CARBON AND ITS COMPOUNDS

Carbon has atomic number 6 and mass number 12. Its electronic configuration is 2:4.
It belongs to group(IV) of the periodic table because it has four electrons in its outer most energy level.
It belongs to period 2 of the periodic table because it has two energy levels containing electrons.
It belongs to a class of elements called metalloids or semi-metals.

Define the following terms as used in this topic.

(i) Allotropy/Allotropism

This is the existence of an element in more than one form, without change of state.
Or
This is the existence of an element in two or more different forms but in the same physical state.

(ii) Allotropes.

These are the various forms of an element which exist in more than one form, without change of state.

(iii) An allotrope.

Is one of the two or more distinct forms of an element.
Or
Is one of the physical forms in which an element exists in the same state.

ALLOTROPES OF CARBON

Identify the allotropes of carbon.

- Diamond.
- Graphite.
- Amorphous carbon.

N.B
Diamond and graphite are the crystalline forms of carbon whereas amorphous carbon is non crystalline.
Identify other elements that show allotropy and state their allotropes.

(i) Oxygen
- ✓ Ordinary oxygen.
- ✓ Ozone.

(ii) Sulphur
- ✓ Amorphous sulphur
- ✓ Monoclinic sulphur.
- ✓ Rhombic sulphur.

- ✓ Plastic sulphur.
- ✓ Colloidal sulphur.

(iii) Phosphorus

- ✓ White/yellow phosphorus
- ✓ Red phosphorus.

GRAPHITE

The structure of graphite.

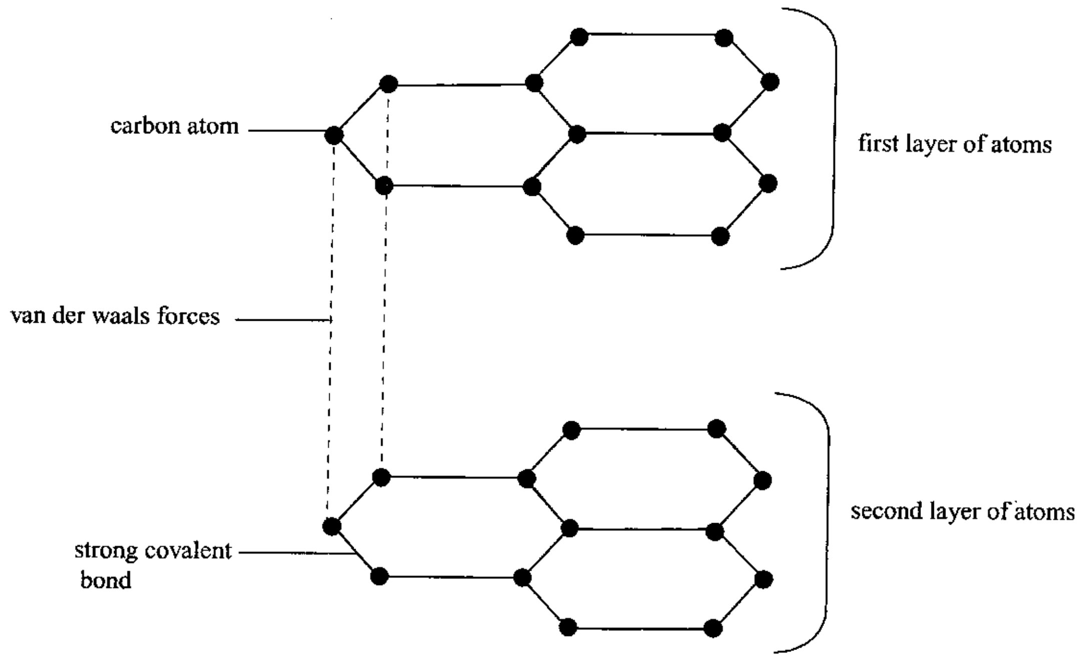

Fig 1.2 Structure of graphite

Graphite consists of layers of hexagonal rings of carbon atoms. Each layer is a giant molecule in the two dimensions.

In each layer, the carbon atoms are arranged in form of a hexagonal ring.

Each carbon atom is covalently bonded to three other atoms.

Therefore three out of the four valency electrons of each carbon atom are used up in the formation of covalent bonds. The remaining electron is delocalized over the whole layer. The layers lie and slide over each other and are joined by weak van der waals forces.

(a) Explain why graphite is slippery?

- It's because of the weak intermolecular forces of attraction between the layers which enable them slide over each other.

(b) State the uses of graphite.

- Used as electrodes in electrolysis. This is because graphite contains delocalized electrons.
- Used as a lubricant in moving parts of machines. Its because graphite is soft and slippery due to the weak van der waals forces of attraction between the layers.
- Used in the manufacture of pencil leads. Its because graphite is soft and slippery.
- Used as a protective coating on iron tools to reduce rusting.

DIAMOND

The structure of diamond.

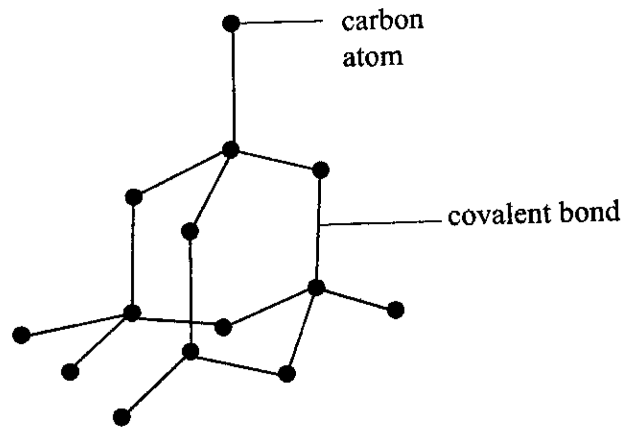

Fig 1.3 Structure of diamond

Diamond is made of crystal unit 5 carbon atoms repeated indefinitely forming interlacing hexagons.
Each carbon atom is joined by covalent bonds to four others; the four atoms are arranged tetrahedrally as shown above.

USES OF DIAMOND

- Used to make necklaces, ear rings, e.t.c . This is because diamond sparkles or glitters, shines and reflects light in an attractive way.
- Used to make glass cutters, drilling devices. This is because diamond is very hard and has a high melting point.
- Used in making insulators. This is because diamond lacks delocalized electrons hence a poor conductor.

Give the differences between diamond and graphite.

graphite	*diamond*
➢ Dark grey and opaque	Colourless and transparent.
➢ Soft and slippery	Very hard.
➢ Conducts electricity	Does not conduct electricity.
➢ Has a low density($2.3gcm^{-3}$)	Has a high density($3.5gcm^{-3}$)
➢ Has a layered structure.	Has no layered structure.
➢ Has a hexagonal shape.	Has a tetrahedral shape.

AMORPHOUS CARBON

Has no clear shape (shapeless) i.e. non crystalline.

It's a fair conductor of electricity, and black in colour.

Has the lowest density among all the allotropes of carbon.

Exists in several forms.

Forms of Amorphous carbon.

1. **Wood charcoal**

   Formed by burning wood in limited supply of air.

   Use

   Used as fuel mainly in homes for cooking.

2. **Animal charcoal.**

   Its formed by burning animal bones in and remains in limited supply of air.

   Use

   Used to remove the brown colour from sugar to white during its manufacture.

3. **Sugar charcoal.**

   This is the purest form of amorphous carbon and is formed by reacting concentrated sulphuric acid with cane sugar.

   The acid behaves as a dehydrating agent by removing the elements of water from sugar.

   $$C_{12}H_{22}O_{11}(s) \xrightarrow{Conc.\ H_2SO_4} 12C(s) + 11\ H_2O(l)$$

4. **Lamp black**

   Formed by burning hydro carbons like petrol, oils, kerosene in limited supply of air.

   Uses

   - Used to make shoe polish.
   - Used to make printer ink.
   - Used to make carbon papers.

5. **Coke.**

   It is formed by heating coal in absence of air. This process is called **destructive distillation of coal.**

   Uses.

- Used in extraction of iron (acts as a reducing agent)
- Used as a source of fuel.

CHEMICAL PROPERTIES OF CARBON.

All allotropes of carbon have similar chemical properties but with different physical properties.

1. **Reaction with oxygen (combustion)**

   Charcoal was burnt in excess oxygen.

   (a) State what was observed

   The black solid burnt with an orange flame and made bright sparks, giving off a colourless gas.

   (b) Write equation for the reaction.

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

   Note; the above reaction is referred to as complete combustion of carbon.

   In limited supply of oxygen, carbon monoxide is formed. This is incomplete combustion of carbon.

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

This reaction also takes place in a charcoal burner when there is a sufficient supply of air.

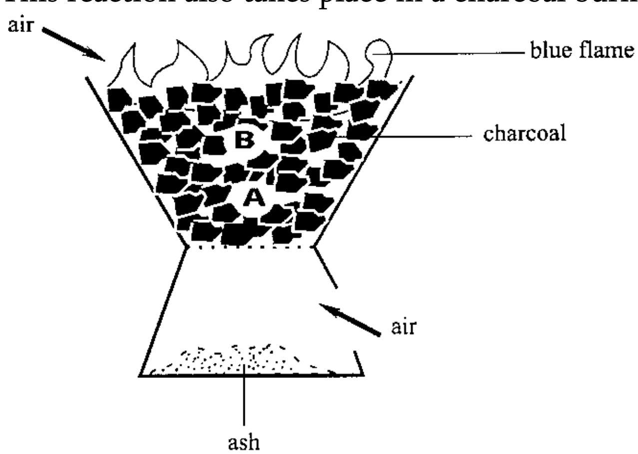

Fig 1.11 A burning charcoal burner

At A, there is plentiful supply of oxygen and charcoal burns to form carbon dioxide.

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

At B, the rising carbon dioxide is reduced by red-hot charcoal to form carbon monoxide.

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

At the surface of the burner, the hot carbon monoxide burns in the air with a blue flame to form carbon dioxide.

$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$

If the charcoal burner is in a poorly ventilated room with insufficient air, the reaction at the surface fails to takes place. The poisonous carbon monoxide is released into the room. If someone stays in such a room, he or she may die within a short while due to carbon monoxide poisoning.

2. **Reaction of carbon with acids like Nitric acid and sulphuric acid.**
   (a) State the condition(s) under which carbon reacts with nitric acid or sulphuric acid.
   - The acids must be concentrated.
   - Heating

   (b) A piece of red-hot charcoal was put in concentrated nitric acid.
   (i) State what was observed
   The red-hot charcoal continued to burn, then dissolved with effervescence of reddish-brown fumes.
   A colourless liquid formed.
   (ii) Explain your observation
   Concentrated nitric acid is a strong oxidizing agent. It oxidizes carbon to carbon dioxide, then the acid is reduced to nitrogen dioxide which are reddish- brown fumes. Water is formed which is a colourless liquid.

   (c) Write an equation for the reaction.
   $C(s) + 4HNO_3(aq) \longrightarrow CO_2(g) + 4NO_2(g) + 2H_2O(l)$

Carbon was warmed with concentrated sulphuric acid.

(a) **State what was observed.**
Carbon dissolved with effervescence of a colourless gas; and a colourless liquid was formed.

(b) **Explain your observation**
Concentrated sulphuric acid is an oxidizing agent. It oxidizes carbon to carbon dioxide, a colourless gas and then itself is reduced to sulphur dioxide and water, a colourless liquid.

(c) **Write equation for the reaction**

$C(s) + 2H_2SO_4(aq) \longrightarrow CO_2(g) + 2SO_2(g) + 2H_2O(l)$

3. **Carbon as a reducing agent.**
   Carbon is a powerful reducing agent and it reduces oxides of metals below zinc in the reactivity series.
   Copper(II) oxide and carbon was heated strongly.
   (a) State what was observed.
   The black solid turned brown and a colourless gas is formed.
   (b) Write the equation for the reaction.
   $2CuO(s) + C(s) \longrightarrow 2Cu(s) + CO_2(g)$
   (c) Explain your observation in (a) above.

Carbon is a reducing agent, it reduces copper(II) oxide which is black to copper which is brown and its oxidized to carbon dioxide, a colourless gas.

Lead(II) oxide and carbon was heated strongly.

(a) **State what was observed.**

The reddish-brown solid turned to grey and a colourless gas was formed.

(b) **Write the equation for the reaction.**

$2PbO(s) + C(s) \longrightarrow 2Pb(s) + CO_2(g)$

(c) **Explain your observation in (a) above.**

Carbon is a reducing agent. It reduces reddish-brown lead(II) oxide to lead which is grey and its oxidized to carbon dioxide, a colourless gas.

Zinc oxide and carbon was heated strongly.

(a) **State what was observed.**

The yellow solid turned to grey and a colourless gas formed.

(b) **Write equation for the reaction.**

$2ZnO(s) + C(s) \longrightarrow 2Zn(s) + CO_2(g)$

(c) Explain your observation in (a) above.

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Questions

A mixture of iron(III) oxide and carbon was heated strongly.

(a) State what was observed.

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(b) Write equation for the reaction.

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(c) Explain your observation in (a) above.

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(a) Define the following terms;

(i) An isotope.

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(ii) An allotrope.

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(b) Name two crystalline forms of carbon.

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(c) State;

(i) One property of each of the allotropes of carbon named in (b)

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(ii) One use of each of the allotropes

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(d) Name one allotrope of carbon that is used

(i) For making shoe polish.

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(ii) In sugar industry

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Diamond and graphite are crystalline allotropes of carbon

(a) State;

(i) Two differences between diamond and graphite

Graphite	*Diamond*

(ii) Two uses of diamond.

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(iii) Two uses of graphite.

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(b) Name one allotrope of carbon that is used ;

(i) In extraction of iron

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(ii) As an electrode

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(c) State one property of the allotrope of carbon that you have named in (b) above which is the reason for its use;

(i) In extraction of iron.

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(ii) As an electrode.

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(d) Carbon-12 and carbon-14 are the two common atoms of carbon and carbon-14 is used extensively in determining ages of old objects. State;

(i) One word which means the relationship between atoms like carbon-12 and carbon-14.

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(ii) The property of carbon-14 that is applied when it's used in determining the ages of old objects.

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Describe briefly an experiment to show that diamond and graphite are allotropes of carbon.

Equal masses of graphite and diamond are separately burnt in excess oxygen. Both yield equal masses of carbon dioxide. The carbon dioxide formed is identified by passing it into lime water, which turns milky.

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

Describe the reaction of sulphur and carbon

Carbon and sulphur in tetrachloromethane react when strongly heated forming carbon disulphide.

$C(s) + 2S(s) \longrightarrow CS_2(l)$

Describe three reactions in which carbon behaves as a reducing agent. Illustrate your answer with equations.

- ✓ Heated carbon reduces heated iron(III) oxide to iron metal and its self is oxidized to carbon monoxide gas.

  $Fe_2O_3(s) + 3C(s) \longrightarrow 2Fe(s) + 3CO(g)$
- ✓ Hot carbon reduces hot concentrated sulphuric acid to sulphur dioxide and water and itself is oxidized to carbon dioxide.

  $C(s) + 2H_2SO_4(aq) \longrightarrow CO_2(g) + 2SO_2(g) + 2H_2O(l)$
- ✓ Hot carbon reduces hot concentrated nitric acid to nitrogen dioxide and water and itself is oxidized to carbon dioxide.

  $C(s) + 4HNO_3(aq) \longrightarrow CO_2(g) + 4NO_2(g) + 2H_2O(l)$
- ✓ Hot carbon reduces carbon(IV) oxide to carbon(II) oxide and itself is oxidized to carbon monoxide.

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

Explain why graphite conducts electricity while diamond does not.
Graphite has mobile electrons which conduct electricity while diamond lacks mobile electrons and hence does not conduct electricity.
Describe the structure of graphite. (Diagram not required)
The graphite crystal consists of layers of carbon atoms arranged in two dimensions.
In each layer, the carbon atoms are arranged in hexagonal rings in which each carbon atom is covalently bonded to three other carbon atoms.
Three of the valence electrons are used in the formation of the covalent bonds and the remaining electron is delocalized over the whole layer. The atoms in the layer are joined by strong covalent bonds but the layers are joined by weak intermolecular forces (van der Waals forces) and hence the layers slide easily over each other.
Describe how you would show by a chemical test that graphite is made up of carbon atoms.
A small amount of graphite is burnt in a hard combustion tube and the gas given off is bubbled through lime water, which turns milky. This shows that the element in graphite is carbon, which is oxidized to carbon dioxide that turns lime water milky.

(a) (i) State what is meant by the term "isotope"

An isotope is an atom of an element that has the same atomic number but different mass number with another atom of the same element.

(ii).Write the full symbol of carbon-12 isotope (the number of protons in carbon=6)

$$^{12}_{6}C$$

(b) State;

(i) What the archaeologists use carbon-14 for;

Determining the ages of old objects.

(ii) The property of carbon-14, which makes it suitable for archaeological use

Carbon-14 is radioactive with long half-life.

(a) Soot is a form of carbon.

(i) Write an equation for complete combustion of soot in oxygen.

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(ii) State the allotrope of carbon to which soot belongs.

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(iii) State two industrial uses of graphite.

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(iv) Give a reason why diamond is used as a cutting tool whereas graphite is used in pencils.

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(b) State one difference between charcoal and graphite.

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(c) Give one use of;

(i) Charcoal.

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(ii) Graphite.

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(d) state one property of each of charcoal and graphite which makes it suitable for the use that you have given in ©

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(e) graphite was heated in excess air and the gas given off passed through aqueous calcium hydroxide solution for a long time

(i) State what was observed.

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(ii) Write equation(s) for the reaction.

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COMPOUNDS OF CARBON

1. **CARBON DIOXIDE.**

With the aid of a well labeled diagram, explain how a dry sample of carbon dioxide gas can be prepared in the laboratory.

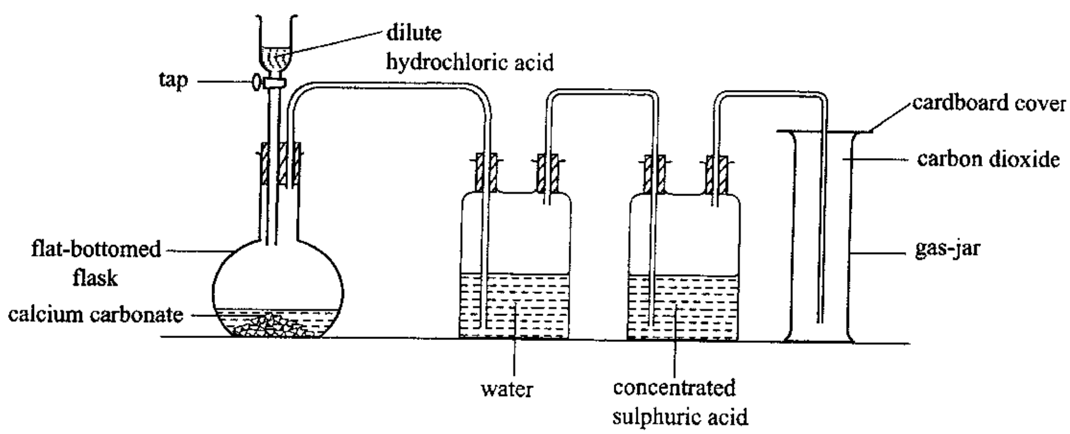

Fig 1.5 Preparation of carbon dioxide

Calcium carbonate which is a solid is placed in a flat bottomed flask fitted with a tap funnel and a delivery tube.

Dilute hydrochloric acid which is a liquid is added onto calcium carbonate through a tap funnel at room temperature, effervescence of carbon dioxide gas occurs.

$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

The gas is then passed through water to remove the acid sprays and then through concentrated sulphuric acid to dry it because the gas is acidic. The dry gas is collected by down ward delivery because it is denser than air.

Explain why dilute sulphuric acid is not used in the preparation of carbon dioxide using calcium carbonate.

Dilute sulphuric acid reacts with calcium carbonate to form calcium sulphate which is insoluble and forms a protective coating on the particles of calcium carbonate preventing further reaction. So no substantial amount of carbon dioxide is obtained by this reaction.

$CaCO_3(s) + H_2SO_4(aq) \longrightarrow CaSO_4(s) + CO_2(g) + H_2O(l)$

Explain why it's not advisable to prepare carbon dioxide gas by reacting lead(II) carbonate with ;(include equations for the reaction)

(i) **Dilute hydrochloric acid**

Dilute hydrochloric acid reacts with lead(II) carbonate to form lead(II) chloride.

$$PbCO_3(s) + 2HCl(aq) \longrightarrow PbCl_2(aq) + CO_2(g) + H_2O(l)$$

Lead(II) chloride is insoluble and forms a coating on the particles of lead(II) carbonate preventing further reaction. Therefore little amount of carbon dioxide is produced by this reaction.

(ii) Dilute sulphuric acid

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Write an ionic equation for the reaction between calcium carbonate and dilute hydrochloric acid.

$CaCO_3(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$

Or $CO_3^{2-}(s) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$

TEST FOR CARBON DIOXIDE

State how carbon dioxide can be identified in the laboratory.

By bubbling the gas through lime water. Lime water turns milky.

Or By bubbling the gas through calcium hydroxide solution. A white precipitate is formed.

PROPERTIES OF CARBON DIOXDE GAS.

(a) **Physical properties.**

- ✓ It's denser than air that is why it's collected by down ward delivery.
- ✓ Turns damp blue litmus paper red.
- ✓ It is an inflammable gas.
- ✓ It's slightly soluble in water forming carbonic acid.

$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

(b) **Chemical properties.**

(i) **With burning magnesium.**

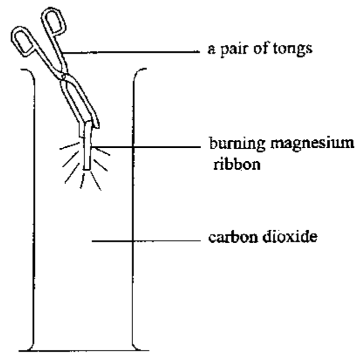

Fig 1.7 Burning magnesium ribbon in carbon dioxide

Burning magnesium was lowered into a gas jar of carbon dioxide.

(a) **State what was observed**

Magnesium continued to burn with a spluttering flame (bright white flame) forming a white solid and black specks.

(b) **Write the equation for the reaction.**

$2Mg(s) + CO_2(g) \longrightarrow 2MgO(s) + C(s)$

(c) **Explain your observation.**

Burning magnesium produces a lot of heat energy which decomposes carbon dioxide into carbon observed as black particles and oxygen gas.

$CO_2(g) \xrightarrow{heat} C(s) + O_2(g)$

Oxygen supports the burning magnesium and reacts with it forming magnesium oxide which is a white solid.

$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

(ii) Reaction of carbon dioxide with lime water or calcium hydroxide solution.

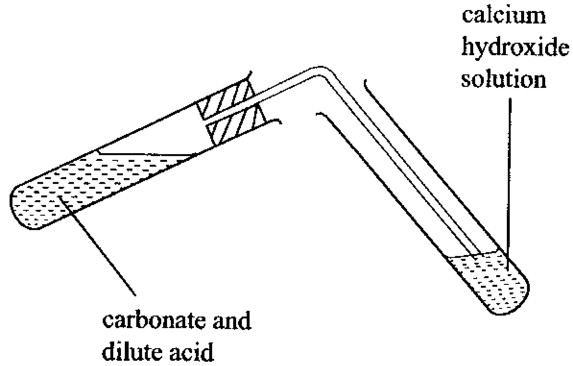

Fig 1.8 Effect of carbon dioxide on lime-water

Carbon dioxide was bubbled through lime water until in excess.

(a) State what was observed.

A white precipitate was formed which dissolved to form a colourless solution.

(b) With the aid of equations, explain your observation

Carbon dioxide which is acidic reacted with calcium hydroxide a base forming insoluble calcium carbonate which is a white precipitate.

$Ca(OH)_2(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$

Calcium carbonate reacts with more carbon dioxide in presence of water forming calcium hydrogen carbonate, a colourless solution.

$CaCO_3(s) + H_2O(l) + CO_2(g) \longrightarrow Ca(HCO_3)_2(aq)$

Note;

Overall equation for the above reactions

$Ca(OH)_2(aq) + 2CO_2(g) \longrightarrow Ca(HCO_3)_2(aq)$

Carbon dioxide was bubbled through lime water in limited supply.

(a) State what was observed.

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(b) Write the equation for the reaction that took place.

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(c) Explain your observation in (a) above.

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(iii) **Reaction of carbon dioxide with sodium hydroxide.**

Carbon dioxide was bubbled through sodium hydroxide solution until in excess.

(a) State what was observed.

No observable change at first but later, a white precipitate is formed.

(b) With the aid of equations, explain your observation above.

Carbon dioxide which is acidic reacted with sodium hydroxide a base forming sodium carbonate, a colourless solution.

$2NaOH(aq) + CO_2(g) \longrightarrow Na_2CO_3(aq) + H_2O(l)$

Sodium carbonate in presence of water then reacts with more carbon dioxide forming sodium hydrogen carbonate, a white precipitate.

$Na_2CO_3(aq) + H_2O(l) + CO_2(g) \longrightarrow 2NaHCO_3(s)$

Note;

The overall equation for the above reaction is;

$NaOH(aq) + CO_2(g) \longrightarrow NaHCO_3(s)$

Carbon dioxide was bubbled through sodium hydroxide solution in limited supply

(a) State what was observed

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(b) Write the equation for the reaction

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(c) Explain your observation in (a) above.

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Uses of carbon dioxide.

- Used in fire extinguishers. It's because carbon dioxide does not support burning/combustion and is denser than air.
- Used in the manufacture of fizzy drinks e.g. sodas.
- Used as a refrigerant. It's because solid carbon dioxide (dry ice) is a coolant and it sublimes.
- Used in the manufacture of baking powder.
- Used in the formation of rain fall, where solid carbon dioxide is dropped into clouds using an air craft to condense them so as to release rain.

Questions

(a) State;

(i) Two properties that make carbon dioxide to extinguish flames from burning substances.

- Carbon dioxide does not support burning or does not burn
- Carbon dioxide being denser than air displaces the air around the flame hence extinguishing it.

(ii) The role of carbon dioxide produced from the dough during the baking of bread.

Makes the bread to swell and rise during baking.

(b) Name one compound that when reacted with dilute hydrochloric acid can produce carbon dioxide.

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(c) Excess carbon dioxide was passed through ice-cold sodium hydroxide solution.

(i) State what was observed.

