers

The production of nitrate fertilizers involves several key steps to ensure the final product provides essential nitrogen for plant growth. Here's an overview of the process:

1. Ammonia Production (Haber Process)

- Nitrogen gas (N_2) from the air and hydrogen (H_2) from natural gas react under high temperature and pressure with an iron catalyst.
- This produces ammonia (NH_3), which is the starting material for nitrate fertilizers.

2. Oxidation of Ammonia (Ostwald Process)

- Ammonia is oxidized in the presence of a platinum catalyst to form nitric oxide (NO
- The nitric oxide reacts with oxygen to produce nitrogen dioxide (NO_2).

3. Absorption to Form Nitric Acid

- Nitrogen dioxide (NO_2) is absorbed in water to produce nitric acid (HNO_3).
- This forms the basis for nitrate fertilizers.

4. Neutralization Reaction

- The nitric acid is neutralized with ammonia to produce ammonium nitrate (NH_4NO_3), a key fertilizer component.
- This reaction generates heat, which is carefully managed to prevent uncontrolled decomposition.

5. Granulation or Prilling

- The ammonium nitrate is processed into solid pellets (prills) or granules to improve handling and application.
- Some formulations may include additional nutrients like calcium or magnesium.

6. Quality Control & Packaging

- The fertilizer undergoes testing for purity, moisture content, and nutrient balance.
- It is then packaged and prepared for distribution to agricultural industries.

Disadvantages of fertilizers

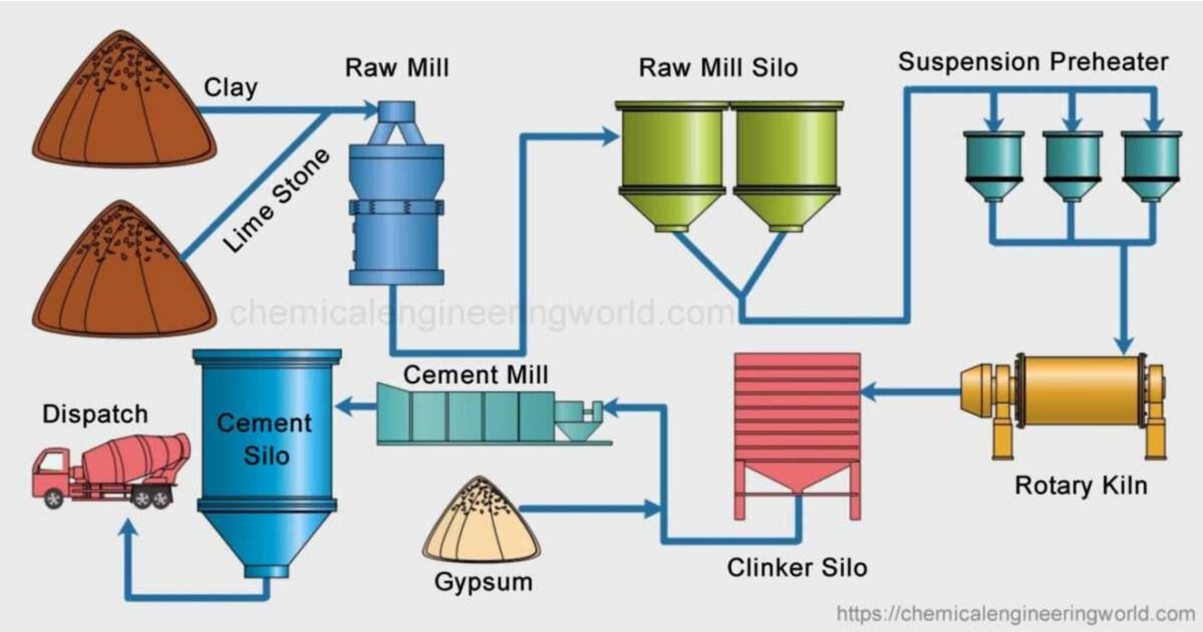
- Overuse of chemical fertilizers can lead to **loss of soil fertility** by altering the natural balance of nutrients.

- Excessive application can make the soil **acidic** or **saline**, reducing its ability to support plant life.
- Cause water pollution reducing the ability of water body to support life.
- Inhalation or contact with fertilizers can cause health hazards

Cement manufacturing

Cement is a key ingredient in construction industry.

Steps in cement production



Cement production involves several steps that transform raw materials into a strong binding material used in construction. Here's an overview of the process:

1. Mining and Preparation of Raw Materials

- **Limestone** ($CaCO_3$) and **clay** are the primary raw materials.
- They are extracted from quarries and crushed into fine particles.