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(ii) Write the equation for the reaction.

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(d) Explain why diamond is used as a cutting tool.

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(e) Carbon dioxide can be prepared in the laboratory using calcium carbonate and substance **T**.

(i) Identify **T**

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(ii) Write the equation for the reaction leading to the formation of carbon dioxide as stated above.

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(f) Draw a well labeled diagram for the set up of apparatus that can be used to prepare a dry sample of carbon dioxide.

(g) With the aid of the diagram you have drawn in (f) above, explain how carbon dioxide is prepared.

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(h) Explain with the aid of equations the changes that take place when excess carbon dioxide is bubbled into sodium hydroxide solution.

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(i) When excess carbon dioxide gas was passed through a saturated solution of aqueous calcium hydroxide, a white precipitate formed which dissolved to form a colourless solution. Identify;

i) The white precipitate.

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ii) The anion in the colourless solution.

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(j) Write equation(s) for the reaction(s) that took place above.

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(k) To the colourless solution formed above, soap solution was added.

(i) State what was observed.

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(ii) Give one chemical method that can be used to prevent the reaction to the observation made in k (i) above.

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2. **CARBON MONOXIDE, CO**

Is a colourless, poisonous gas with no smell.
It's naturally found in gaseous fuels like coal gas.
It is formed by partial combustion of carbon.
$2C(s) + O_2(g) \longrightarrow 2CO(g)$

Preparation of carbon monoxide.

(i) By dehydration of oxalic acid (Ethanedioic acid) using hot concentrated sulphuric acid.

$H_2C_2O_4(s) \xrightarrow{Conc.H_2SO_4} CO(g) + CO_2(g) + H_2O(l)$

(ii) By reacting sodium methanoate with concentrated sulphuric acid.

$$HCOONa(s) + H_2SO_4(l) \longrightarrow NaHSO_4(aq) + CO(g) + H_2O(l)$$

Note; diagram for the laboratory preparation of carbon monoxide and description is not required because it is poisonous.

Carbon monoxide can be prepared in the laboratory by dehydration of substance **W** using concentrated sulphuric acid.

(i) Name substance **W**

....

(ii) Write equation for the reaction leading to the formation of carbon dioxide.

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Physical properties of carbon monoxide.

- ✓ Colourless gas and odourless.
- ✓ Highly poisonous.
- ✓ Slightly denser than air
- ✓ Neutral to litmus i.e. a neutral oxide hence neither acidic nor basic.

Chemical properties of carbon monoxide.

1. **Reaction with oxygen.**

Carbon monoxide was burnt in excess air forming product J

(a) State what was observed.

- Burns quietly with a blue flame.

(b) Write the equation for the reaction.

$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$

(c) State how the product J can be identified.

- By bubbling the product **J** through lime water. Lime water turns milky.

2. **Reducing action of carbon monoxide.**

Carbon monoxide reduces heated oxides of copper, iron, lead and zinc to their corresponding metals and its self oxidized to carbon dioxide.

(a) **Dry carbon monoxide was passed over heated copper(II) oxide as shown in figure 1.12 below.**

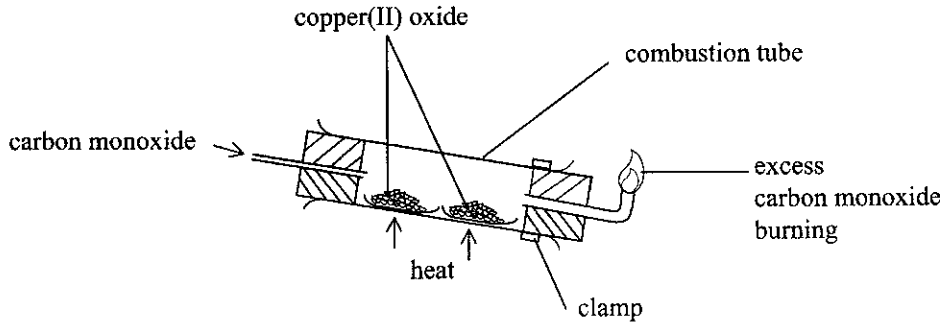

Fig 1.12 Reducing action of carbon monoxide

(i) State what was observed.

The black powder turned to brown and a colourless gas formed.

(ii) Write equation for the reaction in (a) above.

$CuO(s) + CO(g) \longrightarrow Cu(s) + CO_2(g)$

(b) **Explain your observation in (a) above.**

Carbon monoxide is a reducing agent. It reduces copper(II) oxide which is black to copper which is brown and its self is oxidized to carbon dioxide which is a colourless gas.

(a) Carbon monoxide was passed over lead(II) oxide.

(i) State the conditions for the reaction.

- Dry carbon monoxide.
- Heating lead(II) oxide.

(ii) State what was observed above under the conditions mentioned in (a)(i)

The reddish-brown solid turned to grey and a colourless gas was formed.

(b) Write the equation for the reaction.

$PbO(s) + CO(g) \longrightarrow Pb(s) + CO_2(g)$

(c) Explain your observation in (a)(i)

Carbon monoxide is a reducing agent. It reduces Lead(II) oxide which is reddish-brown to lead which is grey and its self is oxidized to carbon dioxide, a colourless gas.

(a) Dry carbon monoxide was passed over heated zinc oxide.

(i) State what was observed.

Zinc oxide turned from yellow to grey with formation of a colourless gas.

(ii) Write the equation for the reaction.

$ZnO(s) + CO(g) \longrightarrow Zn(s) + CO_2(g)$

(b) Explain your observation in (a)(i) above.

Carbon monoxide reduces yellow zinc oxide to grey zinc and its self is oxidized to carbon dioxide, a colourless gas.

(a) Dry carbon monoxide gas was passed over heated iron(III) oxide.

(i) State what was observed.

The reddish-brown solid turned to grey and a colourless gas was formed.

(ii) Write the equation for the reaction that took place.

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

(b) Explain your observation in (a) (i) above.

Carbon monoxide reduces reddish-brown iron(III) oxide to grey iron and its self oxidized to carbon dioxide, a colourless gas.

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

(i) State what was observed.

The black solid turned to grey and a colourless gas was formed.

(ii) Write the equation for the reaction that took place.

$FeO(s) + CO(g) \longrightarrow Fe(s) + CO_2(g)$

(b) The product formed in (a)(ii) above was dissolved in dilute sulphuric acid.

(i) State what was observed.

The grey solid dissolved with effervescence of a colourless gas forming a green solution.

(ii) Write the equation for the reaction that took place in (b) (i).

$Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$

The figure below is used to investigate the effect of gas **M** on copper(II) oxide.

The gas produced when gas M is passed over heated copper(II) oxide formed a white precipitate when bubbled through calcium hydroxide solution.

(a) Identify;

(i) Gas **M**.

- Carbon monoxide.

(ii) The white precipitate.

- Calcium carbonate.

(b) State what was observed in the combustion tube.

The black powder turned brown.

(c) Write the equation for the reaction taking place in the combustion tube.

$$CuO(s) + CO(g) \longrightarrow Cu(s) + CO_2(g)$$

(d) What property is shown by gas M in the reaction above?

- Reducing property.

(e) Why is it necessary to burn excess gas M at Z

- It is poisonous.

(f) Name two other oxides which can be used instead of copper(II) oxide.

- Iron(III) oxide.
- Lead(II) oxide.

(a) Carbon monoxide is a poisonous gas. Explain.

Carbon monoxide when inhaled combines with haemoglobin (an oxygen carrier molecule) in the red blood cells to form carboxyhaemoglobin. Carboxyhaemoglobin is a stable compound implying that haemoglobin is no longer available to combine with oxygen in the lungs and respiration cannot take place. This leads to suffocation and eventually death.

(b) An old woman prepared food from a poorly ventilated room using a charcoal stove

(i) State what was observed to the old woman at the end of the process.

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(ii) Explain your observation in (b) above. (Include equation(s) where possible).

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3. CARBONATES, CO_3

Action of heat on carbonates;

- All carbonates decompose on heating except potassium carbonate and sodium carbonate.
- Carbonates when heated decompose to give the corresponding oxide and carbon dioxide gas is also given off.

(a) Zinc carbonate was strongly heated in a dry test tube until there was no further change.

(i) State what was observed.

The white powder turned yellow when hot and white when cold.
A colourless gas was formed.

(ii) Write the equation for the reaction that took place.

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

(b) The residue formed in (a) above was cooled and added to dilute sulphuric acid.

(i) State what was observed.

The white solid dissolved forming a colourless solution.

(ii) Write the equation for the reaction.

$ZnO(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2O(l)$

(a) **Lead(II) carbonate was heated strongly to a constant mass.**

(i) State what was observed.

The white powder turned to a reddish-brown solid when hot and yellow when cold.
A colourless gas formed.

(ii) Write the equation for the reaction.

$PbCO_3(s) \longrightarrow PbO(s) + CO_2(g)$

(b) The **residue formed in (a) above was cooled and added to dilute nitric acid and warmed.**

(i) State what was observed.

The yellow solid dissolved forming a colourless gas.

(ii) Write the equation for the reaction.

$PbO(s) + 2HNO_3(aq) \longrightarrow Pb(NO_3)_2(aq) + H_2O(l)$

(a) Copper(II) carbonate was strongly heated until no further change.

(i) State what was observed.

The green powder turned to black and a colourless gas formed.

(ii) **Write the equation for the reaction**.

$CuCO_3(s) \longrightarrow CuO(s) + CO_2(g)$

(b) **The residue formed in (a) above was cooled and added to dilute sulphuric acid and warmed.**

(i) State what was observed.

The black residue dissolved in the acid forming a blue solution.

(ii) Write the equation for the reaction that took place.

$CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$

(a) Ammonium carbonate was heated strongly until there was no further change.

(i) State what was observed.

The white powder decomposed producing a colourless condensate and a colourless gas with an irritating smell.

(ii) Write the equation for the reaction.

$(NH_4)_2CO_3(s) \longrightarrow 2NH_3(g) + CO_2(g) + H_2O(l)$

(b) State how the gaseous product(s) can be identified.

Ammonia is identified using concentrated hydrochloric acid. Dense white fumes are formed.

Carbon dioxide is identified by using lime water. Lime water turns milky.

(a) Complete the equations below.

(i) $Ag_2CO_3(s) \xrightarrow{heat}$

(ii) $(NH_4)_2CO_3(s) \xrightarrow{heat}$

Note; The effect of heat on the carbonates of metals is summarized in the table below.

metal carbonate	*effect of heat on the carbonate.*
K Na	Does not decompose at all.
Ca Mg Zn Fe Pb Cu	Decompose to metal oxides and carbon dioxide
Hg Ag	Decompose to the metal, carbon dioxide and oxygen gas.

Action of dilute acid on carbonates.

When dilute acids are added to carbonates, effervescence of a colourless gas occurs; carbon dioxide, water and a corresponding salt are formed.

Dilute hydrochloric acid was added to sodium carbonate in a test tube.

(a) **State what was observed.**

The white solid dissolved with effervescence of a colourless gas forming a colourless solution.

(b) Write the equation for the reaction.

$Na_2CO_3(s) + 2HCl(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l)$

Or $CO_3^{2-}(s) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$

(a) Dilute nitric acid was added to copper(II) carbonate.

(i) State what was observed.

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(ii) Write the molecular equation for the reaction that took place

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(iii) Write the ionic equation for the reaction that took place.

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Solubility of carbonates.

Lithium carbonate, sodium carbonate, potassium carbonate and ammonium carbonate are the only soluble carbonates in water.

The other carbonates are insoluble e.g. lead(II) carbonate.

Hydrogen carbonates, HCO_3

These are also called bi-carbonates.

(i) **Solubility of bi-carbonates.**

- Sodium hydrogen carbonate, potassium hydrogen carbonate are the only stable bi-carbonates in the solid state. i.e. are insoluble in water.
- Calcium hydrogen carbonate, magnesium hydrogen carbonate are the only stable bi-carbonates in the aqueous solution i.e. are soluble salts in water.

(ii) **Action of heat on bi-carbonates.**

Bi-carbonates decompose on heating to form a metal carbonate, carbon dioxide and water.

Sodium hydrogen carbonate was heated strongly until there was no further change.

(a) State what was observed.

Sodium hydrogen carbonate decomposed to a white powder, a colourless condensate and a colourless gas formed.

(b) Write the equation for the reaction that took place.

$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l)$

Note; potassium hydrogen carbonate also decomposes in the same way like as shown above.

$2KHCO_3(s) \longrightarrow K_2CO_3(s) + CO_2(g) + H_2O(l)$

Water containing calcium hydrogen carbonate was heated strongly.

(a) State what was observed.

A white precipitate formed and bubbles of a colourless gas evolved.

(b) Explain your answer in (a) above.

Calcium carbonate formed is an insoluble salt in water, seen as a white precipitate. Carbon dioxide was formed seen as bubbles of a colourless gas.

$Ca(HCO_3)_2(aq) \longrightarrow CaCO_3(s) + H_2O(l) + CO_2(g)$

Water containing magnesium hydrogen carbonate was heated.

(a) State what was observed.

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(b) Write the equation for the reaction that took place.

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(c) Explain your observation in (a) above.

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(iii) **Action of dilute acids on hydrogen carbonates.**

Dilute acids react with hydrogen carbonates to give a salt, water and carbon dioxide gas. E.g.

Dilute hydrochloric acid was added to sodium hydrogen carbonate in a boiling tube.

(a) State what was observed.

The white powder dissolved with effervescence of a colourless gas forming a colourless solution.

(b) Write the equation for the reaction that took place.

$NaHCO_3(s) + 2HCl(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l)$

Or

$HCO_3^-(s) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$

Dilute sulphuric acid was added to potassium hydrogen carbonate.

(a) State what was observed.

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(b) Write the ionic equation for the reaction.

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SODIUM CARBONATE/ SODA ASH

Describe the laboratory preparation of sodium carbonate.

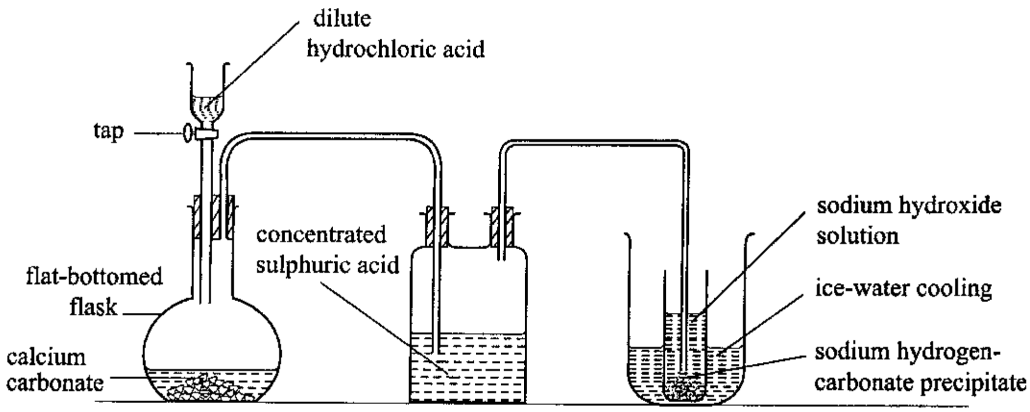


Fig 1.16 Preparation of sodium carbonate

Dilute hydrochloric acid is added to calcium carbonate, carbon dioxide gas is given off.

$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

The carbon dioxide is passed through water to absorb the acid traces and dried by passing it through concentrated sulphuric acid.

The carbon dioxide gas is passed through concentrated solution of sodium hydroxide. Sodium carbonate is formed as follows.

$2NaOH(aq) + CO_2(g) \longrightarrow Na_2CO_3(aq) + H_2O(l)$

Excess carbon dioxide gas is passed through the resultant solution. A white precipitate of sodium hydrogen carbonate is formed.

$Na_2CO_3(aq) + H_2O(l) + CO_2(g) \longrightarrow 2NaHCO_3(s)$

The white precipitate is filtered off, washed with distilled water and dried.

The dried sodium hydrogen carbonate is then heated to a constant mass and sodium carbonate is formed which is a white powder.

$$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

Commercial preparation of sodium carbonate by the solvary process.
(*Industrial preparation of sodium carbonate*)

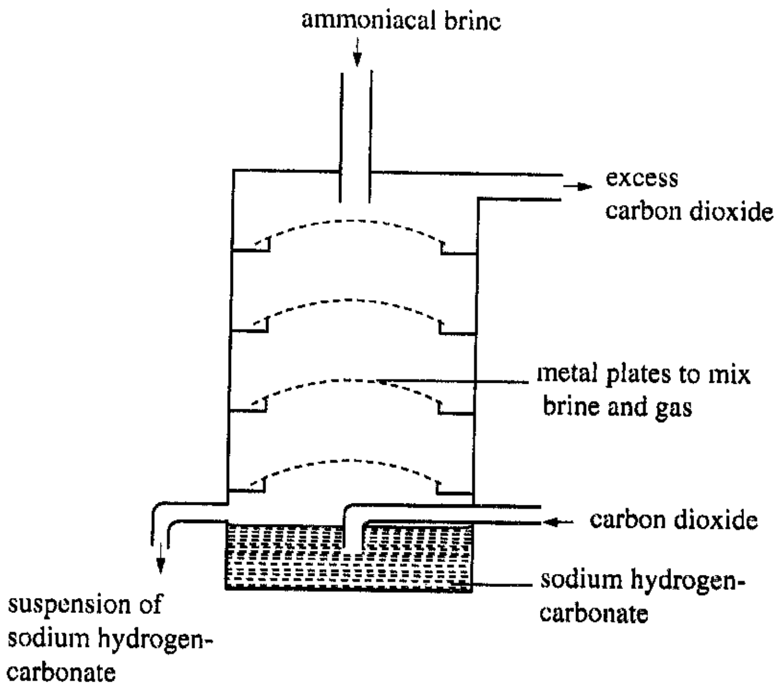


Fig 1.17 Solvay process

The raw materials used in this preparation include;
Brine (concentrated sodium chloride solution), carbon dioxide and ammonia; the procedure is as follow;

- Concentrated solution of sodium chloride is slowly dropped down into a tower which has ammonia moving through it. The Brine- ammonia mixture is then made to pass down the second tower which has carbon dioxide moving through it, ammonium hydrogen carbonate is formed.
  $NH_3(g) + H_2O(l) + CO_2(g) \longrightarrow NH_4HCO_3(aq)$
- The ammonium hydrogen carbonate formed quickly reacts with excess brine to form a white precipitate of sodium hydrogen carbonate.
  $NH_4HCO_3(aq) + NaCl(aq) \longrightarrow NaHCO_3(s) + NH_4Cl(aq)$
- Sodium hydrogen carbonate formed is then filtered off, washed, dried and heated to a constant mass. A white solid powder of sodium carbonate is formed.
  $2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$

USES OF SODIUM CARBONATE

- ✓ Used in the manufacture of glass.
- ✓ Used in softening of water.
- ✓ Used as a constituent of many dry soap powders.

1.1. The Carbon cycle

Carbon cycle is the balancing of carbon dioxide in air i.e. describes the processes that increase or decrease the carbon dioxide concentration in the environment (atmosphere). The atmosphere contains about 0.03% of carbon dioxide by volume and this volume is kept almost constant.

Processes that add carbon dioxide to the atmosphere

1) **Combustion:** Carbon and its compounds burn in air to produce carbon dioxide e.g. burning of coke, coal, wood, petrol, oils etc.

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

2) **Respiration:** When sugars are oxidized in the body, carbon dioxide is produced

$C_6H_{12}O_6(l) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

3) **Thermal decomposition of calcium carbonates:** Carbon dioxide passes into air when limestone or chalk is heated.

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

4) **Fermentation:** in the manufacture of ethanol during fermentation carbon dioxide is produced as a bi-product.

$C_6H_{12}O_6(l) \rightarrow 2C_2H_5OH(l) + CO_2(g) + \text{Energy}$

Processes that remove carbon dioxide from the atmosphere

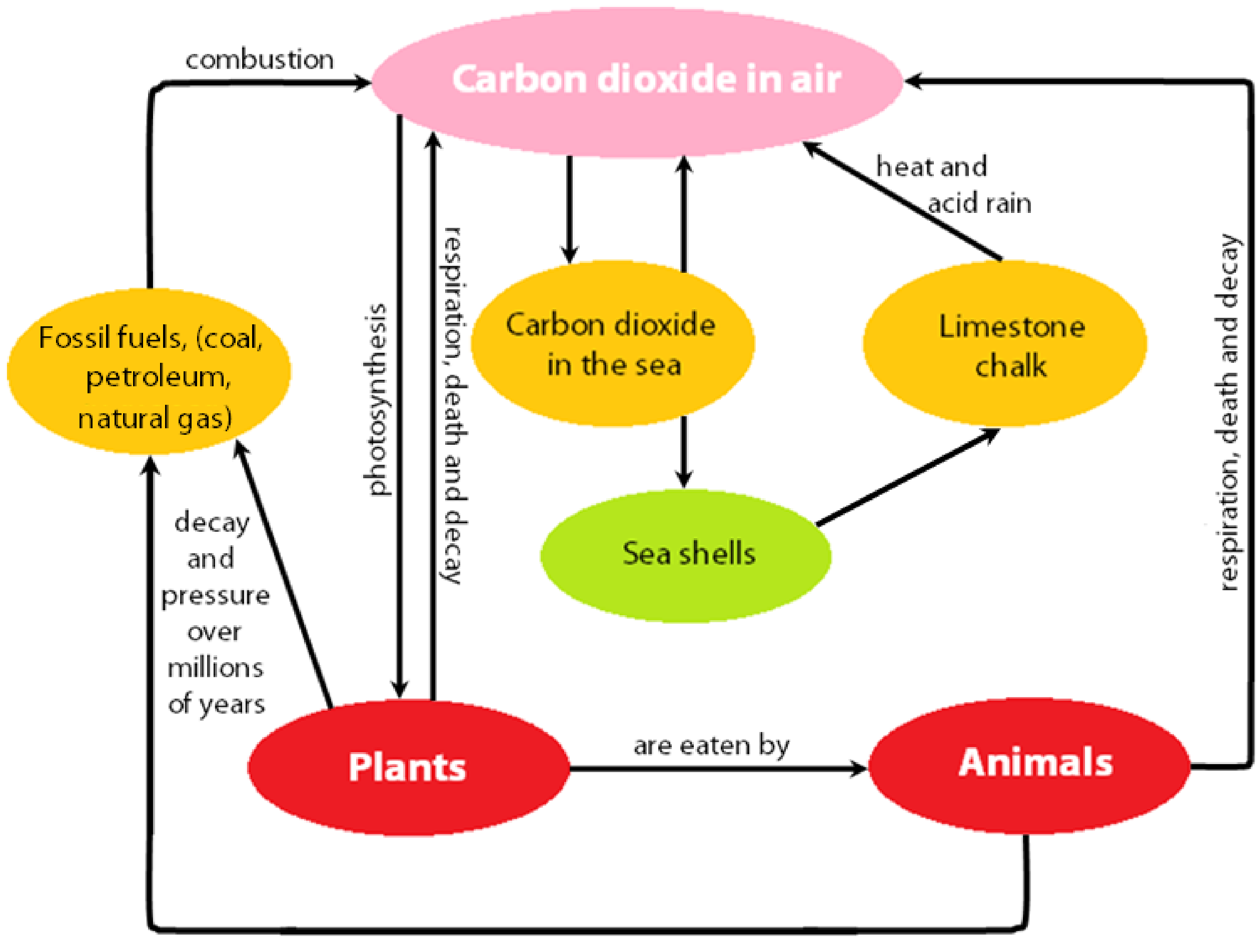
1) **Photosynthesis:** Green plants absorb carbon dioxide from the atmosphere to make their own food

$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(l) + 6O_2(g)$

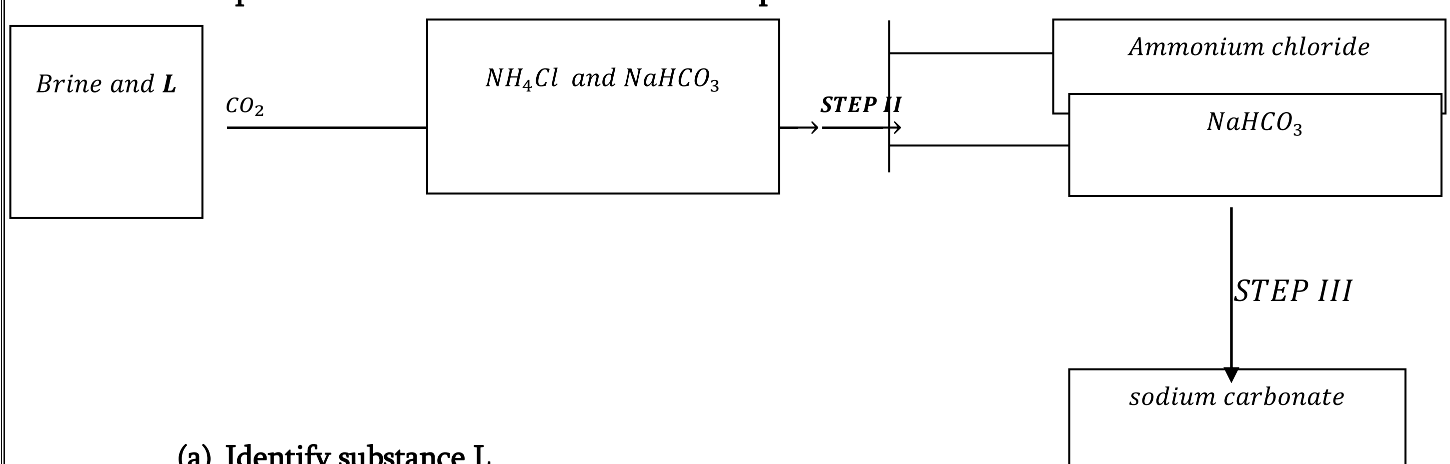
2) **Hardening of mortar:** Mortar and white ash remain slaked lime which slowly absorbs carbon dioxide is produced

$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

3) **Solution in water:** Rain dissolves carbon dioxide to form a weak acid (carbonic acid) which runs into rivers, lakes, seas and oceans



The **simplified flow chart below shows some steps in the manufacture of sodium carbonate.**



(a) Identify substance L

Ammonia.

(b) Write the equation for the reaction that takes place in *STEP I*

$NH_3(g) + H_2O(l) + CO_2(g) + NaCl(aq) \longrightarrow NaHCO_3(s) + NH_4Cl(aq)$

(c) Name the process that takes place in $STEP\ II$

Filtration.

(d) Write the equation for the which takes place in $STEP\ III$

$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$

HOW TO DISTINGUISH BETWEEN $CO_3^{2-}(aq)$ AND $HCO_3^-(aq)$

(a) Name one reagent that can be used to differentiate between carbonate ion and hydrogen carbonate ion.

- Magnesium sulphate solution (or magnesium chloride solution)

(b) State what would be observed if each anion is reacted with the reagent.

- With $\boldsymbol{CO_3^{2-}(aq)}$; A white precipitate formed.
- With $\boldsymbol{HCO_3^-(aq)}$; No observable change.

(c) Explain your observation made

- With $\boldsymbol{CO_3^{2-}(aq)}$; magnesium carbonate is formed which is an insoluble salt seen as a white precipitate.
  $Mg^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow MgCO_3(s)$
- With $\boldsymbol{HCO_3^-(aq)}$; Magnesium hydrogen carbonate is formed which is a soluble salt and hence a colourless solution is formed, therefore no observable change.
  $Mg^{2+}(aq) + 2HCO_3^-(aq) \longrightarrow Mg(HCO_3)_2(aq)$

State what would be observed and write equation for the reaction that would take place if magnesium chloride solution is added to a solution containing;

(i) Carbonate ion.

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(ii) Hydrogen carbonate ion.

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Explain the following observation and write equation(s) for the reaction to illustrate your answer; a white precipitate formed when a mixture of magnesium sulphate solution and sodium hydrogen carbonate solution was heated.

- When magnesium sulphate is reacted with sodium hydrogen carbonate, magnesium hydrogen carbonate is formed.
  $MgSO_4(aq) + 2NaHCO_3(aq) \longrightarrow Mg(HCO_3)_2(aq) + Na_2SO_4(aq)$
- Magnesium hydrogen carbonate is unstable on heating and therefore decomposes to form magnesium carbonate, seen as a white precipitate

$$Mg(HCO_3)_2(aq) \longrightarrow MgCO_3(s) + H_2O(l) + CO_2(g)$$

Dilute sulphuric acid was added to copper(II) carbonate and the gas evolved passed through aqueous calcium hydroxide solution as shown in the figure below. The addition of sulphuric acid was continued until there was no further change.

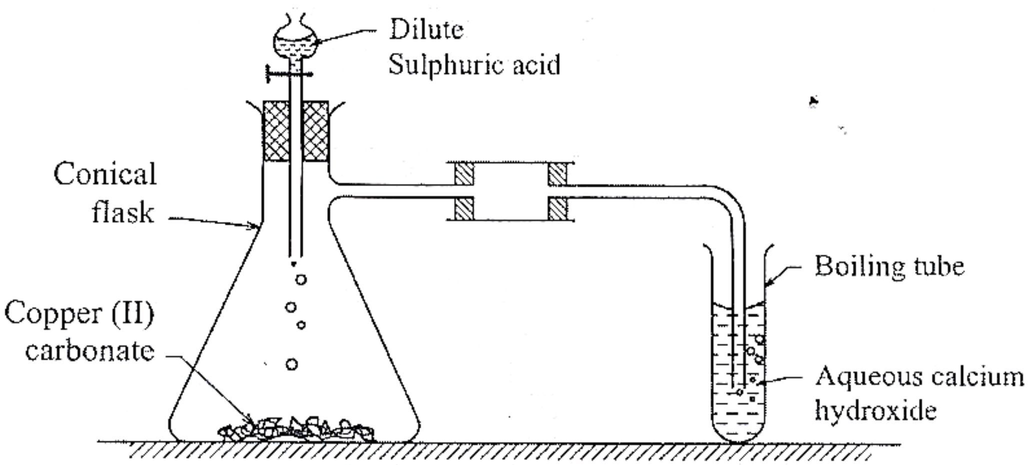

Fig. 1

(a) State what was observed in the conical flask.

The green powder dissolved with effervescence of a colourless gas to give a blue solution.

(b) Write equation(s) for the reaction(s);

(i) Between sulphuric acid and copper(II) carbonate.

$CuCO_3(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$

OR

$CuCO_3(s) + 2H^+(aq) \longrightarrow Cu^{2+}(aq) + H_2O\,(l) + CO_2(g)$

(ii) That took place in the boiling tube.

$Ca(OH)_2(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$

$CaCO_3(s) + H_2O(l) + CO_2(g) \longrightarrow Ca(HCO_3)_2(aq)$

TRIALQUESTIONS

(a) Sodium carbonate is more soluble in water than sodium hydrogen carbonate. Briefly describe how a dry sample of sodium hydrogen carbonate can be obtained from a solution containing both salts.

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(b) Write the equation for the reaction that would take place if;

(i) Dilute hydrochloric acid is added to sodium hydrogen carbonate

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(ii) Sodium hydrogen carbonate was strongly heated.

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(a) Zinc carbonate was strongly heated in a hard glass tube until there was no further change.

(i) State what was observed.

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(ii) Write the equation for the reaction

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(b) The solid product in (a)(ii) was dissolved in dilute hydrochloric acid.

(i) State what was observed if aqueous ammonia is added to the resultant solution in excess.

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(ii) Explain how you would identify the anion present in the resultant solution.

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(a) Sodium carbonate solution was added to aqueous solution of hydrogen chloride.

(i) State what was observed.

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(ii) Write the equation for the reaction that took place.

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(b) 2-3 drops of lead(II) nitrate solution was added to the resultant solution in (a) above.

(i) State what was observed.

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(ii) Write ionic equation for the reaction that took place.

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(a) An aqueous solution of hydrogen chloride was added drop wise to 4.2g of solid sodium hydrogen carbonate until there was no further change. A colourless gas was evolved.

(i) State what was observed.

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(ii) Write equation(s) for the reaction between the gas and calcium hydroxide solution.

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(b) Calculate the volume of the gas, measured at s.t.p that was evolved.

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(a) Briefly describe how a pure dry sample of calcium carbonate can be prepared. (Diagram not required)

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(b) Sodium carbonate was dissolved in water to form sodium hydroxide and carbonic acid as shown in the equation below;

$Na_2CO_3(s) + H_2O(l) \longrightarrow 2NaOH(aq) + H_2CO_3(aq)$

The solution was tested with litmus paper.

(i) State what was observed.

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(ii) Give a reason for your answer in (d)(i)

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(c) Write the equation for the reaction between sodium carbonate solution and magnesium sulphate solution.

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(a) A mixture containing copper(II) sulphate and copper(II) carbonate was shaken with excess water and filtered.

Identify the residue.

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(b) The dry residue was heated strongly.

(i) State what was observed.

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(ii) Write the equation for the reaction.

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(c) A solution of sodium carbonate was added to a solution of calcium ions.

(i) State what was observed.

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(ii) Write the equation for the reaction that took place.

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(d) Dilute hydrochloric acid was added to the mixture formed in © above.

(i) State what was observed.

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(ii) Write the equation for the reaction.

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(a) State what would be observed if concentrated sulphuric acid is added to sugar. Explain your answer.

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(b) Dilute sulphuric acid was added to zinc carbonate. State what was observed and write the equation for the reaction.

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(c) State the conditions under which sulphuric acid reacts with copper and write the equation for the reaction.

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A mixture of zinc sulphate and zinc carbonate was shaken with excess water in a beaker and then filtered.

(a) Identify the substance in the residue.

Zinc carbonate.

(b) The residue was dried and then heated strongly.

(i) State what was observed.

The white solid turned yellow on heating and white on cooling.
A colourless gas was evolved.

(ii) Write the equation for the reaction that took place.

$$ZnCO_3(s) \xrightarrow{heat} ZnO(s) + CO_2(g)$$

(c) (i) Name the reagent that can be used to identify the anion in the filtrate.

- Aqueous barium nitrate and dilute nitric acid. (or Acidified Barium nitrate solution)
- Aqueous barium chloride and dilute hydrochloric acid. (or Acidified Barium chloride solution).

(ii). Write an ionic equation for the reaction that takes place between the reagent and the anion in the filtrate.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$$

(d) Lead(II) carbonate is a salt which is formed according to the equation;

$Pb^{2+}(aq) + 2HCO_3^-(aq) \longrightarrow PbCO_3(s) + H_2O(l) + CO_2(g)$

(i) State what was observed when a solution containing lead(II) ions is treated with aqueous hydrogen carbonate.

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(ii) Name and describe a suitable method by which a pure and dry sample of lead(II) carbonate can be prepared in the laboratory.

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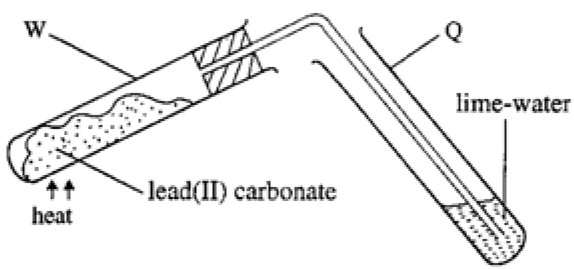
1. The figure below shows an experimental setup to investigate the effect of heat on lead (II) carbonate.



(a) Write the equation for the reaction taking place in test-tube W.

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(b) State what is observed in test-tube Q.

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(c) What is observed in test-tube Q if lead (II) carbonate is replaced with sodium carbonate? Give a reason for your answer.

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2. The figure below shows an experimental setup to investigate the effect of carbon monoxide on oxides of metals.

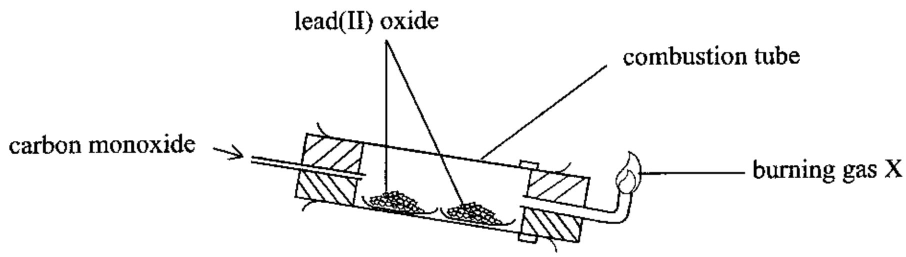

Fig 1.13

a)

i) State the conditions for the reaction taking place in the combustion tube.

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ii) Write the equation for the reaction taking place in the combustion tube.

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b)

i) Name the gas X being burnt at the jet.

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ii) Why is it necessary to burn gas X?

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iii) Write equation for the combustion of gas X.

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c) Name any other oxide that can be used instead of lead(II) oxide.

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d) What would you expect to happen if lead (II) oxide was replaced with magnesium oxide? Give a reason for your answer.

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The flow chart below is a summary of the steps followed in preparation of lead(II) carbonate from sodium carbonate solution and compound **R**. Use it to answer the following questions.

(a) Name ;
- (i) The method used to prepare lead(II) carbonate
- (ii) Compound **Q**
- (iii) **R**
- (iv) The cation in the residue **S**
- (v) Anion in the filtrate **T**

(b) Write the equation for the reaction ;
- (i) Between sodium carbonate and compound **Q**
- (ii) To show the effect of heat on lead(II) carbonate.

(c) State what is carried out in steps;
- (i) Step 2
- (ii) Step 3
- (iii) Step 4

PRODUCER GAS AND WATER GAS

PRODUCER GAS

Producer gas is a fuel made by passing air through a thin layer of white-hot coke in a producer.
It mainly consists of nitrogen and carbon monoxide.

WATER GAS

Water gas is produced by passing steam over coke heated at a temperature of about 1000^oC

$C(s) + H_2O(g) \longrightarrow CO(g) + H_2(g)$

Water gas mainly consists of carbon monoxide and hydrogen gas.

(a) Car exhaust fumes contain gases including carbon dioxide, carbon monoxide and nitrogen.
- (i) Which of the gases above, contributes to acidic rain and how?
- (ii) Describe how you would come to conclude that rain water is acidic.

CO, N_2 CO, H_2

(b) Given and

A B

(i) Identify the gas mixture **A** and **B.**

....

(ii) Which of the above mixture **A** and **B** is hotter?

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(iii) Explain your answer in (b)(ii)

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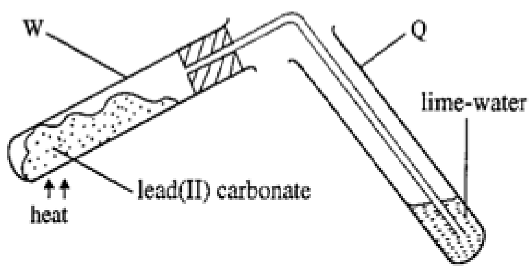
2. The figure below shows an experimental setup to investigate the effect of heat on lead (II) carbonate.



(d) Write the equation for the reaction taking place in test-tube W.

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(e) State what is observed in test-tube Q.

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(f) What is observed in test-tube **Q** if lead (II) carbonate is replaced with sodium carbonate? Give a reason for your answer.

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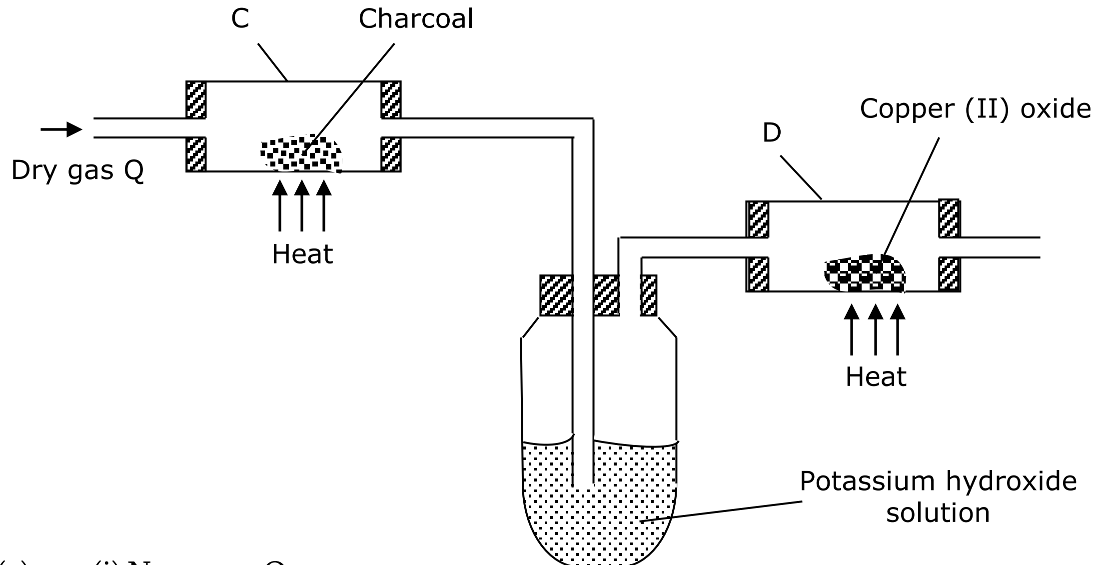
An experiment to prepare carbon monoxide and investigate its effect on copper (II) oxide was carried out using apparatus in the diagram below. Use it to answer questions that follow.



(a) (i) Name gas Q.

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(ii) Write equation for the reaction that took place in tube C.

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(b) (i) Explain using an equation the purpose of potassium hydroxide solution.

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(ii) State what was observed in the tube D.

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(iii) Write an equation and name for the reaction that took place.

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(c) (i) Why is this experiment carried out in a fume board?

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(ii) Give one industrial application of carbon monoxide gas.

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(d) Using equations, briefly describe what happens when;

(i) Burning magnesium is lowered into a gas jar of carbon dioxide.

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(ii) Excess carbon dioxide is passed into a solution of calcium hydroxide and then heat.

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Solutoins.

(a)	(i) Q is carbon dioxide (ii) $CO_2(g) + C(s) \longrightarrow 2CO(g)$
(b)	(i) Removes excess carbon dioxide $2KOH(aq) + CO_2(g) \longrightarrow K_2CO_3(aq) + H_2O(l)$ (ii) Black powder turns to brown solid and colourless gas (iii) $CuO(s) + CO(g) \longrightarrow Cu(s) + CO_2(g)$
(c)	(i) Because carbon monoxide is a poisonous gas (ii) Used in manufacture if carbonated drinks Used as a refrigerating agent
(d)	(i) Magnesium continues to burn with a spluttering flame forming white ash and black solid on the walls of the tube (ii) CO_2 reacts with calcium hydroxide forming white precipitate which later dissolves forming a colourless solution $CO_2(g) + Ca(OH)_2(aq) \longrightarrow CaCO_3(s) + H_2O(l)$ $CaCO_3(s) + H_2O(l) + CO_2(g) \longrightarrow Ca(HCO_3)_2(aq)$

State what is observed when each of the following salts are heated strongly

(i) Sodium carbonate crystals

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(ii) Copper (II) carbonate

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(iii) Lead (II) nitrate

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(iv) Iron (II) sulphate crystal

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(a) Explain the observation in a(i),(ii) and a(iv) above.

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(i) No observable change
(ii) Black residue and colourless gas that turns lime water milky
(iii) Brown residue when hot that turns yellow when cold. Brown fumes
(iv) Green crystals turned to white powder on gentle heating and to reddish brown residue with white fumes
(i) Sodium carbonate is stable and so is not decomposed by heat
(ii) Black residue is due to formation of CuO
Colourless gas is carbon dioxide
$CuCO_3(s) \longrightarrow CuO(s) + CO_2(g)$
(iv) Green crystals lose water of crystallization forming a white powder of anhydrous iron (ii) sulphate
$FeSO_4.7H_2O(s) \longrightarrow FeSO_4(s) + 7H_2O(l)$
$FeSO_4.7H_2O_{(s)} \longrightarrow FeSO_{4(S)} + H_2O_{(l)}$
On strong heating $FeSO_4$ decomposes forming iron (iii) oxide,

sulphur dioxide and SO_3 gases $2FeSO_4(s) \longrightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$

Carbon dioxide is used in the manufacture of sodium carbonate by the Solvay process

(a) State any other two industrial uses of carbon dioxide

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(b) Name the raw materials that supply carbondioxide in the Solvay process

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(c) Describe how sodium carbonate is manufactured by the Solvay process.

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(d) Mention two uses of sodium carbonate.

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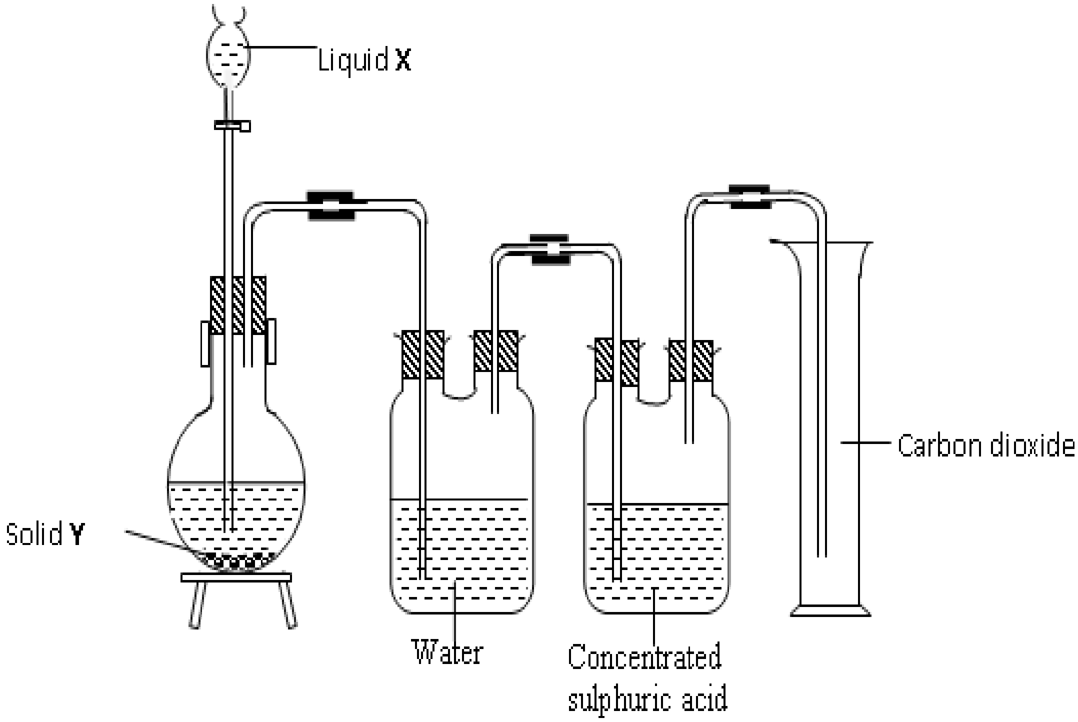
Solutions
Manufacture of carbonated drinks Refrigerating agent Calcium carbonate Sodium chloride Limestone ($CaCO_3$) is heated to decompose $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$ Ammoniacal brine is passed into the Solvay tower through which CO_2 has been blown $NaCl(s) + NH_3(g) + CO_2(g) + H_2O(l) \longrightarrow NaHCO_3(s) + NH_4Cl(s)$ $NaHCO_3$ precipitates in the lower part of the tower in form of wet sludge

It is filtered from the white sludge and washed. It is heated to convert it to Na_2CO_3 and CO_2 evolved $2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$ Used to make dry soap powder manufacture of glass softening of water

The diagram below show laboratory preparation of carbon dioxide gas. Study it and answer the questions that follow.



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a) Name

i) Liquid **X**. (½ mark)

....

ii) Solid **Y**. (½ mark)

....

b) Write equation for the reaction leading to formation of carbon dioxide. (1½ marks)

....

c) State the role of:

i) Water. (½ mark)

....

ii) concentrated sulphuric acid. (½mark)

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d) Write equation of reaction that would take place when burning magnesium is lowered into a gas jar carbon dioxide. (1½ mark)

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(a) 5.0 g of calcium carbonate was heated strongly until there was no further change.

(i) Write equation for the reaction.

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(ii) Calculate the mass of the solid left.(Ca=40, C=12, O=16)

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(b) The residue in (a) was shaken with water and the product tested with blue litmus paper. State what was observed.

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ORGANIC CHEMISTRY

Organic chemistry is a branch of chemistry that deals with the compounds of carbon except oxides of carbon, carbonates, hydrogen carbonates and carbides of metals. Or

Is the study of structures and properties of carbon compounds.

Carbon has its own branch of chemistry because of the following reasons;

(i) It is a unique element which bonds with itself and atoms of other elements forming relatively stable bonds with high bond energies. These bonds can be single, double or triple.

(ii) Carbon forms very stable compounds since a lot of energy is required to break bonds in these compounds. The high carbon-carbon bond energy leads to carbon forming long Caron-Carbon chain a property known as ***Catenation.***

Define the term Catenation

- ✓ Is the ability of carbon atoms to covalently bond to one another to form long carbon chains which are straight, branched or cyclic.

  Or
- ✓ Is the continuous linkage of carbon atoms to form long carbon chains which are straight, branched or cyclic.

(iii)Carbon uses four electrons for bonding and thus each carbon atom is capable of forming four covalent bonds making it possible have different groups attached to chains of carbon atoms.

Note:

Compounds in which carbon exhibits carbon-carbon single bonds are called ***Saturated compounds*** while those in which a multiple bond i.e. carbon-carbon double bond ($C = C$) or carbon-carbon triple bond ($C \equiv C$) is exhibited are called ***Unsaturated compounds***.

Define the following terms:

(i) Saturated compound.

- ✓ Is a compound in which all its atoms exert their usual combining power with other atoms.

(ii) Unsaturated compound.

- ✓ Is a compound in which some atom (or atoms) is not exerting all its combining power with other atoms.

(iii)Hydrocarbon.

- ✓ Is an organic compound containing hydrogen and carbon atoms only.

(iv)Saturated hydrocarbons.

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(v) Unsaturated hydrocarbons.

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HOMOLOGOUS SERIES

This is a group of compounds which can be prepared by similar methods, can be represented by the same general formula, have similar chemical properties, show gradual change of physical properties and each member differs from the next by presence of additional methylene (-CH_2-).

FUNCTIONAL GROUP

This is an atom, group of atoms, a double or triple bond that determines the principle chemical nature of a compound. Or

Is an atom or group of atoms responsible for the chemical properties of the compound. Or

Is the most reactive part of an organic compound characterized by relatively weak bonds.

Below are functional groups and their corresponding Homologous seriies.

Functional group	***Homologous series***	***Example***
$-C-$	*Alkane*	CH_4
$-C=C-$	*Alkene*	$H_2C=CH_2$
$-C\equiv C-$	*Alkyne*	$H-C\equiv C-H$
$-OH$	*Alkanol (Alcohol)*	CH_3OH

Characteristic properties of Organic compounds.

- Almost all organic compounds are covalent. They exist as molecules and their physical properties to a great extent depend on the size, shape and structure of the molecules.
- In general, organic compounds are gases, liquids or relatively low melting point solids. This is because the organic molecules are only held by weak molecular forces of attraction called the ***Vander waal'sforces.***
- Both melting and boiling points increase with increasing molecular mass (increasing number of carbon atoms) in the homologous series.
- The hydrocarbons are generally insoluble in water because they are non-polar. However, they can dissolve in non-polar solvents such as trichloromethane (chloroform) and methylbenzene (toluene).

Structure determination of Organic compounds

The organic product is first purified by fractional or steam distillation and then elemental analysis is quantitatively carried out by spectrometry where the percentage compositions of each element in the organic compound is determined.
Empirical formula and then molecular formula is determined from which the structural formula of the organic compound is determined.

Note:

Define the following terms;

(i) ***Empirical formula***

- ✓ Is the simplest formula of a compound which shows the ratio of the atoms of the elements present in that compound.

(ii) ***Molecular formula.***

- ✓ Is the formula of a compound indicating the actual number of atoms of each element present in that compound.

  Or
- ✓ Is the formula that shows the total number of atoms of each element present in one molecule of a specific compound.

(iii)***Structural formula***

- ✓ This is the formula that shows the sequence and the actual arrangement of atoms in a molecule or compound.

  Or
- ✓ Is the formula that shows the arrangement of atoms in the molecule by means of groups of atoms.