2. Raw Material Mixing and Grinding

- The crushed materials are mixed in precise proportions.
- The mixture is then ground into a fine powder called **raw meal**.

3. Preheating and Calcination

- The raw meal is heated in preheaters to remove moisture.
- It then enters the **rotary kiln**, where high temperatures (up to 1450°C) cause **calcination**—a process that decomposes limestone into calcium oxide (CaO) and releases carbon dioxide (CO_2).

4. Clinker Formation

- Inside the kiln, the calcium oxide reacts with other components, forming **clinker**, which consists of small, hard nodules.

5. Clinker Cooling

- The hot clinker is cooled using air or water.
- This rapid cooling improves its chemical structure and quality.

6. Grinding and Addition of Gypsum

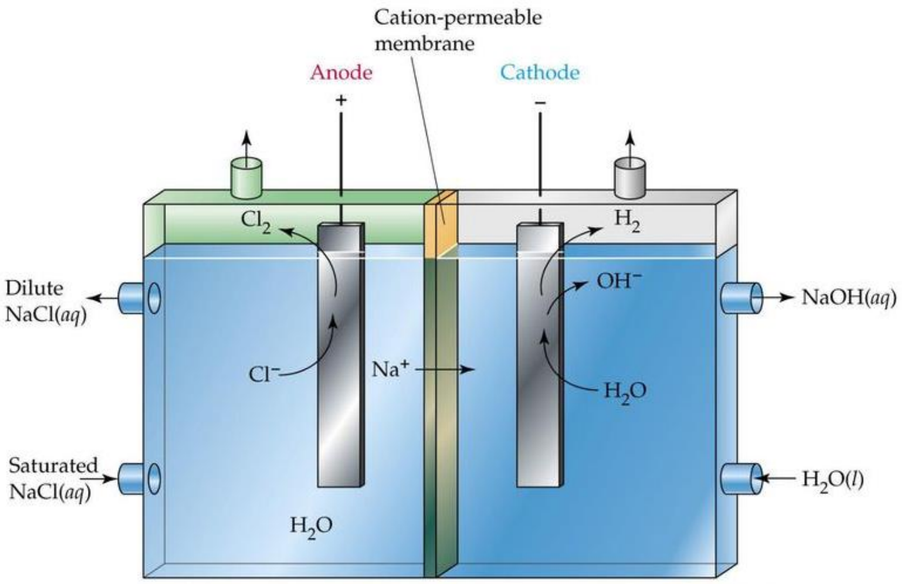
- The cooled clinker is ground into fine powder.
- **Gypsum** ($CaSO_4$) is added to control the setting time of cement.
- Some special additives may be mixed in to modify properties.

7. Packaging and Distribution

- The finished cement is stored in silos before packaging.
- It is then distributed in bags or bulk for construction use.

Manufacture of sodium hydroxide and chlorine

The membrane cell



The **membrane cell process** is one of the most efficient methods for manufacturing **sodium hydroxide (**NaOHand **chlorine (**Cl_2**)** through the electrolysis of brine (NaCl } solution). Here's how it works:

1. Preparation of Brine Solution

- **Purified brine** (concentrated sodium chloride solution) is prepared to prevent impurities from affecting the reaction.
- The solution is filtered to remove calcium and magnesium ions.

2. Electrolysis in the Membrane Cell

- The **membrane cell** consists of two compartments separated by an **ion-exchange membrane**.
- An electric current is passed through the solution, causing key reactions.

3. Reactions at the Electrodes

- **At the Anode (+):** $2Cl^- \rightarrow Cl_2 + 2e^-$

  Chlorine gas (Cl_2**)** is released.

- **At the Cathode (-):**

  $2H_2O\ (l) + 2e^- \rightarrow H_2\ (g) + 2OH^-\ (aq)$

  Hydrogen gas (H_2**)** is produced.

- Hydroxide ions (OH^-) combine with sodium ions (Na^+) to form sodium hydroxide (NaOH) solution.

4. Separation of Products

- The **chlorine gas** is collected and cooled for industrial use such disinfection of water and swimming pools, manufacture of bleach, and production of plastics
- The **sodium hydroxide** is concentrated and purified for commercial applications such as manufacture of soaps and detergents, extraction of aluminium, cleansing etc.
- The **hydrogen gas** can be utilized as a fuel or in chemical processes.

Advantages of the Membrane Cell Process

- **Higher purity**: Produces **pure NaOH** without contamination from chlorine.
- **Energy-efficient**: Requires **less electricity** compared to other methods.
- **Eco-friendly**: Reduces the release of harmful mercury and asbestos waste.