Note:

To determine molecular formula of a compound from the obtained empirical formula, the relative molecular mass or the vapour density of the compound must be known.

$$\boxed{Relative\ molecular\ mass\ (R.M.M) = 2 \times Vapour\ density\ (V.D)}$$

Examples:

1. 0.0444g of an organic compound, M, containing elements, carbon, hydrogen and oxygen on complete combustion gave 0.0792g of carbon dioxide and 0.0324g of water. Given that molecular mass of M is 74. Determine:-

(i) Empirical formula of M. $(C = 12; H = 1; O = 16)$

$\underline{Mass\ of\ Carbon}$

$$Molar\ mass\ of\ CO_2 = (1 \times 12) + (2 \times 16)$$
$$= 12 + 32$$
$$= 44g$$

$44g\ of\ carbon\ dioxide\ contain\ 12g\ of\ carbon.$

$$0.0792g\ of\ carbon\ dioxide\ contain\ \left(\frac{12}{44} \times 0.0792\right) g\ of\ carbon$$
$$= 0.0216g\ of\ carbon.$$

$\underline{Mass\ of\ Hydrogen}$

$$Molar\ mass\ of\ H_2O = (2 \times 1) + (1 \times 16)$$
$$= 2 + 16$$
$$= 18g$$

$18g\ of\ water\ contain\ 2g\ of\ hydrogen.$

$$0.0324g\ of\ water\ contain\ \left(\frac{2}{18} \times 0.0324\right) g\ of\ hydrogen$$
$$= 0.0036g\ of\ hydrogen.$$

$$Mass\ of\ Oxygen\ in\ the\ compound = 0.0444 - (0.0216 + 0.0036)$$
$$= 0.0192\ g$$

$Elements\ present$	C	H	O
$Mass\ composition$	0.0216	0.0036	0.0192
$Moles\ of\ atoms$	$\frac{0.0216}{12}$ $= 0.0018$	$\frac{0.0036}{1}$ $= 0.0036$	$\frac{0.0192}{16}$ $= 0.0012$
$Mole\ ratio$	$\frac{0.0018}{0.0012}$ $= 1.5$	$\frac{0.0036}{0.0012}$ $= 3.0$	$\frac{0.0012}{0.0012}$ $= 1.0$
$Simplest\ ratio$	1.5×2 $= 3$	3.0×2 $= 6$	1.0×2 $= 2$

$\therefore \boldsymbol{The\ Empirical\ formula\ of\ M\ is\ C_3H_6O_2}$

(ii) Molecular formula of M

$(C_3H_6O_2)_n = 74$

$[(3 \times 12) + (6 \times 1) + (2 \times 16)]n = 74$

$74n = 74$

$\frac{74n}{74} = \frac{74}{74}$

$n = 1$

$\therefore \boldsymbol{T\ he\ molecular\ formula\ of\ M\ is\ C_3H_6O_2}$

2. When 5.4g of a hydrocarbon P, was burnt in air, 5.4g of water and 17.6g of carbon dioxide were given off.

a) Calculate the;-

(i) Empirical formula of P ($C = 12; H = 1$)

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(ii) Molecular formula of P ($Vapour\ density\ of\ P = 27$)

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b) Write the structural formula of P

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3. A hydrocarbon Y, on complete combustion produced 35.2g of carbon dioxide and 14.4g of water.

a) Calculate the;-

(i) Empirical formula of Y ($C = 12; H = 1$)

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(ii) Molecular formula of Y ($Vapour\ density\ of\ Y = 14$)

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b) Write the structural formula of Y

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ISOMERISM

This is the existence of two or more compounds with the same molecular formula but with different structural formula due to the difference in the arrangement of atoms.

Isomers

These are compounds with the same molecular formula but different structural formula.

Define the trem ***an isomer***

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$\boldsymbol{N.B}$

All hydrocarbons with four or more carbon atoms per molecule possess isomers e.g. Butane (C_4H_{10})

Write all the possible isomers of Butane (C_4H_{10})

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ALKANES

These are saturated hydrocarbons (containing single covalent bonds) with a general molecular formulaC_nH_{2n+2}; where n *represents the number of carbon atoms*.

Alkanes are referred to as the *paraffins* i.e. they have little affinity to react.

Nomenclature of Alkanes (Naming of Alkanes)

According to the***International Union of Pure and Applied Chemistry*** (***IUPAC***), all members of alkanes have their names ending with suffix " − *ane*"

Below are the first five members in the Alkane homologous seris;

Number of carbon atoms(n)	*Molecular formula*(C_nH_{2n+2})	*Name*	*Structural formula*
1.	CH_4	*Methane*	
2.	C_2H_6	*Ethane*	
3.	C_3H_8	*Propane*	
4.	C_4H_{10}	*Butane*	
5.	C_5H_{12}	*Pentane*	

SOURCES OF ALKANES

The main sources of alkanes include;

(i) From natural gas.

Natural gas is formed from decomposition of plants and animal remains. It mainly consists of methane and small amounts of other gases such as ethane, propane and butane.

(ii) From petroleum.

Petroleum contains a wide range of alkanes ranging from low molecular mass gases to high molecular mass waxy solids.

Petroleum is formed from anaerobic decomposition of plants and animals.

Alkanes are obtained from petroleum during the process of oil refining (by fractional distillation) where the hydrocarbons (alkanes) are separated from the non-volatile compounds.

FRACTIONAL DISTILLATION OF PETROLEUM(CRUDE OIL)

Crude oil which consists of a mixture of gases, liquids and solids is separated by fractional distillation.

During fractional distillation of crude oil, it is heated to about 400℃ and the hot liquids are passed through a fractionating tower. The tower consists of trays at different levels. Therefore as hot vapour passes up the tower, they condense at different levels of the tray according to their boiling points as shown in the diagram below;

Uses of the fractions from fractional distillation of petroleum

i. ***Natural gas***; −*e. g propane and butane* are used as fuels for cooking and lighting.
ii. ***Petrol*** is used as fuel for vehicles and other moving machines.
iii. ***Paraffin*** (***kerosene***) is used as a fuel and for lighting.
iv. ***Diesel*** is used as a fuel in diesel engines.
v. ***Lubricating oil*** is used for lubrication in moving machine parts.
vi. ***Bitumen and wax*** is used to make Vaseline, grease, candles, road and run way surfaces.

Fractional distillation of crude oil is an important method in oil refineries.

a. State the principle that fractional distillation uses in the refineries.
b. The table below shows the products from typical fractional distillation of crude oil.

Name of fraction	***Boiling point range***
Natural gas	*Below* 40℃
Petrol (*gasoline*)	40℃ − 175℃
Kerosene	175℃ − 275℃
Diesel	275℃ − 375℃

Bitumen	*Above* 425°C

State which one of the fractions is commonly used;

(i) To make protective coatings on the roads

- ✓ **Bitumen.**

(ii) As a solvent for paints

- ✓ **Kerosene.**

c. Explain why people prefer to use gas cookers instead of paraffin stoves.

- ✓ **Natural gas used in gas cookers burns completely with a non luminous flame which does not form soot.**
- ✓ **The non luminous flame from gas cookers is very hot compared to that of paraffin stoves which is luminous.**

d. Paraffin wax is used in the manufacturing of candles

(i) Name the products of the complete combustion of paraffin wax.

- ✓ Water and carbon dioxide.

(ii) How do you test for any of the products for complete combustion of paraffin wax?

- ✓ By adding anhydrous copper(II) sulphate to water, it turns from white to blue.
- ✓ By bubbling carbon dioxide gas into calcium hydroxide solution, a white precipitate is formed.

(a) (i) State the components of crude oil

(ii) Briefly describe how the components are separated

(b) Crude oil is used as a raw material to make polymers as shown below

$Crude\ oil \longrightarrow Fractions \longrightarrow Monomers \longrightarrow Polymers$

i. Name the process used to;

- Separate Crude oil into fractions.

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- Break down the fractions from crude oil into monomers of ethene and Propene.

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ii. Write the formula and structure of ethene.

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CRACKING OF CRUDE OIL

Define the term "cracking"

This is the breaking down of large complex hydrocarbons into smaller molecules of short carbon chains by use of heat or catalyst.

Or

Cracking is the heating of a less volatile high molecular mass alkane at high temperatures under high pressure in absence of air to yield low molecular mass alkanes and alkenes. E.g.

$C_{10}H_{22} \longrightarrow C_4H_{10} + 2C_3H_6$

Cracking is done industrially by passing the high molecular alkane through steam heated to 700-900℃, then followed by fractional distillation to separate the products.

Types of Cracking

There are basically two types of cracking; i.e.

- Thermal cracking (pyrolysis)
- Catalytic cracking

Thermal Cracking

This is the heating of hydrocarbons of long carbon chains to break them down into those of shorter chains at about 500℃ under pressure of about 200 atmospheres. E.g.

$C_{16}H_{34} \xrightarrow{500℃/200\ atm} C_8H_{18} + C_8H_{16}$

Thermal cracking can also be defined as the heating of large hydrocarbons at high pressure to break them into smaller molecules.

Catalytic cracking

This is the heating of long chain hydrocarbons in the presence of a catalyst especially aluminium oxide such that the hydrocarbons break into those of shorter chains.

N.B; *Catalytic cracking takes place at a relatively low temperature and pressure.*

Importances of cracking in petroleum industry

- Used for production of high grade petrol.
- Used in production of unsaturated hydrocarbons such as ethene and Propene.
- Used in production of alkanes.

Propene is made by 'cracking' the naphtha fraction of hydrocarbons in petroleum according to the following equation.

$$C_{10}H_{22} \longrightarrow 2C_3H_6 + hydrocarbon\ \boldsymbol{X}$$

a. Explain the term cracking.

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b. State and explain the two types of cracking.

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c. State the importances of cracking in the petroleum industry.

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d. Determine the molecular formula of the hydrocarbon **X**

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PREPARATION OF ALKANES

Alkanes can be prepared from unsaturated hydrocarbons as described below.

a. ***By addition of hydrogen to an alkene in the presence of a suitable catalyst***

This process is called catalytic hydrogenation of alkenes

The catalysts used in this process include;

- Platinum at room temperature
- Palladium at room temperature.
- Nickel catalyst at 150℃

$$\underset{Ethene}{C_2H_4} + H_2 \xrightarrow{Ni/150℃} \underset{Ethane}{C_2H_6}$$

b. ***By addition of hydrogen to an alkyne using a suitable catalyst***.

The catalysts mentioned above can also be used here. E.g.

$$\underset{Ethyne}{C_2H_2} + 2H_2 \xrightarrow{Ni/150℃} \underset{Ethane}{C_2H_6}$$

PROPERTIES OF ALKANES

Physical properties of Alkanes

- Straight chain alkanes with 1-4 carbon atoms i.e. the first four members are gases at room temperature. Those with 5-7 carbon atoms are liquids and the rest are waxy solids at room temperature.
- Alkanes are practically insoluble in water and less dense than water; however, they insoluble in organic solvents like trichloromethane, methylbenzene.
- Their boiling and melting points increase with increase in relative molecular mass; this is because as relative molecular mass increases, the magnitude of the Vander waal's forces of attraction also increases. More energy is required to overcome these forces of attraction for the alkanes to melt or boil.
- Alkanes have carbon-carbon single bonds hence they are saturated compounds.

Chemical properties of Alkanes.

Alkanes are generally inert (unreactive) to chemical reagents; this is because;

i. The carbon-carbon and carbon-hydrogen bonds are very strong and cannot break easily unless alkanes are heated to high temperatures or subjected to radiations of high energy.
ii. Carbon and hydrogen have almost the same electronegativity and so the bonds are not polarized, thus not easily attacked by reagents. i.e.
    The alkanes lack unshared electrons to be attacked by electrophiles.
    An electrophile is an electron seeking species (electron deficient species)

However, alkanes undergo the following few reactions under certain conditions;

1. ***Combustion***

Alkanes burn in plenty (excess) oxygen to form carbon dioxide and water vapour. This reaction is called **complete combustion** of alkanes. E.g.

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

$2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(g)$

Complete and balance the following equations;

i. $C_3H_8(g) + O_2(g) \longrightarrow$

ii. $C_4H_{10}(g) + O_2(g) \longrightarrow$

In limited supply of oxygen, alkanes burn forming carbon monoxide and water. This is called **incomplete combustion** of alkanes. E.g.

$2CH_4(g) + 3O_2(g) \longrightarrow 2CO(g) + 4H_2O(l)$

$2C_2H_6(g) + 5O_2(g) \longrightarrow 4CO(g) + 6H_2O(g)$

Complete and balance the following equations when the following alkanes undergo incomplete combustion;

i. $C_3H_8(g) + O_2(g) \longrightarrow$

ii. $C_4H_{10}(g) + O_2(g) \longrightarrow$

Note; –

i. Sometimes alkanes burn in limited supply of oxygen to produce carbon and water i.e.
   $CH_4(g) + O_2(g) \longrightarrow C(s) + 2H_2O(g) + Heat$
ii. The combustion of alkanes produces considerable amount of heat. This explains why alkanes are used as fuel for domestic and industrial uses.
iii. Incomplete combustion occurs in cylinders of petrol engines that results into release of poisonous carbon monoxide. It is therefore dangerous to run a car engine in a garage where there is no free air circulation.

Exercise.

The molecular formula of compound **M** is C_3H_8

(i) Write the structural formula of **M**.

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(ii) Name **M**.

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(iii) Name the group of organic compounds to which **M** belongs.

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(b) It is not wise to burn **M** in a living room with closed windows and doors. Give a reason.

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(c) Write the equation for complete combustion of **M**

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(d) State one use of **M**

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2. ***Sustitution reactions of Alkanes.***

A substitution reaction is a reaction in which an atom or group of atoms in a compound is/are replaced by other atom(s)

Alkanes undergo substitution reactions with halogens.

Reaction of Alkanes with chlorine (chlorination)

Alkanes react with chlorine in the presence of sun light or ultra violet light or at a temperature of 250-400°C i.e.

$CH_4(g) + Cl_2(g) \longrightarrow CH_3Cl(g) + HCl(g)$

$N.B$

- ✓ The above reaction occurs in the presence of sun light.
- ✓ The alkane must be in excess.
- ✓ If chlorine was in excess, then carbon tetra chloride (CCl_4) is the major product and hydrogen chloride is also produced.

Exercise

1. Methane can react with chlorine

   a) State the condition(s) for the reaction

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   ……………………………………………………………………………………

   b) Write the equation for the reaction that took place.

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c) Write the names of the products formed.

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d) State the type of reaction in (b) above.

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2. (a) A compound **Q**, vapour density=15 consists of 80.0% carbon, and the rest being hydrogen. ($C = 12;\ \ H = 1$)

(i) Calculate the empirical formula of **Q**.

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(ii) Determine the molecular formula of **Q**.

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(iii) Write the structural formula of **Q**.

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(b) The enthalpy of combustion of **Q** is 84.7$KJmol^{-1}$. Calculate the enthalpy change when 2.5g of **Q** is completely burnt in oxygen.

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BIO GAS

Bio gas is formed by anaerobic action of bacteria on cellulose and other organic matter.

Bio gas contains 75% methane and other gases which include carbon dioxide, ammonia and hydrogen sulphide.
The source of bio gas animal wastes and to some extent plant wastes.

Production of Bio gas.

A simple bio gas generator consists of a container in which animal wastes or plant wastes are mixed with a limited amount of water and then covered to exclude aerial oxidation.
At temperatures 25-30°C, anaerobic bacteria present decompose the wastes to form bio gas.

Uses of Bio gas

- ✓ Used for cooking and lighting purposes.

Gas **X** constitutes the greatest portion of bio gas

a. Identify **X.**

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b. Name the other gases present in bio gas in small quantities.

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c. Write the equation for the complete combustion of the gas **X** in air.

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Advantages of Bio gas production

- ✓ It is cheap to produce as the raw materials are readily available.
- ✓ The solid by-products can be used as fertilizers.

Dis advantages of Bio gas production

- ✓ Some of the gases in bio gas e.g. hydrogen sulphide are air pollutants.
- ✓ Hydrogen sulphide and ammonia in bio gas cause eye irritations.

ALKENES

These are unsaturated hydrocarbons with a carbon-carbon double bond and with a general molecular formula C_nH_{2n}.
Where $n \geq 2$
The carbon-carbon double bond is the functional group (most reactive part) of the alkene molecule.

Nomenclature of the Alkenes.

According to the IUPAC system, alkenes are named by dropping the ending "**ane**" from the names of the corresponding alkanes and replacing it with the suffix "ene".
The first four members of the alkene homologous series are;

Number of carbon atoms (n)	Molecular formula (C_nH_{2n})	Name	Structural formula

2	C_2H_4	Ethene	
3	C_3H_6	Propene	
4	C_4H_8	Butane	
5	C_5H_{10}	Pentene	

What is an alkene?
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……………………………………………………………………………………………………

Physical properties of Alkenes

- The melting and boiling points of alkenes increase with increase in relative molecular mass. This is because the magnitude of the vander waal's forces of attraction increases with increase in molecular mass.
- Alkenes are generally insoluble in water but soluble in non-polar solvents.

ETHENE

This is the first member of the alkene homologous series and its molecular formula is C_2H_4

Draw the structural formula of ethene.
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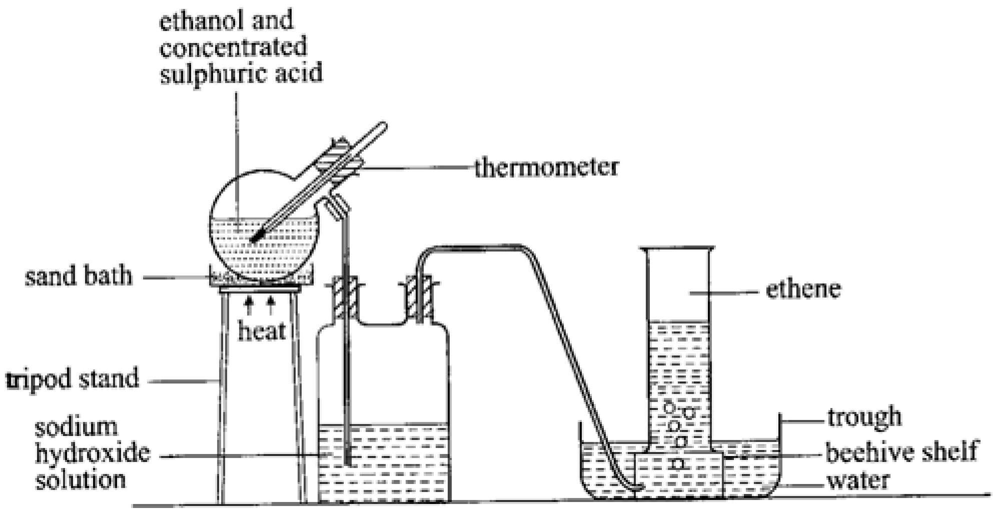
Laboratory preparation of Ethene

With the aid of a well labeled diagram, describe how ethene gas can be prepared in the laboratory.

Diagram



A mixture of ethanol and excess concentrated sulphuric acid in a round bottomed flask fitted with a thermometer is heated strongly to a temperature of about 180°C. concentrated sulphuric acid dehydrates the ethanol forming ethene gas. The gas is passed through concentrated sodium hydroxide solution to absorb sulphur dioxide produced in small amounts when ethanol slightly reduces the acid.

Ethene is then collected over water because it is slightly soluble in water.

Excess sulphuric acid is used to prevent formation of ether.

Write the equation for the reaction leading to the formation of ethene.

$C_2H_5OH(l) \xrightarrow{Conc.H_2SO_4/180°C} C_2H_4(g) + H_2O(l)$

Or

$C_2H_5OH(l) \xrightarrow{-H_2O} C_2H_4(g)$

Ethene can be prepared in the laboratory from ethanol and sulphuric acid.

a. State the conditions for the reaction. $(1\frac{1}{2} marks)$

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b. Write the equation for the reaction leading to the formation of ethene. $(1 mark)$

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Ethene can be prepared in the laboratory using the set of apparatus shown in figure 1

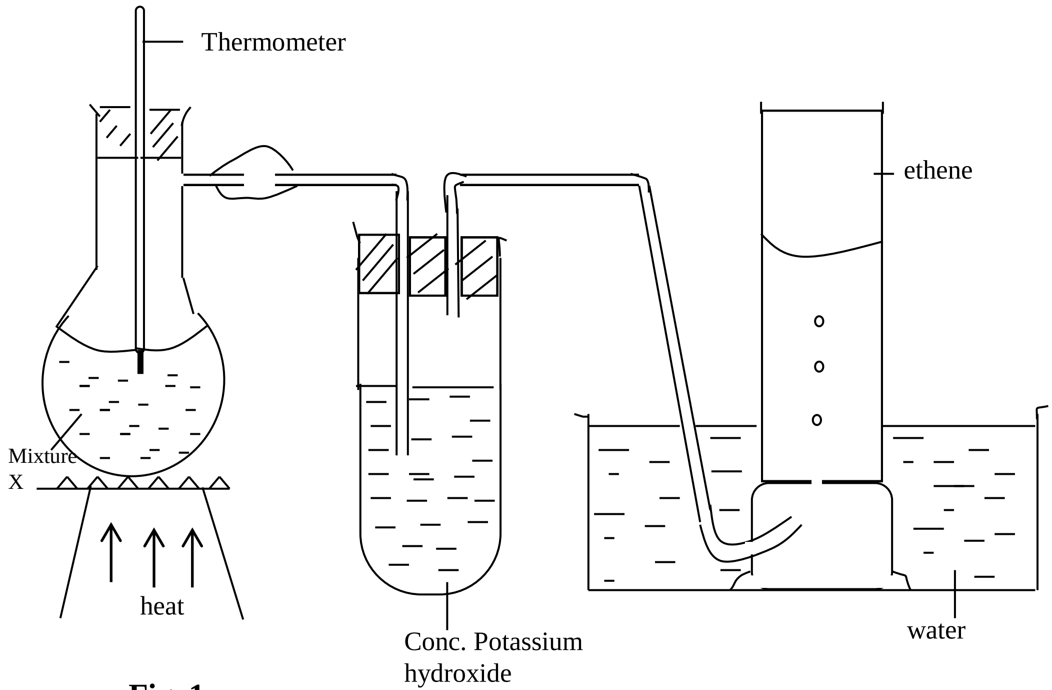

Fig. 1

(a) Name the mixture being heated (1 mark)

____

(b) Write the equation of reaction (1 mark)

____

(c) What is the function of the

(i) Concentrated Potassium hydroxide solution?

____(½ mark)

(ii) Thermometer

____(½ mark)

(d) Ethene was bubbled through a solution of acidified potassium permanganate

(i) State what is observed. (1 mark)

____

(ii) Name one other gas which shows similar behavior like ethane with potassium permanganate. (½ mark)

____

Properties of Ethene

Ethene as the first alkene may be used to indicate the physical and chemical properties .

Physical properties of Ethene.

- Ethene is a colourless gas.
- It is slightly less dense than air.
- It is slightly soluble in water.

- It is sweet smelling.
- It is a non-poisonous gas.

Chemical properties of Ethene.

1. ***Combustion.***

   Ethene burns in excess oxygen to form carbon dioxide and water.
   $C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l)$
   However, ethene burns in limited oxygen supply to form carbon monoxide and water.
   $C_2H_4(g) + 2O_2(g) \longrightarrow 2CO(g) + 2H_2O(l)$

2. ***Addition reactions of ethene.***

   Ethene and other unsaturated compounds undergo addition reactions.
   An addition reaction is a reaction in which an atom or group of atoms is/are added to an unsaturated compound to form a single product without loss of any simple molecule. Or
   An addition reaction is a reaction in which a molecule adds to an unsaturated compound by breaking the double bond or triple bond.
   Examples of Addition reactions of ethene include the following;

   a. ***Reaction of Ethene with bromine***

   When ethene is bubbled through bromine liquid, the red liquid turns to colourless.
   $C_2H_4(g) + Br_2(l) \longrightarrow C_2H_4Br_2(l)$
   Or
   $H_2C = CH_2(g) + Br_2(l) \longrightarrow BrCH_2CH_2Br(l)$
   The product formed in the above reaction is called $1,2-dibromoethane$

N.B. Addition of bromine across the double bond takes place readily in the presence of an organic solvent such as tetra chloromethane (CCl_4) or ether. The solvent dissolves the halogen (bromine) to form a solution such that when ethene is bubbled through the solution, the reaction takes place more efficiently.

   b. ***Reaction of Ethene with bromine water.***

   When ethene is bubbled through bromine water, the red brown (or reddish brown) solution turns colourless.
   $H_2C = CH_2(g) + Br_2(aq) \xrightarrow{H_2O} BrCH_2CH_2OH(aq)$
   The product formed in the above reaction is called $2-bromoethanol$

   c. ***Reaction of Ethene with Acidified potassium manganate(VII) solution.***

   When ethene gas is bubbled through acidified potassium manganate(VII) solution, the solution turns from purple to colourless.
   Equation:

N.B.
The reactions in (a), (b) and (c) test for unsaturation; i.e. can be used to distinguish between ethene and ethane or any alkene and alkane.

   d. ***Reaction of Ethene with hydrogen.***

When a mixture of hydrogen and ethene is passed over a finely divided Nickel catalyst which is heated to about 150℃, ethane if formed. This reaction is called catalytic hydrogenation of ethene.

$$C_2H_4(g) \ + \ H_2(g) \xrightarrow{Ni/150℃} C_2H_6(g)$$
$(Ethene)$ $(Ethane)$

Or

$$H_2C = CH_2(g) \ + \ H_2(g) \xrightarrow{Ni/150℃} CH_3CH_3(g)$$
$(Ethene)$ $(Ethane)$

e. ***Reaction of Ethene with Chlorine***

When chlorine gas is mixed with ethene and the mixture left in sunlight, the two combine forming a colourless oily liquid called 1,2-dichloroethane.

$$C_2H_4(g) \ + \ Cl_2(g) \ \longrightarrow \ C_2H_4Cl_2(l)$$

Or

$$H_2C = CH_2(g) \ + \ Cl_2(g) \ \longrightarrow ClCH_2CH_2Cl(l)$$

f. ***Reaction of Ethene with sulphuric acid***.

Ethene undergoes an addition reaction with fuming concentrated sulphuric acid to form an oily liquid called **Ethyl hydrogen sulphate.**

$$H_2C = CH_2(g) \ + \ H_2SO_4(l) \ \longrightarrow \ CH_3CH_2HSO_4(l)$$
$(Ethyl\ hydrogen\ sulphate)$

When the above oily liquid is boiled with water, ethanol is formed.

$$CH_3CH_2HSO_4(l) \ + \ H_2O(l) \xrightarrow{boil} CH_3CH_2OH(l) \ + \ H_2SO_4(l)$$

g. ***Polymerisation reaction of Ethene***.

Ethene under high pressure becomes a liquid, when this liquid is strongly heated to about 200℃ in presence of a little oxygen catalyst, a white waxy solid (Polyethene) is obtained.

$$nH_2C = CH_2 \ \longrightarrow \ \left[H_2C - CH_2\right]_n$$

h.

Uses of Ethene

- ✓ Used in the manufacture of ethanol.
- ✓ Used in ripening of fruits.
- ✓ Used in the manufacture of plastics (synthetic polymers like Polyethene)
- ✓ Also used in preparing other solvents.
- ✓ Used in synthesis of petrol.

Keep fit exercise

1. Ethanol can be converted to substances **P** and **Q** according to the reaction scheme shown below;

$$\underset{}{C_2H_5OH} \xrightarrow{Step\ I} \underset{\boldsymbol{P}}{C_2H_4} \xrightarrow{Step\ II} \underset{\boldsymbol{Q}}{C_2H_6}$$

a) Name substances **P** and **Q.**

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b) Write the structural formula of **P**.

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c) Name the reagent used in step I

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d) Write the equation for the complete combustion of **P** and **Q** in excess air;

(i) P

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(ii) Q

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2. The molecular mass of gas **X** is 28 and its simplest formula is CH_2. $(C = 12; H = 1)$

a) Determine the molecular formula of **X**

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b) Write;

(i) The structural formula of **X**.

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(ii) The equation for the reaction between **X** and bromine.

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c) (i) Name one other reagent that could be used to identify **X**.

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(ii) State what would be observed if the reagent you have named in (c) (i) was reacted with **X**.

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3. An alkene **Q** has molecular formula C_4H_8

a) (i) What is meant by an alkene?

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(ii) Write the structural formula of **Q**

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b) (i) Describe what would be observed if **Q** is passed through bromine.

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(ii) Write an equation to show the reaction that occur in (b) (i)

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(iii) Name the product formed in (b) (ii)

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4. (a) Biogas contains mainly methane.
Name two raw materials that can be used to produce biogas.

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(b) Write equations for;

(i) Complete combustion of methane.

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(ii) Incomplete combustion of methane.

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5. An Alkane **T** of formula mass 30 consists of 80% carbon.

a) Calculate the empirical formula of **T**

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b) Determine the molecular formula of **T**.

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c) Write the structural formula of **T**

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6. (a) Ethanol reacts with sulphuric acid to form gas **W** that turns reddish brown bromine water to colourless.

(i) Identify gas **W.**

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(ii) State the conditions for the reaction.

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(iii) Write the equation leading to the formation of the gas **W**

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(b) Write the equation for the reaction between the gas **W** and excess oxygen.

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7. Ethanol can be converted to ethene according to the following equation.

$C_2H_6O(l) \xrightarrow{-H_2O} C_2H_4(g)$

a) State the necessary conditions for the conversion of ethanol to ethene.

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b) Name one reagent that can be used to distinguish between ethene and sulphur dioxide. State what would be observed if the reagent you have named is separately treated with each gas.

Reagent

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Observation

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………………………………………………………………………………………
………………………………………………………………………………………

c) Write equation to illustrate your observation in (b) between ethene and the reagent you have named in (b)

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8. (a) Write;

(i) Structural formula of ethene.

……………………………………………………………………………………

……………………………………………………………………………………

(ii) The name of compound **R**, having a molecular formula of C_4H_{10}

……………………………………………………………………………………

(b) State what would be observed if bromine liquid was separately added to a sample of;

(i) Ethene.

……………………………………………………………………………………

……………………………………………………………………………………

(ii) Compound **R**

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(c) Briefly explain your observation in (b) above.

✓ Ethene is unsaturated while **R** is saturated.

9. (a) Ethene belongs to a class of hydrocarbons with a general formula C_nH_{2n}

(i) What is meant by the term hydrocarbon?

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(ii) Write the structural formula of a hydrocarbon with n=3 in the formula C_nH_{2n}

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(b) Ethene can be prepared from ethanol and sulphuric acid.

(i) Name the type of reaction for producing ethene from ethanol and sulphuric acid.

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(ii) Name three conditions for the reaction in (b)

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10. Ethene $H_2C = CH_2$ can be prepared from ethanol and it can form a polymer.

a) Write equation for the reaction to show how;

(i) Ethene can be produced from ethanol.

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(ii) Ethene can form a polymer.

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b) Ethene was bubbled through a solution of bromine in Tetra chloromethane. State what was observed and write the equation for the reaction that takes place.

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c) Give a reason why ethane cannot affect the reaction in (b) as ethene.

✓ Ethane is saturated unlike ethene which is unsaturated.

11. The general formulae of compounds **Q** and **R** are C_nH_{2n} and C_nH_{2n+2} respectively.

a) Write the molecular formula and the name of **Q** and **R** for $n = 2$

i. **Q**; Formula

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…………………………………………………………………………………………

Q; Name

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…………………………………………………………………………………………

ii. **R**; Formula

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…………………………………………………………………………………………

R; Name

…………………………………………………………………………………………
…………………………………………………………………………………………

b) State the structure difference between **Q** and **R**

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c) (i) Name a reagent which can be used to distinguish between **Q** and **R**.

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(ii) State what would be observed if the reagent you have named in (c) (i) was treated separately with **Q** and **R**

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(iii) Write equation for any reaction that would take place to illustrate your observation in (c)(ii)
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12. (a)Alkanes and alkenes are hydrocarbons.

i. Define the term hydrocarbon.
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ii. State the structural difference between alkanes and alkenes.
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(b) The boiling points of straight chain alkanes have 2 to 7 carbon atoms are shown in the table below.

Number of carbon atoms	2	3	5	6	7
Boiling points(°C)	-79	-42	37	69	98

i. Plot a graph of boiling point against number of carbon atoms.

ii. From the graph, determine the boiling point of the alkane with four carbon atoms.

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(c) (i) What is the shape of your graph.

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(ii) State the relationship between the boiling point of an alkane and the number of carbon atoms in the alkane.

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(d) (i) Name one reagent other than bromine that can be used to distinguish between ethane and ethene.

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(ii) State what would be observed if the reagent you have named in (d)(i) was separately treated with ethane and ethene.

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(e) Ethene burns in air according to the following equation;

$C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(g)\,; \Delta H = -1410kjmol^{-1}$

Calculate the amount of heat evolved when 12.5g of ethene is completely burnt.

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13. The molecular formulae of organic compounds J and M are C_3H_6 *and* C_3H_8 respectively.

a) Write the structural formula and name of J and M

Compound	***Structural formula***	***Name***
J		
M		

b) Name a reagent that can be used to distinguish between **J** and **M**

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c) State what would be observed if the reagent you have named in (b) was treated with;

i. **J**

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ii. **M**

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14. (a)A compound, **Y**, contains 52.17% carbon, 13.04% hydrogen and the rest being oxygen. The vapour density of **Y** is 23. Determine the;

i. Empirical formula of **Y**.

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ii. Molecular formula of **Y**.

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(b) When **Y** was heated with excess concentrated sulphuric acid, a colourless gas, **Z**, which turned bromine water colourless evolved. Identify.

i. **Y**

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ii. **Z**

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15. (a)The molecular formula of ethene is C_2H_4. Write the structural formula of ethene.

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(b) Bromine is one of the reagents that can be used to test for the presence of ethene.

i. State what would be observed if ethene is treated with bromine and write the equation for the reaction.

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ii. Name one other reagent that can be used to test for the presence of ethene.

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(c) Name one compound from which ethene can be prepared.

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16. (a)(i) State the conditions under which sulphuric acid reacts with ethanol to form ethene.

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(ii) Write the equation for the formation of ethene from ethanol and sulphuric acid.

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(iii) State the property of sulphuric acid shown in the reaction in (a) (ii)

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(b) Name one reagent, a part from bromine that can be used to distinguish between ethene and ethane; and in each case, state what would be observed if the reagent is separately treated with ethane and ethene.

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(c) A hydrocarbon, **T,** molecular mass 42, contains 85.7% carbon.

i. Calculate the empirical formula of **T**. ($C = 12; H = 1$)

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ii. Determine the molecular formula of **T**.

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iii. Write the structure of **T**.

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(d) **T** was reacted with bromine. State what was observed and write the equation for the reaction.

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17. A colourless gas **G** turned potassium manganate(VII) solution colourless.

a) Name two gases that are likely to be **G**.

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b) **G** also turned a solution of bromine in tetrachloromethane colourless, but did not have any effect on acidified potassium dichromate solution.

(i) Identify **G**.

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(ii) Write an equation to show the reaction between **G** and bromine in tetrachloromethane.

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c) **G** was burnt in air containing plentiful supply of oxygen. Write the equation for the reaction that took place.

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d) Name **two** substances that can react to produce **G**

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18. (a) Define the term hydrocarbon

- Is an organic compound that consists of carbon atom(s) and hydrogen atoms only.

(b) Hydrocarbon **R** consists of 85.7 % carbon composition by mass and has a vapour density of 28

i. Calculate the empirical formula of **R**

$$Percentage\ of\ hydrogen = 100 - 85.71$$
$$= 14.29\%$$

$Elements$	C	H
$\%\ Composition$	85.71	14.29
$Moles\ of\ atoms$	$\frac{85.71}{12} = 7.14$	$\frac{14.29}{1} = 14.29$
$Mole\ ratio$	$\frac{7.14}{7.14} = 1$	$\frac{14.29}{7.14} = 2$

$\therefore Empirical\ formula\ formula\ of\ \boldsymbol{R}\ is\ CH_2$

ii. Determine its molecular formula.

$$Relative\ molecular\ mass = 2 \times vapour\ density$$
$$= 2 \times 28$$
$$= 56$$
$$(CH_2)_n = 56$$

$[(12 \times 1) + (1 \times 2)]n = 56$
$14n = 56$
$n = 4$
$\therefore Molecular\ formula\ of\ \boldsymbol{R}\ is\ C_4H_8$

iii. Write three possible structural isomers of compound **R** and give their corresponding I.U.P.A.C names

- $CH_3CH_2CH = CH_2$ $But-1-ene.$
- $CH_3CH = CHCH_3$ $But-2-ene.$
- $CH_3CH(CH_3) = CH_2$ $2-Methylpropene.$

(c) (i) Name two reagents that can be used to identify the functional group in compound **R**

- Liquid bromine.
- Acidified potassium manganate(VII) solution.

(ii) State what would be observed if **R** is separately treated with the reagents stated in c (i) above.

- With liquid bromine; Red liquid turns colourless.
- With acidified potassium manganate(VII) solution; Purple solution turns colourless.

(d) (i) State the conditions under which **R** reacts with hydrogen gas

- Presence of nickel catalyst.
- Temperature of 150°C

(ii) Write the equation for the reaction that would take place if compound **R** reacts with hydrogen gas.

- $C_4H_8(g) + H_2(g) \xrightarrow{Ni/150^\circ C} C_4H_{10}(g)$

(iii) State the homologous series to which the product formed in d (ii) belongs.

- Alkanes.

(iv) State one other industrial application of the reaction that took place in d (ii).

- Hardening of vegetable oil to form margarine by hydrogenation.

19. (a) Ethene can be prepared in the laboratory by heating concentrated sulphuric acid with an alcohol.
    (i) Name the alcohol used.
    ……………………………………………………………………………………………
    (ii) Write the equation for the reaction leading to the formation of ethene.

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(b) Ethene is an unsaturated compound.

(i) What is meant by unsaturated compound?

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(ii) Name one reagent that can be used to test for unsaturation and state what is observed.

Reagent……………………………………………………………………………
Observation…………………………………………………………………………
……………………………………………………………………………………

(c) Under appropriate conditions, ethene molecules react to form compound, **Z** of formula $\left[CH_2 - CH_2 \right]_n$

(i) State one word which means formation of compound **Z**.

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(ii) State one use of **Z**

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(iii) State the effect of **Z** on the environment.

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$(JJEB\ paper$ 2 2019 $Qtn.$ 6)

20. An organic compound **G** of formula C_2H_6O when heated with concentrated sulphuric acid gave gas **H** of formula C_2H_4

(a) Name the classes of the compounds to which G and H belong;

(i) **G**……………………………………………………………………………

(ii) **H**……………………………………………………………………………

(b) Gas **H** was bubbled through liquid bromine in a test tube.

(i) State what was observed.

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(ii) Write the equation for the reaction that took place.

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(c) Compound C_2H_6O can be prepared from glucose $C_6H_{12}O_6$

(i) Name the process by which glucose is converted to compound C_2H_6O

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(ii) Write the equation for the reaction leading to the formation of C_2H_6O from glucose.

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$(Wakissha\ paper\ 2\ 2019\ Qtn. 10)$

21. An organic compound **Q** contains 52.2% carbon, 34.8% oxygen and the rest being hydrogen with molecular mass of 46. Calculate the molecular formula of **Q**.

(b) **Q** was heated with concentrated sulphuric acid to form a colourless gas W. identify the;

(i) Compound **Q**.

(ii) Gas **W**

(c) Write the structural formula of **W**.

(d) (i) Name one reagent can be used to identify the gas **W** in the laboratory

(ii) State what is observed when the reagent is used.

22. Glucose $C_6H_{12}O_6$ can be converted into ethanol by catalytic reaction caused by the enzyme produced by yeast.

(a) Name the;

(i) Reaction in which yeast converts glucose to ethanol.

(ii) Enzyme produced by yeast during the above reaction.

(iii) Write the equation for the reaction leading to the formation of ethanol by the process named in (a)(i) above.

(b) Ethanol can be converted to gas **X** by heating it with sulphuric acid. Name the;

(i) Gas **X**

(ii) Reaction leading to the formation of gas **X** from ethanol.

(iii) Write the equation for the reaction leading to the formation of **X** from ethanol.

(c) (i) Name one reagent that can be used to identify gas **X** apart from bromine water in the laboratory.

(ii) State what is observed when the reagent is used.

(iii) State other two conditions for the reaction when converting ethanol to gas **X**.

(d) State one difference between the following the following terms;

(i) Natural polymer and synthetic polymer.

(ii) Biodegradable polymers and non-biodegradable polymers.

(iii) Name two examples of non-degradable polymers.

(e) Natural rubber is soft but can be made hard by adding an element **T** and heated.

(i) Name the process above.

(ii) Name element **T**

23. (a)(i) Explain how ethene can be prepared starting from ethanol.

(No diagram is required)

(ii) Name a reagent that would be used to identify ethene and state what would be observed if ethene is treated with the reagent you have named.

(b) (i) Differentiate between the terms monomer and polymer

(ii) Write an equation for the polymerization of ethene; name the product and indicate which one of the substances is the monomer.

(c) (i)The polymer derived from ethene is a synthetic, a thermo-softening plastic and non-biodegradable. Explain.

(ii) State the disadvantage of the polymer of ethene which is the result of its non-biodegradable property.

$(Aceiteka\ 2019\ paper\ 2\ Qtn.13)$

ALKYNES

These are unsaturated hydrocarbons containing a carbon-carbon triple bond as their functional group. They have a general molecular formula C_nH_{2n-2} where $n \geq 2$

They functional group of alkynes is the carbon-carbon triple bond $(-C \equiv C -)$.

Nomenclature of Alkynes.

The alkynes are named by dropping the ending "ane" of the corresponding alkane and replacing it with the suffix "yne"

The table below shows the first four members of the alkyne homologous series;

Number of carbon atoms (n)	Molecular formula (C_nH_{2n-2})	Name	Structural formula
2	C_2H_2	Ethyne	
3	C_3H_4	Propyne	
4	C_4H_6	Butyne	
5	C_5H_8	Pentyne	

ETHYNE(Acetylene)

Ethyne is the first member in the alkyne homologous series and may indicate some of the physical properties and chemical properties of alkynes.

Physical properties of Ethyne.

- Ethyne is a colourless, odourless and sweet smelling gas.
- It is slightly soluble in water.

Chemical properties of Ethyne.

1. ***Combustion.***

Ethyne burns in excess oxygen forming carbon dioxide and water. The reaction is exothermic.

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l)$

However, in limited supply of oxygen ethyne burns to form carbon monoxide and water.

Write the equation for incomplete combustion of ethyne.

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2. ***Addition reactions.***

The triple bond in ethyne contributes a lot to its chemical properties. Ethyne undergoes addition reactions with the substances that alkenes react with except that ethyne reacts more slowly than alkenes. For example, it takes ethyne some time to turn bromine liquid from red to colourless unlike ethene that almost does it instantly.

(i) ***Reaction of ethyne with bromine.***

When ethyne is bubbled through bromine liquid, the red liquid turns colourless. The triple bond is first converted to a double bond, then into a single bond.

$HC \equiv CH + Br_2 \longrightarrow Br - CH = CHBr$

$(1,2 - dibromoethene)$

$Br - CH = CHBr + Br_2 \longrightarrow Br_2CHCHBr_2$

$(1,1,2,2 - tetrabromoethane)$

(ii) ***Reaction of ethyne with hydrogen.***

A mixture of ethyne and hydrogen when passed over a finely divided Nickel catalyst heated at about 150°C produces ethene. However, further hydrogenation can occur and the final product is ethane.

$HC \equiv CH + H_2 \xrightarrow{Ni/150℃} H_2C = CH_2$

$H_2C = CH_2 + H_2 \xrightarrow{Ni/150℃} CH_3CH_3$

Uses of Ethyne

- ✓ Used in the manufacture of polyvinyl chloride plastic which has a wide variety of uses.
- ✓ Used in oxyacetylene flame, used in welding and metal cutting.

POLYMERISATION

This is the repeatitive combination of small molecules to form a large molecule with a high molecular mass.
Or
This is the combination of many molecules of the same or different compounds with relatively low molecular masses to form one complex molecule with very high molecular mass.

Define the following terms;

i. Polymer

   This is a complex molecule with high molecular mass formed by combination of many molecules of relatively low molecular masses.
   Or
   A polymer is a compound formed by repeatitive combination of smaller molecular units called monomers.

ii. Monomers

   These are relatively low molecular mass molecules from which a polymer is built/formed.
   Or
   Monomers are simple molecules which combine to form a polymer.

Types of polymerisation.

Chemically, there are fundamentally two types of polymerization i.e.

(i) Addition polymerization.
(ii) Condensation polymerization.

Addition polymerisation

This is a type of polymerization in which simple identical unsaturated molecules repeatedly combine to form a single complex molecule without loss of any simple molecules.
Or
This is the combination of many small unsaturated molecules to form a large molecule without any other product.
This type of polymerization reduces the degree of unsaturation in a compound.
The condition for this type of polymerization is that the monomers should be unsaturated.
In this type of polymerization, the polymer possesses the same empirical formula as the monomer. E.g. in the formation of Polyethene

$nH_2C = CH_2 \longrightarrow \lbrace H_2C - CH_2 \rbrace_n$

Ethene *polyethene*

Condensation polymerisation.

This is a type of polymerisation whereby low molecular mass compounds of different kinds containing two or more functional groups repeatedly combine to form a large complex molecule with loss of small molecules such as water ammonia and hydrogen chloride.
Or

This is the combination of two types of bifunctional groups monomers to form a large molecule with elimination of small molecules.
In this type of polymerisation, the empirical formula of the momoners is not the same as that for the polymer.
The condition for this type of polymerisation is that each monomer should have atleast two function groups. E.g. formation of starch from glucose; formation of nylon 6,6 from Hexane-1,6-diamine and Hexane-1,6-dioic acid.

TYPES OF POLYMERS.

Polymers can broadly be divided into two types namely;

(i) Natural polymers.
(ii) Artificial (synthetic) polmers.

Natural polymers

These are polymers that are found existing naturally.
Or
Natural polymers are polymers that exist in nature.
The tabble below shows some natural polymers, their monomer, type of polymerisation and the uses of the polymer.

Polymer	*Monomer*	Type of polymerisation	*Uses of the polymer.*
Proteins	Amino acids	Condensation	✓ Used to repair worn out tissues. ✓ Helps in body building.
Starch	Glucose	Condensation	✓ Source of energy to the body.
Silk	Amino acids	Condensation	
Cellulose	Glucose	Condensation	✓ Used in cell walls.
Natural rubber	Isoprene (2-methylbuta-1,3-diene)	Addition	✓ Used in making car tyres ✓ Used in making gum boots ✓ Used in making shoe soles. Etc
Glycogen	Glucose	Condensation	
Lipids (fats and oils)	Fatty acids and glycerol	Condensation	✓ Source of energy to the body.

Other examples of natural polymers include;

- ✓ Sisal.
- ✓ Cotton

- ✓ Banana fibre.
- ✓ Wool.

Name ;

(i) Two natural polymers that are formed by condensation polymerisation.

- ✓ Starch.
- ✓ Proteins.

(ii) The monomer(s) of the polymers above.

- ✓ For starch; the monomer is glucose.
- ✓ For proteins; the monomers are aminoacids.

Artificial (***Synthetic polyers***)

These are polymers that are man made.

The table below shows some synthetic polymers, their monomers, type of polymerisation and the uses of the polymer.

Polymer	*Monomer(s)*	Type of polymerisation.	*Uses of the polymer*
Polyethene	Ethene	Addition	✓ Used for making squeeze bottle. ✓ Making packaging materials for food and clothes. ✓ Making refrigerator ice trays. ✓ Making funnels and bottle crates. ✓ Used in making dust bins. ✓ Used in making plastic bowls.
Polyvinyl chloride (P.V.C) or polychloroethene	Chloroethene	Addition	✓ Used to make rain coats. ✓ Used to making floor coverings. ✓ Used to make curtains. ✓ Used to make table mats. ✓ Used to make water pipes. ✓ Used to make water tanks. ✓ Used to make beer and soda crates. ✓ Used in electrical insulation ✓ Used to make films.
Polyphenylethene	Phenylethene (styrene)	Addition	✓ Used in making packaging

(polystyrene)			materials. ✓ Used to make thermal and electrical insulators. ✓ Used to make house hold items like combs, plastic cups and a common lining in refrigerators. ✓ Making foam mattresses. ✓ Making table ware containers.
Polypropene	Propene	Addition	✓ Making water pipes ✓ Making ropes ✓ Making valves. ✓ Making wrapping films. ✓ Making sacks. ✓ Used to make buckets and food containers.
Polymethyl-2-methyl propenoate (Perspex)	Methyl-2-methylpropenoate.	Addition	✓ Used to make transparent windows of cars and aircrafts. ✓ Used to make lenses. ✓ Used to make TV guard screens.
Polypropenonitrile	Propenonitrile	Addition	✓ Used to make wollen garments.
Synthetic rubber	2-chlorobuta-1,3-diene	Addition	✓ Used to make shoes ✓ Used to make car tyres ✓ Used to make gloves ✓ Used to make condoms.

Other examples of sythetic polmers include;

- ✓ Nylon which is used to make fabrics (nylon clothes) and fishing nets. It is also used to make ropes, carpets, curtains, parachutes.
- ✓ Terylene (polyester) which is used to manufacture items of clothes. It is also used to make conveyor belts, suits, curtains, fishing linings, sails etc.
- ✓ Melamine which is used to make plates and cups.
- ✓ Bakelite which is used to make electric sockets, switches and plugs.

ADDITION POLYMERS

Classes of Addition polymers

There are two main classes of addition polymers and these include;

(i) Plastics.

(ii) Rubber.

PLASTICS

A plastic is a solid material capable of being remoulded.

Or

A plastic is a substance which when soft can be made into different shapes.

Types of plastics.

There are two types of plastics and these include;

- ❖ Thermo softening plastics (Thermoplastics)
- ❖ Thermo setting plastics (Thermo sets)

Thermo softening plastics (Thermo plastics)

Define the term thermo softening plastics

These are plastics which become soft when heated and can be moulded into required shapes.

These plastics only harden when they cool.

Thermo plastics contain no linkages between individual chains and therefore on heating, the distance between each chain increases causing the polymer to soften and become more flexible.

Since the only binding forces between polymeric chains are weak intermolecular attractions, it requires only small change in temperature to over come them and bring about softening. On cooling, the process is reversed.

Examples of thermo plastics include;

- ✓ Polyethene.
- ✓ Polychloroethene.
- ✓ Polypropene.

Polyethene

Polyethene is a polymer of ethene. i.e. The combining monomers to form polyethene are ethene molecules.

State the conductions for thr production of polyethene from ethene molecules.

- o Presence of oxygen as a catalyst.
- o High pressure (about 150atmospheres)
- o High temperature (about 200°C)

Write the equation for the reaction leading to the formation of polyethene

$nH_2C = CH_2 \longrightarrow \left(H_2C - CH_2\right)_n$

$Ethene$ $\qquad\qquad$ $polyethene$

There are two types of polyethene i.e.

- Low density polythene.
- High density polythene.

Low density polyethene

This is made by polymerising ethene at high pressure of 1000-2000 atmospheres and a temperature of 200°C . oxygen is used as a catalyst. It has a lower softening temperature of $105°C - 120°C$. The low density polyethene is due to poor packing of branced polymer chains.

The low density polyethene is soft, light and fkexible.

Uses of low density polethene

- ✓ Used for making polythene bags.
- ✓ Used for insulation of electric cables because they withstand bad weather conditions.
- ✓ Used to make squeeze bottles such as wash bottles.
- ✓ Used to make plastic bags.

Disadvantages of low density polyethene

- ✓ At boiling water temperature, they become soft so much and they become flappy and lose shape.

High density polyethene.

This is made by polymerising ethene at low pressure (5-25atmospheres) and low temperature $(20°C - 50°C)$ in presence of Zeigler catalyst. This process by which high density polyethene is prepared is called the Zeigler process. Ethene is paased through an inert aromatic hydrocarbon solvent containing a suspension of titanium(IV) chloride and triethyl aluminium as a catalyst (Zeigler catalyst). The catalyst is later decomposed by a dilute acid and the polymer is separated by filtration.

High density polyethene has a high softening temperature of about 140°C. The high density is due to the close packing of the unbranched polymer chains. Very few of these polymers may be branched.

High density polyethene is much harder and stiff and donot lose shape at boiling water temperature.

Uses of High density polyethene.

- ✓ Used for making beer and soda crates.
- ✓ Used to make bowls.
- ✓ Used to make buckets.
- ✓ Used to make food boxes.

Polychloroethene/polyvinylchloride(P.V.C).

Polyvinyl chloride is made by polymerising vinyl chloride (chloroethene).

State the condition for the reaction leading to the formation of polychloroethene

- Heat.
- Presence of hydrogen peroxide.
- High pressure.