Negative impact of industrialization on environment

Environmental challenges resulting from industrialization include

- Air and water pollution
- Deforestation to provide energy and space for industries
- Habitat destruction

- Noise pollution

Measures to minimize industrial pollution

Minimizing industrial pollution is crucial for environmental protection and sustainable development. Here are some effective measures:

1. Adoption of Cleaner Production Techniques

- Using energy-efficient machinery and processes to reduce emissions.
- Implementing closed-loop systems to minimize waste production.

2. Waste Management and Recycling

- Encouraging industries to recycle and repurpose materials instead of discarding them.
- Proper disposal methods for hazardous waste to prevent contamination.

3. Air Pollution Control

- Installing **scrubbers, electrostatic precipitators**, and **filters** in factories to reduce emissions.
- Switching to cleaner fuels such as **natural gas** or **renewable energy sources**.

4. Water Pollution Reduction

- Treating industrial wastewater before releasing it into natural water bodies.
- Using **biological treatment** and **reverse osmosis** to purify contaminated water.

5. Soil and Land Conservation

- Limiting deforestation and land degradation caused by industrial expansion.
- Using **bio-remediation** techniques to restore polluted land.

6. Regulations and Compliance

- Governments enforcing **strict environmental laws** and pollution control policies.
- Industries adopting **ISO 14001** standards for environmental management.

7. Sustainable Energy Sources

- Promoting the use of **solar, wind, and hydropower** instead of fossil fuels.
- Developing **green technologies** to reduce dependence on non-renewable energy.

8. Public Awareness and Corporate Responsibility

- Educating businesses and communities about the impact of industrial pollution.
- Encouraging corporate responsibility programs focused on sustainability.

Tackling industrial pollution requires a combined effort from industries, governments, and individuals.

Revision questions

12. (a) carbon monoxide was passed over heated iron (II) oxide

(i) Write equation for the reaction that took Place.

(ii) Write equation for the reaction between the solid product in (a)(i) and dilute sulphuric acid.

(b) Chlorine was bubbled through the product in (a)(i)

(i) State what was observed

(ii) Write equation for the reaction that took place

13. (a) Name the raw materials which are used in extraction of iron using a blast furnace (02mark)

(b) Briefly describe the reactions that lead to the formation of iron during extraction using a blast furnace. (Your answer should include equations for the reactions)

(c) state what would be observed and write equations for the reactions that would take place when the following gases are passed over heated iron

(i) dry chloride

(ii) steam

(d) Dilute hydrochloric acid was added to iron filling and a mixture warmed. Write the equation for the reaction that took place.

14. In extraction of cast iron using a blast furnace, spathic iron ore, which contain some impurities, is first roasted in air. It is then mixed with some other substance and finally introduced into the blast furnace. Cast Iron can be obtained from iron (II) carbonate ore.

(a) Name the major impurity in the iron ore (1mark)

(b)(i) Give the chemical name of spathic ore (1mark)

(ii) Write an equation for the reaction which takes place when iron (II) carbonate is roasted in air (2 ½ mark)

(c) Name the substances that are fed into the blast furnace

(i) From the top

(ii) From the bottom

(d) Outline the reactions leading to

(i) The formation of cast ion

(ii) The removal of the major impurity you have named in (a)

(e) State the major components of steel

15. (a) Name one ore of iron and write its formula (1mark)

(b) During extraction of iron ore, lime stone and coke are added into the blast furnace. Explain the roles

(i) coke (5marks)

(ii) lime stone (4marks)

(use equations to illustrate your answers)

(c) write equation for the reaction leading to iron (II) sulphate (2marks)

(d) Iron (II) sulphate was heated strongly

(i) state what is observed (1½ marks)

(ii) write equation for the reaction that took place (1½ mark)

16. Iron forms compounds in which it shows a valence of two and three

(a) state the general color of iron compounds in which iron is

(i) divalent

(ii) trivalent

(b) write the formula and name of the sulphates of iron in which iron is in (b)(i) and (ii).