Write the equation leading to the formation of polychloroethene.

$nH_2C = CHCl \longrightarrow -\!\!\!(H_2C - CHCl)_n\!\!\!-$

chloroethene *polychloroethene*

Polyvinyl chlorides are more rigid, tough than polyethene.

Polyvinyl chlorides can be softened by addition of plasticine.

Uses of polyvinyl chloride

- ✓ Used to make rain coats.
- ✓ Used to make water pipes.
- ✓ Used to make light switches and sockets.
- ✓ Used to make floor coverings like carpets.
- ✓ Used to make table mats.
- ✓ Used to make insulators for electric cables.

Polypropene

This is also known as polypropylene. It is made by polymerising propene.

State the conditions for the reaction leading to the formation of polypropene.

- Presence of phosphoric(V) acid.
- High temperature.
- Moderate pressure.

Write the equation for the reaction leading to the formation of polypropene.

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Uses of polypropene

- ✓ Used to make pipes.
- ✓ Used to make ropes.
- ✓ Used to make wrapping films.
- ✓ Used to make valves.
- ✓ Used to make packaging materials.

Thermo setting plastics (thermo sets)

Define the term thermo setting plastics.

These are plastics which do not soften or melt on heating and therefore can not be remoulded into different shapes once they are set.

Or

These are plastics that become hard on heating and can not be moulded into new shapes..

Thermosetting plastics are cross linked hence individual chains are bonded to each other. They set hard on heating and can not be re melted.
Examples of thermo sets include;

- Bakelite.
- Melamine.

Uses of Bakelite

- ✓ Used for making electric plugs.
- ✓ Used to make sauce pan handler.
- ✓ Used to make switches and electric sockets.

Uses of Melamine

- ✓ Used for making cups and children dishes.
- ✓ Used for making plates.

NOTE
Properties of plastics can be modified by addition of compounds called **plasticisers**.
The following are some compounds that can be added to plastics in order to improve/modify their properties.

- ➢ Dyes and pigments are added to give the desirable colour.
- ➢ A cheap material called a filler can also be added to increase the bulk of the plastics.

***All synthetic polymers are plastics in nature*.**

Advantages of plastics

- ✓ They are good thermal and electrical insulators.
- ✓ They can easily be shaped and moulded (they are ductile)
- ✓ They are resistant to acids and alkalis and they do not rust.
- ✓ Plastics can be coloured when they being manufactured and they do not need repainting.
- ✓ They are light and therefore portable.
- ✓ They are cheap.

Disadvantages of plastics

- ✓ Produce poisonous fumes when they are burnt.
- ✓ They non biodegradable i.e. they do no decay naturally.
- ✓ Where serious fire hazards occur, molten plastics can inflict very severe burn.
- ✓ They block water pipes.
- ✓ They kill animals when swallowed.

RUBBER

Natural rubber

This is obtained from the bark of a rubber tree as a milky liquid called latex or sap.
Latex can be coagulated by addition of a little ethanoic acid to a solid of high molecular weight.
Natural rubber is a hydrocarbon polymer whose monomer is 2-methylbuta-1,3-diene (isoprene).
In its crude form, natural rubber is soft and sticky, and quite unsuitable for most of its purposes. The properties of rubber are improved by **vulcanisation**.

Vulcanisation of Rubber

In this process, rubber is heated with sulphur at 140°C. Sulphur atoms form cross linkages between the polymeric chains of natural rubber making it stronger and more elastic.

***Uses of vulcanised Rubber*.**

- ✓ Making tyres.
- ✓ Making tubes.
- ✓ Making soles of shoes.
- ✓ Making gum boots.
- ✓ Making belts.
- ✓ Making toys
- ✓ Making erasers.
- ✓ Making gloves.
- ✓ Making condoms.
- ✓ Making balloons.
- ✓ Making rubber bungs.
- ✓ Making bangles.
- ✓ Making bracelets.
- ✓ Making rubber for rubbing pencil work

***Synthetic rubber*.**

This is also called Neoprene. It is made by polymerising 2-chlorobuta-1,3-diene.

$(CH_2 = CHClCH = CH_2)$

CONDENSATION POLYMERS

FIBRES

These are polymers which can be drawn into threads. This is because the forces of attraction between the linear molecules are weak but those between individual atoms are strong.

Classification of fibres

There are basically two classes of fibres i.e

- ❖ Natural fibres
- ❖ Artificial (synthetic) fibres.

Natural fibres

These are sub divided into two;

- Animal fibres.
- Plant fibres

Examples of animal fibres are;
- ✓ Silk.
- ✓ Wool.

Examples of plant fibres are;
- ✓ Cotton.
- ✓ Sisal.

Examples of artificial (synthetic) fibres are;
- ✓ Polyester.
- ✓ Nylon.
- ✓ Terylene.

Advantages of Artificial(synthetic) polymers over natural polymers.
- ✓ Relatively low production cost compared to the cost of extracting natural polymers.
- ✓ They are usually stronger and more resistant to corrosive substances like acids compared to natural polymers.
- ✓ They can easily be modified depending on the purpose for which the polymer is required unlike natural polymers which are hard to modify.
- ✓ Their quality can easily be improved in terms of apperance, strength e.t.c.

Disadvantages of synthetic polymers.
- ✓ Many are non biodegradable causing pollution to the environment.
- ✓ When burnt, they produce toxic gases like thus endangering lives of people working in the factories.

Advantages of Natural polymers over synthetic polymers.
- ✓ Natural polymers are biodegradable thus their accumulation can not damage the soil compared to synthetic polymers.
- ✓ Natural polymers do not cause any health hazard during their manufacture as they exist naturally.

Keep fit exercise.

1. (a) (i)What is a polymer?

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(ii)Distinguish between a natural polmer and a synthetic polymer. In each case give **two** examples.

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(iii)Differentiate between thermosets and thermo plastics. In each case give **two** examples.

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2. (a) Natural rubber is soft and it is normally made hard before use.

(i) Name **one** process by which natural rubber is made hard.

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(ii) State how natural rubber is made hard by the process you have named in (a) (i)

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(b) State;

(i) **Five** reasons why naural rubber is made hard before use.

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(ii) **Five** uses of natural rubber.

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(c) Give any four differences between raw rubber and vulcanised rubber.

Raw rubber	***Vulcanised rubber***
✓ It is soft and sticky. ✓ It is soluble in organic solvents. ✓ Easily melts ✓ It is a thermo plastic	✓ It is hard and non sticky. ✓ Insoluble in organic solvents. ✓ Resistant to heat. ✓ It is a thermo setting plastic.

3. (a) Explain what is meant by the term polymerisation.

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(b) State and distinguish between the **two** types of polymerisation.

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(c) Name **three** examples of polymers formed by;

(i) Addition polymerisation.

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(ii) Condensation polymerisation.

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(d) Name **one** synthetic polymer formed by addition polymerisation and state **two** uses of the named polymer.

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(e) Name any **four** natural polymers.

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(f) State **two** advantages of natural polymers over synthetic polymers.

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4. (a) Define a "fibre".

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(b) State any **four** examples of natural fibre and any **two** examples of synthetic fibre.

(i) Natural fibre.

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…………………………………………………………………………………

(ii) Synthetic fibre.

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5. On polymerisation, ethene formed a compound **T**, molecular mass=16,660.

(i) Determine the number of moles of ethene molecules that combined to form **T**.
$(C = 12; H = 1)$ $\quad (\boldsymbol{Ans = 595\ molecules})$

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(ii) State the term which is used to describe a single unit of the ethene molecule in **T**.

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6. Ethene can undergo polymerisation.
   a) Name the product of polymerisation of ethene.

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   b) Write the equation for the reaction leading to the formation of the product that you have named in (a) above.

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   c) State **two** uses of the product you have named in (a) above.

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7. (a) Mention the monomers in the following polymers;
   (i) Polyethene.

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   (ii) Polypropene

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   (iii) Polyvinyl chloride

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   (b) Write the structural formulae of the monomers named in (a) above

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   (c) Write equation for the reaction leading to the formation of ;
   (i) Polypropene.

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(ii) Polyvinyl chloride.

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8. (a) What are plastics?

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(b) State and define the **two** types of plastics giving **two** examples in each case.

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(c) State the disadvantages of usin plastics.

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9. Under suitable conditions, ethene can be converted to a compound with general formula; $-\!\!\left(CH_2 - CH_2\right)\!\!_n$

a) What name is given to the process in which ethene is converted to $-\!\!\left(CH_2 - CH_2\right)\!\!_n$

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b) State the conditions for the reaction.

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c) What name is given to the compound $-\!\!\left(CH_2 - CH_2\right)\!\!_n$

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d) Write the equation for the reaction leading to the formation of the compound named in (c) above.

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10. Describe the process of vulcanisation of rubber.In you description include;

(i) The importance of vulcanisation in rubber industry.

(ii) Two useful items of vulcanised rubber.

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Check points

1. (a) Natural rubber is soft and it is normally made hard before use.
   i. Name one process by which natural rubber is made hard.
      - ✓ Vulcanization.
   ii. State how natural rubber is made hard by the process you have named in (a)(i)
      - ✓ Rubber is mixed with sulphur and heated.

   (b) State
   i. Two reasons why natural rubber is made hard before use.
      - ✓ Improves on temperature working range.
      - ✓ Makes rubber tougher.
      - ✓ Makes rubber stronger.
      - ✓ Makes rubber durable. (***Any two***)
      - ✓ Makes rubber resistant to wear and tear.
      - ✓ Makes rubber resistant to heat.
      - ✓ Improves on the tensile strength/ elasticity.
   ii. Two uses of rubber.
      - ✓ Making tyres.
      - ✓ Making tubes.
      - ✓ Making soles of shoes.
      - ✓ Making gum boots.
      - ✓ Making belts.
      - ✓ Making toys
      - ✓ Making bangles.
      - ✓ Making bracelets.
      - ✓ Making rubber for rubbing pencil work.
      - ✓ Making erasers.
      - ✓ Making gloves.
      - ✓ Making condoms.
      - ✓ Making balloons.
      - ✓ Making rubber bungs.

      (***Any two***)

2. (a) State the different between the following pairs of terms;

i. Synthetic polymer and natural polymer.

  - ✓ A synthetic polymer is manmade whereas a natural polymer is found existing naturally.

ii. Thermosetting polymer and thermo softening (or thermoplastics)

  - ✓ A thermosetting polymer does not easily soften (sets hard) on heating and on cooling it cannot be remoulded (or reshaped/remelted)
  - ✓ A thermo softening polymer on the other hand becomes soft and more flexible on heating and on cooling it hardens; it can therefore be remoulded (or reshaped/remelted).

or

Thermosetting polymer	***Thermossftening polymer***
✓ Does not easily soften on heating and cannot be remoulded.	✓ Soft and flexible and can be remoulded and harden on cooling.

(b) (i) State the conditions under which sulphuric acid can react with ethanol to produce ethene.

- ✓ Concentrated acid.
- ✓ Excess acid.
- ✓ Hot acid.

(ii) Write the equation leading to the formation of ethene.

- ✓ $C_2H_5OH(l) \xrightarrow{-H_2O} C_2H_4(g)$

(c) When reacted together, ethene molecules can form a polymer.

i. Name the polymer.

- ✓ Polyethene.

ii. Write the equation leading to the formation of the polymer.

- ✓ $n(H_2C = CH_2) \longrightarrow \left[H_2C - CH_2 \right]_n$

iii. State one use of the polymer.

- ✓ Used in making Polyethene bags.
- ✓ Making plastic chairs.
- ✓ Making water pipes. (***Any one***)
- ✓ Making shoes.
- ✓ Making basins.

(d) Name one;

i. Synthetic polymer other than the one named in (c)

  - ✓ Nylon.
  - ✓ Polystyrene

- ✓ Perspex.
- ✓ Polypropene.
- ✓ Synthetic rubber.
- ✓ Polyvinyl chloride.
- ✓ Terylene.
- ✓ Bakelite.
- ✓ Dacron.

(*Any one*)

ii. Natural polymer other than rubber.

- ✓ Silk.
- ✓ Cellulose.
- ✓ Sisal.
- ✓ Cotton.
- ✓ Wool.
- ✓ Proteins.
- ✓ Starch.
- ✓ Glycogen.
- ✓ Banana fibre.

(*Any one*)

(e) State one;

i. Use of each of the polymers you have named in (d)

- ✓ Nylon is used in fabrics.
- ✓ Perspex is used in making windows of air crafts.
- ✓ Polyvinyl chloride is used in making beer and soda crates, water pipes, water tanks
- ✓ Polypropene is used in making sacks, ropes (***Any one***)
- ✓ Synthetic rubber is used in making shoes, gloves, condoms

ii. Disadvantages of the polymer formed in (c)

- ✓ It pollutes the soil.
- ✓ It pollutes water.
- ✓ It burns to produce poisonous gases.
- ✓ Kills animals when swallowed.
- ✓ Blocks water pipes.

Note; ***non biodegradable not allowed for this particular case***

ALCOHOLS/ALKANOLS

What is an alcohol?

An alcohol is an organic compound that consists of hydroxyl group as the functional group.

Or

Is a saturated organic compound which contains the hydroxyl group as the functional group.

Alcohols have a general molecular formula, $C_nH_{2n+1}OH$ or $C_nH_{2n+2}O$

Where $n = 1,2,3 \dots \dots . e.t.c$

Alcohols containing only one hydroxyl group are called monohydric alcohols, those with two hydroxyl groups are called dihydric alcohols (Diols) and those with three hydroxyl groups are called trihydric alcohols (Triols)

Examples of monohydric alcohols

- ✓ Methanol
- ✓ Ethanol
- ✓ Propanol
- ✓ Butanol

e.t.c.

Examples of dihydric alcohols

- ✓ Ethane-1,2-diol ($HOCH_2CH_2OH$)

Examples of trihydric alcohols

- ✓ Propane-1,2,3-triol (glycerol)

Note: **At ordinary level, we only look at one class of alcohols that is monohydric alcohols.**

Nomenclature of alcohols

Alcohols are named by dropping last letter "e" of the alkane corresponding to the alcohol and replacing it by suffix "ol".

The table below shows the first four members of the alcohol homologous series;

Number of carbon atoms (n)	Molecular formula ($C_nH_{2n+1}OH$)	Name	Structural formula
1		Methanol	
2		Ethanol	
3		Propanol	
4		Butanol	

ETHANOL

Ethanol is the second member in the alkanol homologous series and may indicate some of the physical properties and chemical properties of alcohols.

Ethanol is the most important among alcohols and is often called an alcohol.

Physical properties of Ethanol

- ✓ It is a volatile liquid and boils at 78°C.
- ✓ It is a colourless liquid with a pleasant smell (a strong characteristic smell).
- ✓ It is miscible with water i.e. very soluble in water.
- ✓ It has a burning taste.
- ✓ It is neutral to litmus i.e. has no effect on litmus paper.

Chemical properties of Ethanol

1. ***Combustion***

Ethanol burns completely in excess air with a blue non luminous flame producing carbon dioxide and water.

$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$

2. ***Dehydration***

When a little concentrated sulphuric acid is added to ethanol, an oily liquid called ethyl hydrogen sulphate is produced and the reaction is exothermic.

$C_2H_5OH(l) + H_2SO_4(l) \longrightarrow C_2H_5HSO_4(l) + H_2O(l) + Heat$

When excess concentrated sulphuric acid is heated with ethanol, ethene is produced.

$C_2H_5OH(l) \xrightarrow{Conc.H_2SO_4/180°C} C_2H_4(g) + H_2O(l)$

Preparation of Ethanol.

Ethanol is manufactured/ prepared by the process of fermentation of carbohydrates such as starch and sugars.

Fermentation is a process in which carbohydrates like starch and sugars are converted to alcohols by enzymes.

Or

Fermentation is a process by which complex sugars and starch are broken down to form ethanol and carbon dioxide by the action of enzymes.

The enzymatic break down of glucose yields simple compounds like ethanol and carbon dioxide. Some heat is as well generated. Fermentation takes place in the absence of oxygen (anaerobic process).

Preparation of Ethanol from starch

Starch is heated with malt at a temperature of 60°C. Malt contains an enzyme diastase which hydrolyses starch to maltose.

$2C_6H_{10}O_5(aq) + H_2O(l) \longrightarrow C_{12}H_{22}O_{11}(aq)$

$(Starch)$ $(Maltose)$

Yeast is added at room temperature to the mixture and left to ferment for 2-3 days. Yeast contains two enzymes; maltase and zymase. Maltase catalyses the hydrolysis of maltose to glucose as below.

$C_{12}H_{22}O_{11}(aq) + H_2O(l) \longrightarrow 2C_6H_{12}O_6(aq)$

$(Maltose)$ $(Glucose)$

Zymase catalyses the breakdown of glucose into Ethanol, carbon dioxide, producing heat in the process.

$C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g) + Heat$

$(Glucose)$ $(Ethanol)$

The crude ethanol produced can be concentrated or purified by fractional distillation.

Preparation of Ethanol from millet.

Describe with the aid of equation(s), how crude ethanol, locally called "malwa" can be obtained from millet seeds.

- Millet seeds are ground to flour.

- The flour is mixed with correct amount of water to form paste.
- Millet paste is covered in a container or buried in the ground for four days to ferment.
- The fermented paste is removed and roasted to obtain malt. Then dried under sun light.
- Millet grains are soaked in water for five days to allow it germinate.
- The germinated millet seeds are dried then ground to form yeast.
- Yeast is added to malt in appropriate proportion and carefully determined amount of water is then added.
- Yeast contains two enzymes; maltase that catalyses the hydrolysis of maltose to glucose and zymase that catalyses the decomposition of glucose to ethanol and carbon dioxide.
- The mixture is covered and stored in warm place for three days so that alcoholic drink locally called "malwa" is formed.
  Equation leading to the formation of ethanol
- $C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Preparation of Ethanol from Ripe bananas.
Ripe bananas are squeezed to obtain the juice.
The juice is filtered to remove the solid particles.
The juice is mixed with roasted sorghum flour and the mixture allowed to ferment for 3 days in a warm place. A crude form of ethanol locally known as "Tonto" is obtained.
N.B
Beer is made by the fermentation of the starch in barley; wine by fermentation of sugars in grapes. Spirits are obtained by distillation of dilute solutions produced by fermentation and therefore have an increased alcoholic content.
Uses of ethanol.

- ✓ Used as a drink/ beverage e.g. beers, wines and spirits.
- ✓ Used as a medicine.
- ✓ Used as a disinfectant.
- ✓ Used as a preservative.
- ✓ Used as thermometric liquid in thermometers.
- ✓ Used as a solvent for paints, varnishes etc.
- ✓ Used in the manufacture of perfumes.
- ✓ Used in the manufacture of ethene.
- ✓ Used in anaesthia.
- ✓ Used for testing lipids or fats.

- ✓ Used in trapping birds.
- ✓ Used as a fuel.

State the uses of ethanol in the world of sick people

- Used as a solvent for the manufacture of some drugs.
- Used as thermometric liquid in clinical thermometers.
- Used as a disinfectant to sterilize surgical instruments.

Keep fit Exercise

1. Using a suitable yeast, glucose can be converted to ethanol and carbon dioxide according to the following.

$C_6H_{12}O_6 \xrightarrow{Yeast} 2CH_3CH_2OH + 2CO_2$

a) Name the;

i. Enzyme in yeast that converts glucose to ethanol.

....

ii. Process by which glucose is converted to ethanol in the presence of yeast.

....

b) Glucose also produces carbon dioxide when burnt in air. The reaction takes place according to the following equation.

$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(g)$

Calculate the mass of glucose that when burnt, would produce 1.2dm^3 of carbon dioxide at room temperature ($\boldsymbol{Ans = 1.5g}$)

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2. (a) (i)Describe the process of preparation of ethanol from starch. ($4\frac{1}{2}marks$)

- ✓ Starch is converted to maltose by diastase enzyme present in malt;
- ✓ Yeast is then added to the mixture at room temperature.
- ✓ Yeast contains two enzymes; maltase enzyme which converts maltose to glucose and zymase enzyme which converts the glucose to ethanol.

(ii)Write the equation for the process in (a) (i) above.

- ✓ $C_6H_{12}O_6(l) \xrightarrow{Zymase/30℃} 2C_2H_5OH(l) + 2CO_2(g)$

(b) Ethanol can be dehydrated using sulphuric acid to form compound **P**.

i. Name the class of organic compound to which **P** belongs.

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ii. Write the general formula of the class of the compound to which **P** belongs.

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(c) (i) Name the reagent that can be used to identify **P** in the laboratory.

- ✓ Bromine water, bromine, Acidified potassium manganate(VII) solution (***Any one***)

(ii) State what is observed when P is treated with the reagent named in (c) (i).

- ✓ Reddish brown bromine water turns to colourless.
- ✓ Bromine liquid turns from red to colourless.
- ✓ Acidified potassium manganate(VII) solution turns from purple to colourless.

(d) Polyethene is prepared by addition polymerization.

i. State what is meant by the term addition polymerization.

- ✓ This is a type of polymerization that involves the formation of a polymer (a large complex molecule) by joining two or more unsaturated monomers repeatedly with no loss of any small molecule like water.

ii. Name the monomer units in Polyethene.

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iii. Write the equation leading to the formation of Polyethene.

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(e) (i) Give one disadvantage of Polyethene.

- ✓ It is non-biodegradable.

(ii) Suggest one way of overcoming the disadvantage mentioned in (e) (i) above.

- ✓ By recycling.

3. (a)Maize grain contains a compound **Y,** which one can be converted to glucose, C_6H_6O. On fermentation glucose produces ethanol C_2H_6O.

(i) Name compound **Y** *(½ mark)*

- ✓ Starch.

(ii) Starting from maize grains, outline how a solution of ethanol is prepared in your locality (no diagram required). *(05 marks)*

- ✓ Maize grains are crushed into powder.

- ✓ The crushed/powdered maize(maize flour) is mixed with water and warmed with malt at about 60℃ for some time to allow starch to be converted into maltose by the enzyme diastase contained in malt.

$$2(C_6H_{10}O_5)_n(aq) + nH_2O(l) \quad \longrightarrow nC_{12}H_{22}O_{11}(aq)$$

- ✓ Yeast is then added to the maltose formed. The mixture is kept at room temperature for about 2-3 days. Maltase enzyme found in yeast catalyses the breakdown of maltose to glucose.

$C_{12}H_{22}O_{11}(aq) + H_2O(l) \quad \longrightarrow 2C_6H_{12}O_6(aq)$

- ✓ Another enzyme in yeast called zymase catalyses the conversion of glucose formed to ethanol and carbon dioxide. The mixture becomes hot/warm since the temperature rises to about 40℃.

$C_6H_{12}O_6(aq) \quad \longrightarrow 2C_2H_5OH(aq) \ + 2CO_2(g)$

- ✓ The crude ethanol formed is filtered to remove solid residues.
- ✓ The filtrate is fractionally distilled to obtain pure and concentrated ethanol. Distillation takes place at 78℃

(iii) Write equation for the fermentation of glucose. *(01 mark)*

$C_6H_{12}O_6(aq) \quad \longrightarrow 2C_2H_5OH(aq) \ + 2CO_2(g)$

(iv) Name the reaction by which ethene can be obtained from ethanol in the presence of sulphuric acid. *(½ mark)*

- ✓ Dehydration.

(b) Ethene can react to form a polymer. Write equation for the polymerization of the ethene. *(01 mark)*

(c) Ethene reacts to form polymer **E** with relative formula mass of 14,000. Determine the number of moles of ethene molecules that reacted to produce **E**, (H = 1, C = 12)

(d) (i) Other than the polymer of ethene, give one example each of a natural Polymer and a synthetic polymer. *(02 marks)*

(ii) Distinguish between the terms “thermosetting” plastic and “thermo softening” plastic; and give one example in each case. *(03 marks)*

SOAP AND DETERGENTS(Soapy and soapless detergents)

SOAP(Soapy detergent)

Soap is a soluble sodium or potassium salt of a long chain carboxylic acid.

The common chemical name of soap is sodium or potassium stearate.

Manufacture of soap

The basic raw materials for production of soap are vegetable oil/ animal fat and sodium hydroxide solution.

The process of making soap using an alkali and animal fat or vegetable oil is known as **Saponification**.

Briefly describe how soap can be prepared in the laboratory.
An animal fat or vegetable oil is mixed with excess concentrated sodium hydroxide solution.
The mixture is boiled with constant stirring for a long time until enough froth has formed.
A concentrated solution of sodium chloride is then added to the mixture to precipitate the soap.
The soap formed floats on the surface. The mixture is then left to cool and soap is skimmed off and purified.

(a) Mention the main sources of vegetable oil.

- ✓ Sim- sim.
- ✓ Sun flower.
- ✓ Ground nuts.
- ✓ Castor oil seeds.
- ✓ Soya bean.
- ✓ Cashew nut.
- ✓ Cotton seeds.
- ✓ Coconuts.
- ✓ Shea nuts.
- ✓ Palm oil seeds.

(b) **Describe briefly how vegetable oils can be obtained from the sources mentioned above**.

The seed or nut is cleaned and husks are removed.
The seed is roasted and then crushed to form a powder or paste.
The paste is mixed with a suitable organic solvent or boiled with water until the oil floats at the surface. The oil is then decanted off and purified.

(c) **Name the plant product that is locally available, which can be used as a starting material for the laboratory preparation of soap**.

- ✓ Sim sim oil.
- ✓ Cotton seed oil.
- ✓ Coconut oil.
- ✓ Palm oil.
- ✓ Ground nut oil.

(d) **Describe how soap solution can be prepared from the plant product you have named in (c) above**.

Sim -sim oil is mixed with concentrated sodium hydroxide solution.
The mixture is heated until it boils. It is further heated and allowed to boil for some time while stirring constantly until frothing stops.
The resultant solution is soap solution.

(e) Briefly describe how solid soap sample can be obtained from your soap solution in (d)

A saturated or concentrated solution of sodium chloride is added to the soap solution.
The mixture is heated gently and stirred for some time.
It is then cooled, the precipitate formed, which is solid soap is filtered off.

(f) State the main sources of animal fats.
- ✓ Pork.
- ✓ Mutton.
- ✓ Beef.

$N.B$

(i) Vegetable oils are esters formed from long chain carboxylic acids and propane-1,2,3-triol (glycerol); obtained from plants.

(ii) The general equation for the formation of soap is;

$$Fat\ or\ Oil + Alkali \longrightarrow Soap + glycerol$$
$$RCOOR' + NaOH \longrightarrow RCOONa + R'OH$$

(iii) Oils are unsaturated while fats are saturated. Therefore fats occur as solids at room temperature while oils are liquids at room temperature.

(iv) Potassium hydroxide can be used instead of sodium hydroxide during the manufacture of soap. Potassium soaps are normally milder and therefore used mainly as toilet soaps.

The cleansing action of soap

Soap has two active ends; the hydrocarbon chain which is hydrophobic and non polar, and the alkanoate end (COO^-) which hydrophilic and polar.
During washing, the hydrophilic part dissolves in water, while the hydrophobic part surrounds the greasy dirt particles. This process lowers the surface tension of water and the fabric (cloth) is wetted by water.
On agitation, the greasy dirt particles float free on the water surface.

$N.B$

(i) In hard water, soap forms insoluble salts known as scum. This because hard water contains dissolved calcium and magnesium salts. The ions of magnesium and calcium react with soap to form scum (calcium stearate or magnesium stearate)

$$2RCOO^-(aq) + Ca^{2+}(aq) \longrightarrow (RCOO)_2Ca(s)$$
$$2RCOO^-(aq) + Mg^{2+}(aq) \longrightarrow (RCOO)_2Mg(s)$$

Or

$$2NaSt(aq) + Ca^{2+}(aq) \longrightarrow CaSt_2(s) + 2Na^+(aq)$$
$$2NaSt(aq) + Mg^{2+}(aq) \longrightarrow MgSt_2(s) + 2Na^+(aq)$$

(ii) In a strongly acidic medium, the hydrogen ions react with the alkanoate ions to form a weak carboxylic acid.

$$RCOO^-(aq) + H^+(aq) \longrightarrow RCOOH(s)$$

Advantages of soap
- ✓ It is bio degradable and therefore cannot cause pollution.
- ✓ It is cheap in terms of production.

Disdvantages of soapy detergents(soap)

- It forms scum in hard water hence wastage of soap.
- It leaves dirty marks or stains on clothes.

DETERGENTS(Soapless detergents)

A detergent is a sodium or potassium salt of long chain sulphonate or sulphate.
The basic difference between soaps (soapy detergent) and soapless detergent is that soaps have the carboxylate group as the hydrophilic part while detergents have the sulphonate or sulphate group as the hydrophilic part; $R - SO_3^- Na^+ \quad or\ RO - SO_3^- Na^+$
Detergents function in the same way as soap only that detergents do not form scum in hard water.
The soapless detergents are manufactured from concentrated sulphuric acid and hydrocarbons obtained from petrol refining.
Describe the laboratory preparation of a soapless detergent from castor oil.

- Add 1cm^3 of castor oil into a test tube, then carefully add 2cm^3 of concentrated sulphuric acid while stirring with a glass rod.
- Gently warm the mixture and add about 10cm^3 of 4M sodium hydroxide solution and stir. The mixture gets hot, viscous and dark.
- Add 5cm^3 of distilled water and stir. Then decant to separate the liquid from the solids. The solid is the soapless detergent which is then washed with distilled water.

Common examples of detergents.

- Omo.
- Nomi.
- Jik
- Aerial.
- Toss.
- Magic.

During the industrial manufacture of detergents, the following substances may be added;

- Sodium triphosphate and a little sodium perborate are normally added to some laundry detergents.
- Sodium triphosphate forms a complex with calcium and magnesium ions and this prevents scum formation.
- Sodium perborate brightens the washing by acting as a bleaching agent.
- Sodium sulphate is usually added to the detergent during manufacture to increase the bulkiness of the detergent.

***Advantages of soapless detergents over soapy detergents*.**

- ✓ They are more soluble in water than soap and therefore clean more effectively.
- ✓ They do not form scum with hard water therefore can be used in both soft and hard water. Soap forms scum with hard water.
- ✓ Detergents are more economical than soap when used in laundry work.

Disdvantages of soapless detergents

- They are non-biodegradable i.e. are not broken down into harm less chemicals by microorganisms. Soapy detergents are biodegradable.
- Some detergents contain phosphates that promote growth of algae.
- Soap less detergents are more expensive than soap.

Keep fit Exercise

1. (a) State one word which means " formation of soap"

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   (b) During the manufacture of soap, sodium hydroxide was boiled with substance Q.

   (i) Identify substance Q.

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   (ii) Name a substance that can be used to precipitate soap from the solution of the reaction mixture.

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   (c) State what is observed if soap solution was reacted with aqueous magnesium hydrogen carbonate.

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   (d) Write the equation for the reaction that took place in (c) above.

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2. (a) State the difference between fats and oils.

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(b) Fats and oils can be used to make soap.

(i) Define the term soap.

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(ii) Briefly describe how soap can be prepared.

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(c) Explain briefly how sodium chloride solution precipitates soap from soap solution.

- Sodium chloride lowers the solubility of soap in soap solution (mixture) and causes the precipitation of soap which floats on the top of the liquid.

(d) Describe how soap removes the dirt from clothes.

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3. (a) Washing with soap in hard water is an inconvenience. Explain.

   (b) Some soapless detergents molecules cannot be broken down by bacteria. State the chemical nature of such molecules and give a reason why soapless detergents of such nature are disadvantageous.

4. (a) Soap can be prepared from fat or oil.

   (i) State one physical difference between fat and oil.

(ii) Write the chemical name of soap.

(b)During the laboratory preparation of soap, sun flower seed oil was mixed with reagent,**J**. The mixture was then heated and boiled for some time, followed by addition of substance **Y**.

(i) Identify **J**

(ii) Name **Y**

(iii) State the role of **Y**

5. Substance **Q** consists of two carbon atoms covalently bonded. Treatment of **Q** with an acid **R** at 180℃ yielded substance **T** and **Y**. **T** has a faint sweet smell and turns liquid bromine colourless forming substance **W**. **T** reacts with hydrogen at 150℃ in presence of nickel forming compound **G**. Many molecules of **T** combine under high pressure, an organic peroxide and suitable temperature forming substance **X**.
   (a) Name substance **Q**, **R**, **T**, **Y**, **W** and **X**
   (b) State the conditions under which **R** reacts with **Q**
   (c) Write equations for the reactions leading to the formation of ;
      (i) **T** and **Y**
      (ii) **W**
      (iii) **G**
      (iv) **X**
   (d) Give three reasons why substance **X** is considered a thermoplastic.
   (e) Explain why substance **X** is considered an environmental pollutant.
   (f) State one industrial use of substance **X**.
6. On complete combustion, 0.5g of an organic compound **M** consisting of carbon, hydrogen and oxygen only, 0.733g of carbon dioxide gas and 0.300g of water were produced.
   (a) Calculate the empirical formula of **M**.
   (b) Determine the molecular formula of **M**
   $(RMM\ of\ \boldsymbol{M} = 60, H = 1; C = 12; O = 16)$
   (c) Aqueous solution of **M** turns blue litmus paper red; state the chemical nature of **M.**
   (d) Solution of sodium hydrogen carbonate was added to aqueous solution of **M**, state what was observed.
   (e) Write the ionic equation for the reaction that occurred in (d)
   (f) State the homologous series to which compound **M** belongs and give a reason for your answer.

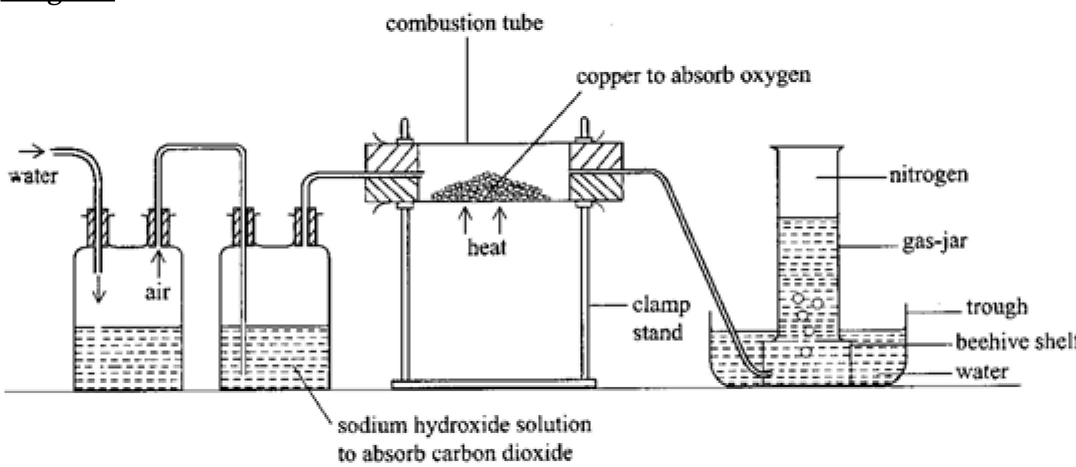
(g) **M** reacts with sodium metal. Write the ionic equation for the reaction that would occur.

NITROGEN AND ITS COMPOUNDS

Nitrogen has atomic number 7 and mass number 14
Its electronic configuration is 2:5
It therefore belongs to group (V) of the periodic table because it has five electrons in its outer most energy level.
It belongs to period 2 of the periodic table because it has 2 energy levels containing electrons.
It has a valency of 3.
It is a non metallic element.
The nitrogen molecule is diatomic;i.e.N_2

LABORATORY PREPARATION OF NITROGEN FROM AIR

Diagram



When water is run into the reservoir of air in the apparatus, air is pushed through the apparatus.
When air reaches the bottle containing sodium hydroxide solution or potassium hydroxide solution, carbon dioxide gas is absorbed from the air.
$2NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$
Oxygen is removed from air, when the air is passed over heated copper.
$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

Nitrogen can be prepared in the laboratory by passing air through solution A and over a heated metal Z

(a) Identify ;

(i) Solution A

- Sodium hydroxide solution or potassium hydroxide solution

(ii) **Metal Z**

- Copper

(b) State the role of;

(i) **Solution A**

- To absorb carbon dioxide.

(ii) **Metal Z**

- To absorb oxygen.

(c) Write the equations to support your answer in (b) (i) and (ii)

(i) $2NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$

(ii) $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

(a) State the approximate percentages by volume of oxygen and nitrogen in the atmosphere.

- 21% oxygen and 78% nitrogen OR
- 20% oxygen and 80% nitrogen

(b) Name the industrial process by which the nitrogen can be obtained free from oxygen.

- Fractional distillation.

(c) Briefly describe how the process you have above can be carried out in the industry.

Air is first compressed to about 200atmospheres pressure, cooled, and allowed to escape from a small jet. Successive expansions and compressions finally liquefy the air. Liquid air is evaporated to yield nitrogen first as distillate (bpt 77K) leaving a liquid very reach in oxygen (bpt 90K at 760mmHg)

UN REACTIVE (INERT) NATURE OF NITROGEN

The triple bond in between the nitrogen atoms in the nitrogen molecule is very strong. Therefore it requires a lot of heat energy in order to be broken before a chemical reaction is initiated.

N.B At high temperatures, nitrogen reacts with some burning metals e.g. magnesium and calcium forming corresponding nitrides which are white crystalline solids.

$3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$

$3Ca(s) + N_2(g) \rightarrow Ca_3N_2(s)$

The nitrides formed if dissolved in water gives off ammonia gas and corresponding hydroxides (alkaline solutions).

$Mg_3N_2(s) + 6H_2O(l) \rightarrow 3Mg(OH)_2(aq) + 2NH_3(g)$

$Ca_3N_2(s) + 6H_2O(l) \longrightarrow 3Ca(OH)_2(aq) + 2NH_3(g)$

Nitrogen is generally uncreative but it reacts with burning magnesium

(a) Why is nitrogen generally uncreative?

It's due to the strong triple bond between the nitrogen atoms in the nitrogen molecule which requires a lot of heat energy to broken.

(b) Give a reason why nitrogen reacts with burning magnesium.

Burning magnesium produces a lot of heat energy which is sufficient to break the triple bond which makes the nitrogen atoms reactive and hence making it possible for the reaction to occur.

(c) State what was observed.

Magnesium continued to burn with a bright white flame forming a white solid residue.

(d) Write the equation for the reaction that took place

$3Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$

(e) Water was added to the solid product of the reaction.

(i) State what was observed.

The white solid dissolved with effervescence of a colourless gas with an irritating, chockingsmell and a colourless solution formed.

(ii) Write the equation for the reaction in e(i)

$Mg_3N_2(s) + 6H_2O(l) \longrightarrow 3Mg(OH)_2(aq) + 2NH_3(g)$

(f) Name one other metal which reacts with nitrogen in similar like magnesium.

Calcium

USES OF NITROGEN

- Used in the manufacture of ammonia
- Used in manufacture of nitric acid
- Used in manufacture of fertilizers
- Used in food packaging
- Used as a refrigerant

(a) The atomic numbers of nitrogen and oxygen are 7 and 8 respectively

(i) **Write the electronic configurations and structural formulae of nitrogen and oxygen**

Nitrogen 2:5, $N \equiv N$

Oxygen 2:6, $O = O$

(ii) **Give a reason why oxygen reacts readily with calcium even at room temperature, whereas nitrogen reacts with the metal only when calcium is burnt in nitrogen**.

The energy required to break the oxygen - oxygen double bonds is much less than that required tobreak the nitrogen to nitrogen triple bonds.

(iii) **Write equations to show the reactions of calcium with oxygen and with nitrogen.**

$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$

$$3Ca(s) + N_2(g) \longrightarrow Ca_3N_2(s)$$

(b) Magnesium burns in air to form a white solid **X** which dissolves in water to form colourless gas **E** which turns wet red litmus paper blue. Identify ;

(i) **E**

……………………………………………………………………………….

(ii) **X**

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(c) Write the equation for the reaction which takes place when;

(i) Magnesium burns in air to form **X.**

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(ii) **X** dissolves in water to form colourless gas **E**.

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(d) An aqueous solution of **E** was added drop wise until in excess to an aqueous solution of aluminium sulphate.

(i) State what was observed.

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(ii) Write ionic equation for the reaction that took place.

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(a) State what would be produced if burning calcium was lowered into a gas jar containing ;

(i) **Nitrogen**

- ✓ Calcium nitride.

(ii) **Oxygen**

- ✓ Calcium oxide.

(b) **(i) Name one substance that can be used to distinguish between the reaction products that you have stated in (a)(i) and (a)(ii).**

- ✓ Water.

(ii). State what would be observed in each case if cold samples of the products that you have stated in (a)(i) and (a)(ii) were treated separately with the substance you have named in (b)(i).

- ✓ Calcium nitride would dissolve with effervescence of a colourless gas that would turn damp red litmus paper blue.
- ✓ Calcium oxide would dissolve quietly

(iii) Write equations for the reaction that would take place between the product you have stated in (a)(i) and the substance you have named in (b)(i).

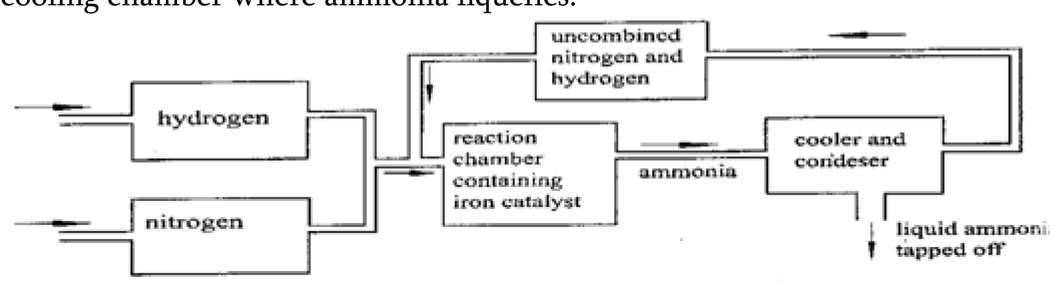
$$Ca_3N_2(s) + 6H_2O(l) \longrightarrow 3Ca(OH)_2(aq) + 2NH_3(g)$$

COMPOUNDS OF NITROGEN

1. **AMMONIA, NH_3**

(a) **Industrial manufacture of ammonia**

Ammonia is prepared industrially (on large scale) by the Haber process
The raw materials are nitrogen and hydrogen gas.
Ammonia is manufactured by heating a compressed mixture of nitrogen gas and hydrogen gas at low temperatures and under high pressure in the presence of finely divided iron catalyst.
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + Heat$
NB. The reaction is reversible so it's impossible to convert all the reactants to products.
To separate the ammonia formed from the mixture, the mixture is subjected to a cooling chamber where ammonia liquefies.



(a) Name the process by which ammonia is prepared on large scale.
- ✓ Haber process

(b) Name the raw materials used in the above reaction.
- ✓ Nitrogen gas.
- ✓ Hydrogen gas.

(c) State the two conditions for the maximum yield of ammonia gas.
- ✓ High pressure.
- ✓ Low temperature.

(d) Write the equation for the reaction that takes place above.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The catalyst used in the Haber process is.

A. Iron
B. Platinum.
C. Manganese(IV) oxide.
D. Vanadium(V) oxide.

Which of the following gases does not burn?

A. Hydrogen.
B. Methane.
C. Nitrogen.
D. Carbon dioxide.

(a) Iron can be used as an industrial catalyst.

(i) Give one other use of iron.

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(ii) Write an equation for the reaction in which iron is used as a catalyst.

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(iii) State two other conditions under which the product in reaction (a)(ii) is manufactured.

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(b) Describe briefly how the gas obtained in reaction (a)(ii) can be prepared in laboratory(diagram not required).

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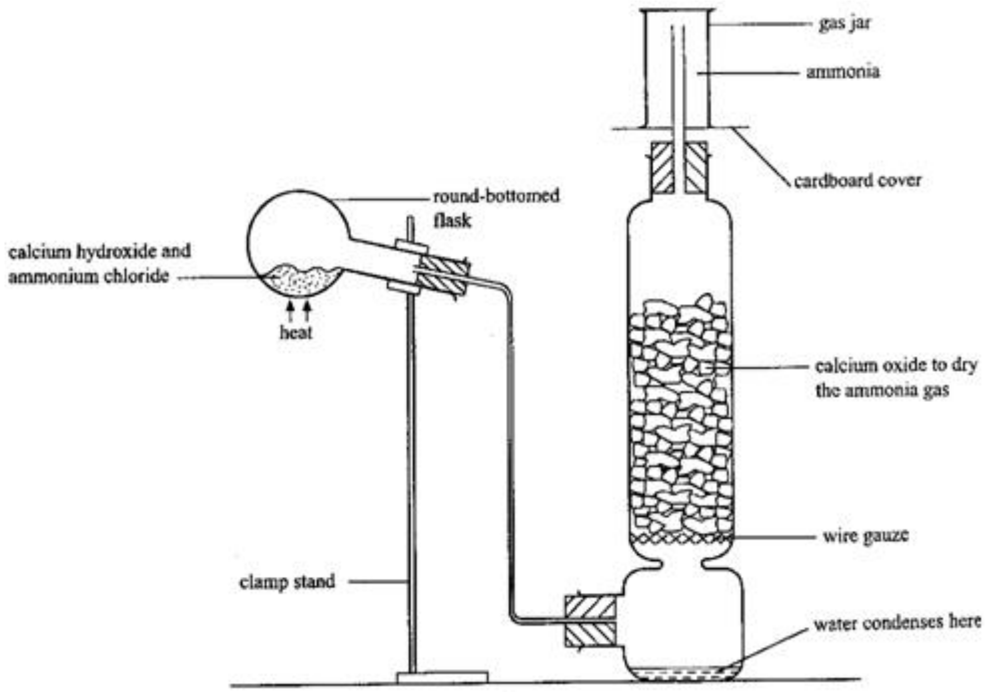
Laboratory preparation of ammonia gas

(a) With the aid of a well labeled diagram, describe how a dry sample of ammonia gas can be prepared in the laboratory.

Diagram



- ✓ A mixture of ammonium chloride and calcium hydroxide is placed in a boiling tube fitted with a delivery tube.
- ✓ The mixture is heated and ammonia gas is produced. The gas is passed through calcium oxide to dry it because the gas is alkaline.
- ✓ Ammonia gas is then collected by upward delivery because it is lighter than air.

(b) Write the equation for the reaction that took place.

$Ca(OH)_2(s) + 2NH_4Cl(s) \longrightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(l)$

(c) Explain why evolution of ammonia is possible as indicated by the reaction above.

- ✓ Calcium hydroxide is a stronger base than ammonia. It therefore readily displaces ammonia from its salt on heating; ammonia being highly volatile as well.

(d) State the condition(s) for the reaction above.

- ✓ Heating the reaction mixture.

(e) Name the drying agent for ammonia and explain why it is preferred to other commonly used drying agents.

- ✓ Calcium oxide is the drying agent for ammonia. It is a base just like ammonia is, it has no effect on ammonia.

- ✓ The other drying agents, which are commonly available, are anhydrous calcium chloride and concentrated sulphuric acid: both react with ammonia forming complex salts of calcium and ammonium sulphate respectively.

(a) Briefly explain why ammonia is not dried using;

(i) Concentrated sulphuric acid.

- ✓ Ammonia is alkaline and therefore reacts with concentrated sulphuric acid to form ammonium sulphate.

$2NH_3(g) + H_2SO_4(l) \longrightarrow (NH_4)_2SO_4(s)$

(ii) Anhydrous calcium chloride.

- ✓ Ammonia reacts with anhydrous calcium chloride to form a complex salt of calcium (tetra ammine calcium chloride)

$CaCl_2(s) + 4NH_3(g) \longrightarrow CaCl_2.4NH_3(s)$

(b) State a method for collecting ammonia gas and give a reason for your answer.

- ✓ Upward delivery because ammonia is lighter than air.

Test for ammonia gas

Name one reagent that can be used to test for ammonia gas in the laboratory and state the corresponding observation if ammonia is tested with the reagent.

Reagent: concentrated hydrochloric acid

Observation: dense white fumes forms.

N.B. Ammonia is alkaline; therefore it turns damp red litmus paper blue

CHEMICAL PROPERTIES OF AMMONIA GAS

1. **Reaction with water(solubility of ammonia)**

   Ammonia is the most soluble gas in water. Its solubility is demonstrated by the fountain experiment.

   It dissolves in water forming an alkaline solution i.e.

   $NH_3(g) + H_2O(l) \rightleftharpoons NH_4OH(aq)$

   This solution turns red litmus paper blue and litmus solution blue.

Which of the following gases is the most soluble gas in water?

A. Hydrogen chloride.

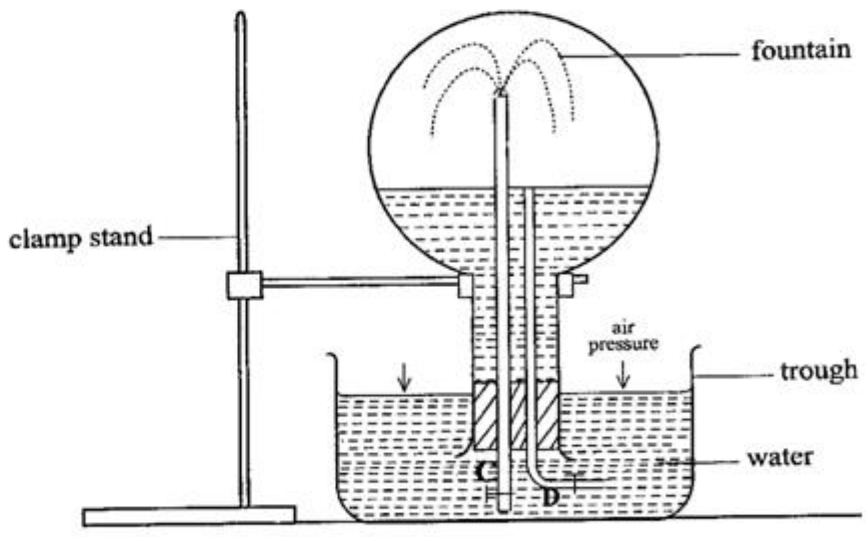
B. Oxygen.

C. Nitrogen.

D. Ammonia.

With the aid of a well labeled diagram, describe an experiment to show that ammonia is very soluble in water.

Diagram



A thick walled round bottomed flask fitted with delivery tubes containing clips C and D is carefully filled with ammonia gas.
Then the flask is clamped and inverted over water in the trough.
Clip D is then opened for a short time closed to allow few drops of water enter the flask.
On opening clip C, the atmospheric pressure forces the water to rise up rapidly and enters the flask to form a fountain.
N.B The resultant solution formed in the flask is aqueous ammonia which is alkaline.
$NH_3(g) + H_2O(l) \rightleftharpoons NH_4OH(aq)$
Sample question;
Draw a well labeled diagram to show that ammonia is highly soluble in water.

2. Reaction of ammonia with copper(II) oxide.
   (a) Dry ammonia gas was passed over heated copper(II) oxide.
      (i) State what was observed.
      A black solid turned brown and a colourless liquid is formed.
      (ii) Write the equation for the reaction that took place.
      $3CuO(s) + 2NH_3(g) \longrightarrow 3Cu(s) + N_2(g) + 3H_2O(l)$
      (iii) State the property shown by ammonia in the above reaction.
      Reducing property.
   (b) Name other oxides which react with ammonia in a similar way like copper(II) oxide.
   Lead(II) oxide.
   Iron(III) oxide.

Study the figure below and answer the questions that follow;
<u>Diagram</u>

(a) Name;
  (i) Gas X .
  (ii) Liquid W
(b) State what is observed in the combustion tube
(c) Why is it possible to collect nitrogen as shown above?

3. Reaction of ammonia with lead(II) oxide.

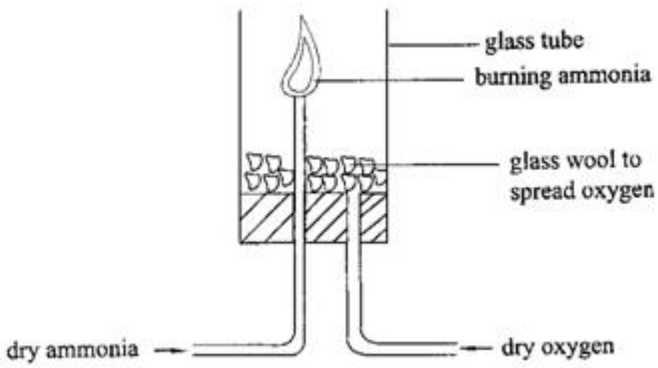
(a) Dry ammonia gas was passed over heated lead(II) oxide
  (i) State what was observed.
  The reddish-brown solid turned to grey and a colourless liquid formed.
  (ii) Write the equation for the reaction that took place.
  $3PbO(s) + 2NH_3(g) \longrightarrow 3Pb(s) + N_2(g) + 3H_2O(l)$
(b) Explain the observation above.
Ammonia is a reducing agent. It reduces reddish-brown lead(II) oxide to lead which is a grey solid and it self oxidized to nitrogen, a colourless gas and water is formed which is a colourless liquid.