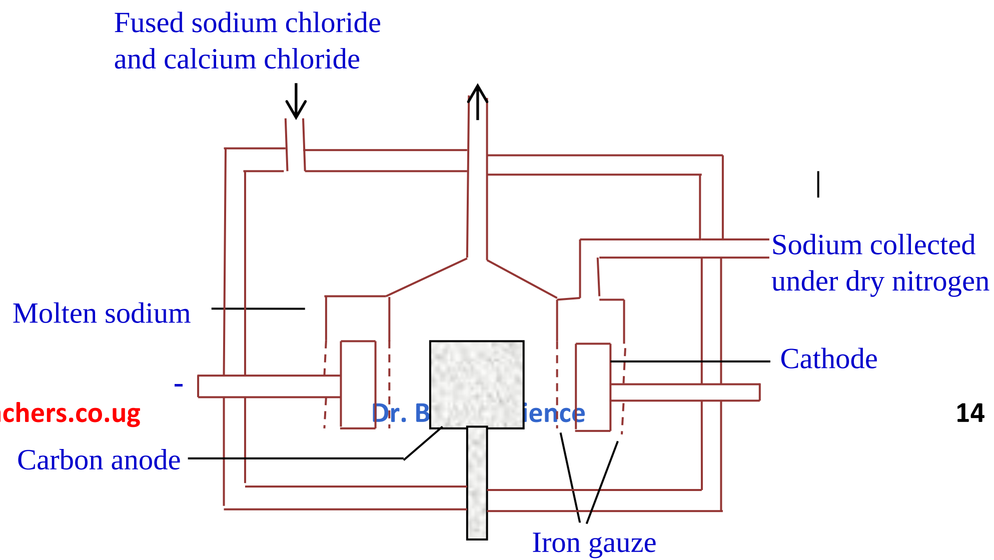
(c) (i) Name a reagent that can be used to distinguish between the sulphates in (b)(i) and (ii).

(ii) state what would be observed when the iron sulphates are reacted with the reagent in (c)(i).

(iii)Write equation for the reaction in (c)(ii).

(a) starting from iron wool, state how the anhydrous chloride of Iron (III) can be prepared and write equation to illustrate your answer. (diagram not required)

17. Sodium is manufactured by electrolysis of molten sodium chloride as shown in the figure below



(a) Name the materials of which the cathode is made

(b) Write an equation for the reaction for the reaction that takes place at

   (i) The cathode

   (ii) anode

(c) What is the purpose of calcium chloride?

(d) State why sodium is collected under dry nitrogen.

Suggested answers

12.	(a)	(i)	$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$
		(ii)	$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$
	(b)	(i)	black crystals formed
		(ii)	$2Fe(s) + 3Cl2(g) \rightarrow 2FeCl_3(g)$
13.	(a)		haematite, Fe_2O_3 and magnetite, Fe_3O_4, and from the siderite, $FeCO_3$
	(b)	(i)	Reduction of the ore the roasted is mixed with coke and lime stone in a blast furnace and heated with hot air coke or carbon burns in oxygen to form carbon dioxide $C(s) + O_2(g) \rightarrow CO_2(g)$ Carbon dioxide reacts with carbon to form carbon monoxide $CO_2(s) + C(s) \rightarrow 2CO(g)$ Carbon monoxide reduces iron (III) oxide to iron $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$
		(ii)	Removal of impurities of silicon dioxide, SiO_2. Lime stone or calcium carbonate decompose on heating $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ Calcium oxide reacts with impurities to form slag of calcium silicate that is pour away $CaO(s) + SiO_2(s) \rightarrow CaSiO_3$
	(b)	(i)	iron glow red forming black crystals and purple vapor $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$
		(ii)	a black solid forms $3Fe(s) + 4H_2O(l) \rightarrow Fe_3O_4(l) + 4H_2$
	(c)		$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(g) + H_2(g)$
14.	(a)		silicon dioxide, SiO_2
	(b)	(i)	Iron (II) carbonate
		(ii)	$FeCO_3 \xrightarrow{heat} FeO(s) + CO_2(g)$

	(c)	(i)	iron ore, coke and lime stone
		(ii)	Hot air
	(d)	(i)	coke or carbon burns in oxygen to form carbon dioxide $C(s) + O_2(g) \rightarrow CO_2(g)$ Carbon dioxide reacts with carbon to form carbon monoxide $CO_2(s) + C(s) \rightarrow 2CO(g)$ Carbon monoxide reduces iron (III) oxide to iron $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$
		(ii)	the impurity is silicon dioxide, SiO_2. Lime stone or calcium carbonate decompose on heating $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ Calcium oxide reacts with impurities to form slag of calcium silicate that is pour away $CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$
	(e)		Iron and carbon
15.	(a)		Haematite, Fe_2O_3 and magnetite, Fe_3O_4, and from the siderite (spathic ore), $FeCO_3$
	(b)	(i)	coke or carbon burns in oxygen to form carbon dioxide $C(s) + O_2(g) \rightarrow CO_2(g)$ Carbon dioxide reacts with carbon to form carbon monoxide $CO_2(s) + C(s) \rightarrow 2CO(g)$ Carbon monoxide reduces iron (III) oxide to iron $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$