4. Reaction of ammonia with iron(III) oxide.

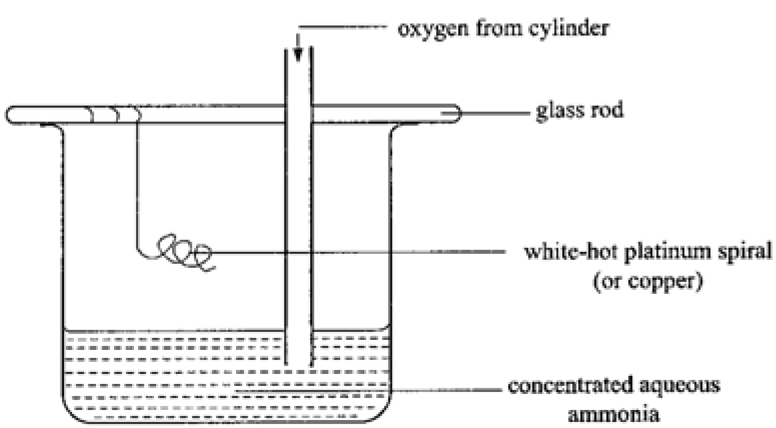
(a) Dry ammonia gas was passed over heated iron(III) oxide.
  (i) State what was observed.
  The reddish-brown solid turned to grey and a colourless liquid formed.
  (ii) Write the equation for the reaction that took place.
  $Fe_2O_3(s) + 2NH_3(g) \longrightarrow 2Fe(s) + N_2(g) + 3H_2O(l)$
(b) Explain your answer in(a) (i) above.
Ammonia is a reducing agent. It reduces reddish-brown iron(III) oxide to iron which is a grey solid and it self oxidized to nitrogen, a colourless gas and water is formed which is a colourless liquid.

5. Combustion of ammonia(oxidation of ammonia)

When dry ammonia is passed over oxygen gas, it burns with a yellowish-green flame forming a colourless gas (nitrogen) and a colourless liquid (water) forms.
Equation.
$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(l)$
Draw a labeled diagram of the set up of apparatus that can be used to show that ammonia can burn in oxygen.
<u>Diagram</u>



<u>Catalytic oxidation of ammonia.</u>
Diagram



A hot platinum spiral or copper wire which acts as a catalyst is suspended in a beaker of concentrated ammonia solution and oxygen bubbled through the solution.
The catalyst remains red-hot because the reaction is exothermic.

Brown fumes of nitrogen dioxide, which are formed due to oxidation of nitrogen monoxide (nitrogen(II) oxide or nitrogen oxide)

$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Ammonia reacts with oxygen in the presence of hot platinum to produce a colourless gas X, which eventually gives brown fumes.

(a) Identify X.

Nitrogen monoxide or nitrogen(II) oxide or NO

(b) Write the equation to show the formation of;

(i) X: $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$

(ii) The brown fumes: $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

(c) State the;

(i) Role of platinum.

Acts as a catalyst.

(ii) Industrial application of the reaction in (b)

It is used in the manufacture of nitric acid (Ostwald's process)

When a hot coil of metal M was suspended over concentrated ammonia solution as shown in the diagram below, the coil glowed and brown fumes were formed.

State;

(i) The identity of the brown fumes.

Nitrogen dioxide or (NO_2

(ii) The name of **M**.

Platinum (or copper)

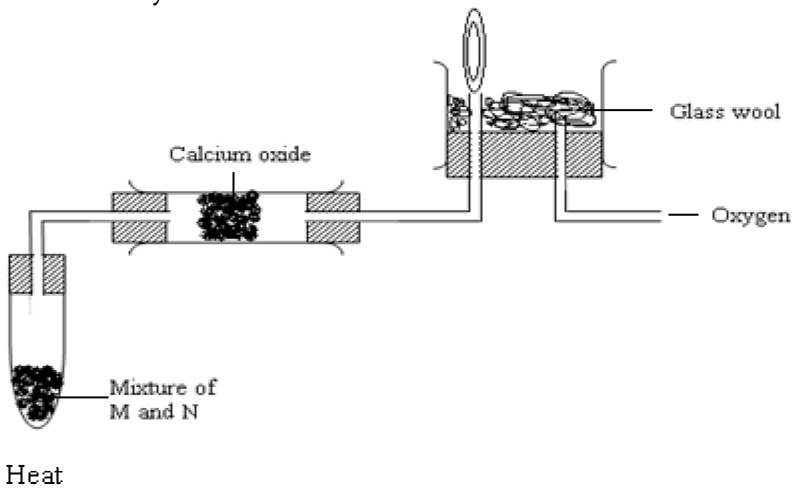
(iii) Why the coil glowed.

The reaction produces heat.

(iv) The industrial application of the reaction shown by the experimental set up.

Manufacture of nitric acid.

In the apparatus shown in the diagram below, compounds M and N are reacted to produce ammonia which is conveyed to vessel T where it is burnt.



(a) Name the substance

(i) M...

(ii) N...

(b) State the role of

(i) The glass wool.

....

(ii) Calcium oxide.

....

(c) Write an equation for the combustion of ammonia.

....

....

6. Reaction of ammonia with chlorine.

Ammonia burns spontaneously in chlorine forming a mist of hydrogen chloride.

$2NH_3(g) + 3Cl_2(g) \longrightarrow N_2(g) + 6HCl(g)$

In excess ammonia, dense white fumes of ammonium chloride forms.

Hydrogen chloride formed reacts with excess ammonia to form white fumes which later settle to a white solid.

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$$

Overall reaction equation.

$8NH_3(g) + 3Cl_2(g) \longrightarrow N_2(g) + 6NH_4Cl(g)$

7. Reaction of ammonia with hydrogen chloride.

A gas jar of hydrogen chloride gas was inverted over one of ammonia gas.

(a) **State what was observed.**

Dense white fumes formed.

(b) **Write the equation for the reaction that took place.**

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$$

Uses of ammonia

- Used in manufacture of nitric acid.
- Used in manufacture of fertilizers e.g ammonium sulphate.
- Liquid ammonia is used as a refrigerant.
- It is used to soften hard water ie ammonia solution removes temporary hardness of water.
- Used in production of nylon(manufacture of synthetic fibres)

Ammonia solution.

Preparation of ammonia solution

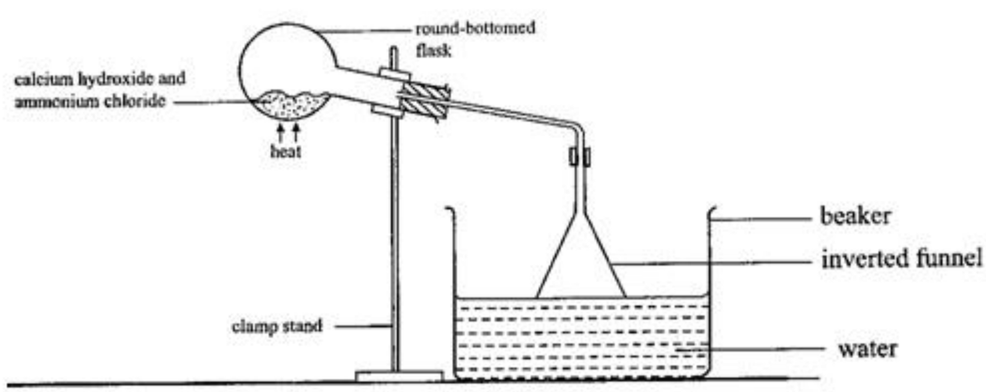
Ammonia solution is prepared by dissolving ammonia gas in water.

Since ammonia is highly soluble in water, it readily dissolves with the aid of a funnel inverted in water.

This arrangement has two advantages;

- It prevents sucking-back which would cause the apparatus to break.
- The funnel increases the surface area for dissolving the gas, compared to the delivery tube which provides a small surface area.

Draw a well labeled diagram to show how aqueous ammonia is prepared in the laboratory



Equation for the dissolution of ammonia

$NH_3(g) + H_2O(l) \rightleftharpoons NH_4OH(aq)$

Reactions of aqueous ammonia.

Aqueous ammonia (ammonium hydroxide) ionizes according to the following equation.

$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

Reaction of ammonia solution with metal ions

1. **Copper(II) ions, Cu^{2+}**

   If aqueous ammonia is added to a solution containing copper(II) ions drop wise until in excess

   Observation; A blue precipitate is formed soluble in excess forming a deep blue solution.

   Equation(s);

   $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

   (Blue precipitate)

   $Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$

   $(Deep\ blue\ solution)$

   $(Tetraammine\ Copper(II)ions)$

Aqueous ammonia solution was added to copper(II) sulphate solution in a test tube drop wise until in excess.

(a) **State what was observed.**

Blue precipitate soluble in excess forming a deep blue solution.

(b) **Write the ionic equation(s) for the reaction(s) that occurs.**

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

$Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$

(c) **Explain your observations in (a) above**.

Copper(II) ions reacts with hydroxide ions to form copper(II) hydroxide which is a blue insoluble precipitate.

The precipitate dissolves in excess ammonia solution to form a soluble complex, tetraamminecopper(II) ion, which is a deep blue solution.

When aqueous ammonia was added drop wise until in excess to a solution of copper(II) nitrate, a blue precipitate,**p**, was formed which dissolved in excess ammonia to give a deep blue solution.

(a) Identify **p**.

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(b) Write the formula and name of the cation in the deep blue solution.

(i) Formula……………………………………………………………………………...

(ii) Name………………………………………………………………………………

2. **Zinc ions,Zn^{2+}**

   If aqueous ammonia is added to a solution containing zinc ions, drop wise until in excess;

Observation; A white precipitate is formed which is soluble in excess forming a colourless solution.

Eqation(s);

$Zn^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Zn(OH)_2(s)$

$Zn(OH)_2(s) + 4NH_3(aq) \longrightarrow Zn(NH_3)_4^{2+}(aq) + 2OH^{-}(aq)$

(tetraammine zinc ion)

Explanation; zinc ion reacts with the hydroxide ions forming zinc hydroxide, a white precipitate. The zinc hydroxide is amphoteric and therefore dissolves in excess aqueous ammonia solution forming a soluble colourless complex, tetraammine zinc ions.

When aqueous ammonia was added drop wise until in excess to a solution containing a cation **X**, a white precipitate was formed which dissolved to give a colourless solution.

(a) Identify **X**

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(b) Write the formula of the cation in the colourless solution.

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(c) Write an ionic equation for the reaction leading to the formation of;

(i) The white precipitate.

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(ii) The colourless solution.

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(d) Name one other metal ion that when treated with aqueous ammonia would form a precipitate soluble in excess ammonia.

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(e) State what would be observed and write the equation for the reaction if the metal ion you have named in (d) was treated with aqueous ammonia until in excess.

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3. Aluminium ion, Al^{3+}

If aqueous ammonia is added to a solution containing aluminium ions drop wise until in excess,

Observation; a white precipitate insoluble in excess is formed.

Equation; $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$

Explanation; aluminum ions react with hydroxide ions to form a white insoluble precipitate of aluminium hydroxide.

(a) Aqueous ammonia was added to aluminum sulphate solution.

(i) State what was observed.

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(ii) Write the equation for the reaction that took place.

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(b) Dilute sodium hydroxide solution was added drop wise until in excess to the product in (a).

(i) State what was observed.

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(ii) Explain your observation in (b)(i) (equation not required)

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4. **Lead(II) ion, Pb^{2+}**

If aqueous ammonia is added to a solution containing lead(II) ions drop wise until in excess;

Observation; a white precipitate insoluble in excess is formed.

Equation; $Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$

Explanation; lead(II) ions react with the hydroxide ions forming lead(II) hydroxide, a white precipitate insoluble in excess .

5. **Iron(II) ion, Fe^{2+}**

If aqueous ammonia is added to a solution containing iron(II) ions drop wise until in excess;

Observation; A dirty green precipitate insoluble in excess.

The precipitate turns brown on standing.

Equation; $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$

Explanation; iron(II) hydroxide is formed, an insoluble hydroxide, seen as a dirty green precipitate. The precipitate turns to brown due to oxidation of iron(II) ions to iron(III) ions brown in colour.

6. **Iron(III) ions Fe^{3+}**

If aqueous ammonia is added to a solution containing iron(III) ions drop wise until in excess;

Observation; A reddish brown precipitate insoluble in excess.

Equation; $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$
Explanation; iron(III) hydroxide is formed, an insoluble hydroxide, seen as a reddish brown precipitate.

(a) (i) Name one reagent that can be used to distinguish iron(II) sulphate solution and iron(III) sulphate solution.

Reagent :Sodium hydroxide solution or Aqueous ammonia solution.

(ii). State what would be observed if the reagent you have named in (a)(i) was separately treated with the two iron salts and write equation for the reaction.

With iron(II) sulphate; A green precipitate insoluble in excess, would be formed.

Equation; $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$

With iron(III) sulphate; Areddish brown precipitate would be formed insoluble in excess.

Equation;$Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$

Identify a reagent that can be used to distinguish between the following pairs of ions and in each case state the corresponding observations.

i) $\boldsymbol{Pb^{2+}(aq)\ and\ Al^{3+}(aq)}$

Reagent; potassium iodide solution

Obsevations;

With $Pb^{2+}(aq)$; a yellow precipitate is formed.

With $Al^{3+}(aq)$; no observable change.

ii) $\boldsymbol{Zn^{2+}(aq)\ and\ Pb^{2+}(aq)}$

Reagent; Aqueous ammonia solution

Observation;

With $\boldsymbol{Zn^{2+}(aq)}$**;** A white precipitate is formed soluble in excess forming a colourless solution.

With $\boldsymbol{Pb^{2+}(aq)}$**;** A white precipitate is formed insoluble in excess.

Give a reagent that can be used to distinguish between the following pairs of ions and in each case state what would be observed and write equation for the reaction where applicable;

(i) $\boldsymbol{Zn^{2+}(aq)\ and\ Al^{3+}(aq)}$

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(ii) $\boldsymbol{Fe^{2+}(aq)\ and\ Fe^{3+}(aq)}$

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OTHER REACTIONS OF AQUEOUS AMMONIA

(I) Reaction of ammonia with dilute hydrochloric acid.

$NH_4OH(aq) + HCl(aq) \longrightarrow NH_4Cl(aq) + H_2O(l)$

(II) Reaction of ammonia with dilute sulphuric acid.

$2NH_4OH(aq) + H_2SO_4(aq) \longrightarrow (NH_4)SO_4$

(III) Reaction with dilute nitric acid.

$HNO_3(aq) + NH_4OH(aq) \rightarrow NH_4NO_3\,(aq) + H_2O(aq)$

NITRIC ACID

Describe how nitric can be manufactured industrially.(Diagram not required)

Ammonia is dried and mixed with excess air and passed over red-hot platinum-Rhodium catalyst.

$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$

Nitrogen monoxide is cooled and allowed to react with oxygen from excess air to form nitrogen dioxide.

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Nitrogen dioxide is absorbed in hot water in presence of more oxygen to form Nitric acid.

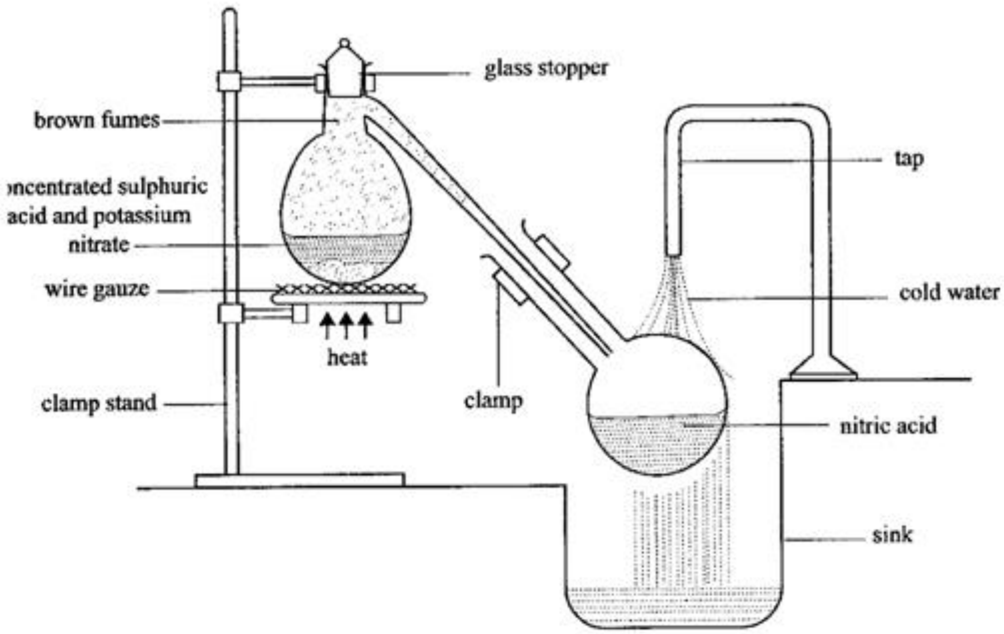
$4NO_2(g) + O_2(g) + 2H_2O(l) \longrightarrow 4HNO_3(aq)/(l)$

Note; The process by which nitric acid is manufactured is referred to as **Ostwald's process.**

LABORATORY PREPARATION OF NITRIC ACID.

(a) With the aid of a labeled diagram, explain how a sample of nitric acid can be prepared in the laboratory.

Diagram.



Concentrated sulphuric acid which is a liquid is added from a tap funnel onto solid potassium nitrate in a glass retort.
The stem of the retort is inserted into a round bottomed flask which acts as a receiver.
The mixture is heated and the acid vapour condensed by tap water running around the receiver.
All the apparatus used is glass because nitric acid attacks even cork.

(b) Write the equation for the reaction leading to the formation of nitric acid.
$KNO_3(s) + H_2SO_4(l) \longrightarrow KHSO_4(s) + HNO_3(l)$

(c) Explain why the above reaction is possible.
Sulphuric acid is a stronger acid than nitric acid. It displaces the weaker and more volatile acid from its salt readily.

USES OF NITRIC ACID.

- Used in the manufacture of fertilizers such as ammonium nitrate ie
  $NH_3(g) + HNO_3(aq) \longrightarrow NH_4NO_3(aq)$
- Used in the manufacture of dyes and explosives.
- Used in the manufacture of drugs.

PROPERTIES OF NITRIC ACID

It behaves chemically in two ways i.e :

i) As strong acid.

ii) As a powerful oxidizing agent

NITRIC ACID AS STRONG ACID

Nitric acid behaves like all other acids when its dilute and cold. The following reactions demonstrate the acid behaviour of nitric acid

a) **Reaction with metal carbonates.**

Dilute nitric acid reacts with metal carbonates with effervescence of a colourless gas (carbondioxide) forming the corresponding salt and water only.

Dilute nitric acid was added to calcium carbonate.

i) **State what was observed.**

The white powder dissolved with effervescence of a colourless gas forming a colourless solution.

ii) **Write the equation for the reaction.**

$CaCO_3(aq) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$

b) **Reaction with hydrogen carbonates.**

Dilute nitric acid reacts with hydrogen carbonates with effervescence of a colourless gas.

Dilute nitric acid was added to sodium hydrogen carbonate.

i) **State what was observed.**

The white solid dissolved with effervescence of a colourless gas forming a colourless solution.

$$HCO_3^-(aq) + H^+(aq) \rightarrow CO_2\ (g) + H_2O(g)$$

Dilute nitric acid was added to copper(II) carbonate.

i) **State what was observed.**

The green powder dissolved with effervescence of a colourless gas forming a blue solution.

ii) **Write the ionic equation for the above reaction.**

$CuCO_3(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + CO_2(g) + H_2O(g)$

c) **Reaction with metals.**

Magnesium and calcium are the only metals that liberates hydrogen with dilute nitric acid and only when the acid is dilute.

Note : if not very dilute , nitric acid is a very strong oxidizing agent so it oxidizes any hydrogen liberated from the reaction to form water.

$Mg(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + H_2(g)$

$Ca(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + H_2(g)$

(a) **Dilute nitric acid was added to magnesium. State what was observed.**

The grey metal (magnesium) dissolved with effervescence of a colourless gas forming a colourless solution.

(b) **Write the equation for the reaction**

$Mg(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + H_2(g)$

d) Reaction with sulphites and hydrogen sulphites

Dilute nitric acid liberates sulphur dioxide from sulphites and hydrogen sulphites.

$SO_3^{2-}(aq) + 2H^+(aq) \longrightarrow SO_2(g) + H_2O(l)$

E.g.$Na_2SO_3(aq) + 2HNO_3(aq) \longrightarrow 2NaNO_3(aq) + SO_2(g) + H_2O(l)$

e) Neutralization reactions.

Dilute nitric acid reacts with bases to produce a salt and water only. i.e

$NaOH(aq) + HNO_3(aq) \longrightarrow NaNO_3(aq) + H_2O(l)$

$CaO(aq) + HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + H_2O(l)$

NITRIC ACID AS AN OXIDISING AGENT

Nitric acid is a very power full oxidizing agent when dilute and even more powerful when concentrated.

(a) Reaction with iron(II) salts.

Concentrated nitric acid oxidizesiron(II) ions to iron(III) ions and the acid is reduced to nitrogen(II) oxide. Eg

If crystals of iron(II) sulphate are added to dilute sulphuric acid followed by concentrated nitric acid, brown fumes of nitrogen dioxide are observed and a brown or yellow solution is left.

Explanation; Iron(II) sulphate is green, when concentrated nitric acid is added, it oxidizes iron(II) ions to iron(III) ions which are brown or yellow.

Nitric acid is reduced to nitrogen monoxide which turns brown when exposed to air.

$6FeSO_4(aq) + 3H_2SO_4(aq) + 2HNO_3(l) \longrightarrow 3Fe_2(SO_4)_2(aq) + 4H_2O(l) + 2NO(g)$

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

(b) Reaction with carbon and sulphur.

Concentrated nitric acid oxidizes carbon to carbon dioxide and sulphur to sulphuric acid.

In both cases, nitric acid is reduced to brown nitrogen dioxide.

$C(s) + 4HNO_3(l) \longrightarrow CO_2(g) + 4NO_2(g) + 2H_2O(l)$

$S(s) + 6HNO_3(l) \longrightarrow H_2SO_4(aq) + 6NO_2(g) + 2H_2O(l)$

(c) Reaction with copper

When copper turnings are added to concentrated nitric acid, a vigorous reaction occurs, reddish-brown fumes (nitrogen dioxide) is produced, and green/blue copper(II) nitrate forms.

Note; In the above reaction, concentrated nitric acid oxidizes copper to copper(II) ions

$Cu(s) + 4HNO_3(l) \longrightarrow Cu(NO_3)_2(aq) + 2H_2O(l) + 2NO_2(g)$

If the volume of the acid is 50% concentrated (equal volume of water as the volume of the acid) nitrogen monoxide is formed.

$3Cu(s) + 8HNO_3(l) \longrightarrow 3\,Cu(NO_3)_2(aq) + 4H_2O(l) + 2NO(g)$

ACTION OF HEAT ON NITRIC ACID (fuming)

When fuming nitric acid is heated, it decomposes to form a reddish-brown mixture of nitrogen dioxide and oxygen.

The nitrogen dioxide dissolves in water and oxygen collects in the test tube.

$4HNO_3(g) \longrightarrow 4NO_2(g) + O_2(g) + 2H_2O(l)$

NITRATES.

Nitrates of group(I) metals of the periodic table i.e. sodium nitrate and potassium nitrate melt to colourless liquids and decompose to form oxygen and pale yellow solid(nitrite).

$$2NaNO_3(s) \longrightarrow 2NaNO_2(s)/(l) + O_2(g)$$
$$2KNO_3(s) \longrightarrow 2KNO_2(s)/(l) + O_2(g)$$

Nitrates of group(II) metals and nitrates of zinc, lead and copper, when strongly heated, produces metal oxides, nitrogen dioxide and oxygen. i.e.

(i) Lead(II) nitrate;

Lead(II) nitrate melts with a crackling sound(decrepitating sound)
It then decomposes into a reddish-brown solid that turns yellow on cooling, brown fumes of nitrogen dioxide and oxygen gas is formed.

$$2Pb(NO_3)_2(s) \longrightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$$

(ii) **Calcium nitrate;**

Calcium nitrate melts, reddish-brown fumes are evolved and a white powder is formed.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

(iii) **Zinc nitrate;**

The white solid decomposes forming reddish-brown fumes. A yellow solid when hot and white when cold is formed.

$$2Zn(NO_3)_2(s) \longrightarrow 2ZnO(s) + 4NO_2(g) + O_2(g)$$

(iv) **Magnesium nitrate;**

The white solid decomposes forming reddish-brown fumes. A white powder is formed.

$$2Mg(NO_3)_2(s) \longrightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(v) **Copper(II) nitrate;**

The green solid decomposes forming reddish-brown fumes and a black solid (powder) is formed.

$$2Cu(NO_3)_2(s) \longrightarrow 2CuO(s) + 4NO_2(g) + O_2(g)$$

Nitrates of silver and mercury, when heated strongly form the metal, nitrogen dioxide and oxygen.

$2AgNO_3(s) \longrightarrow 2Ag(s) + 2NO_2(g) + O_2(g)$
$2Hg(NO_3)_2(s) \longrightarrow 2Hg(s) + 2NO_2(g) + O_2(g)$

ACTION OF HEAT ON AMMONIUM NITRATE

When ammonium nitrate is heated, it melts and decomposes to produce a colourless gas (Dinitrogen oxide) and also steam is given off.

$NH_4NO_3(S) \rightarrow N_2O(g) + 2H_2O\ (g)$

TEST FOR A NITRATE ION, $\boldsymbol{NO_3^-}$

i) An aqueous nitrate, $NO_3^-(aq)$

In aqueous solution, a nitrate ion can be detected by the **brown ring test.**

The suspected solution of the nitrate ions is poured into a test tube. To this solution is then added a little solution of freshly prepared iron(II) sulphate, followed by a few drops of concentrated sulphuric acid.
When **a brown ring** forms where the two layers meet, confirms the presence of a nitrate ion.
Note; the test tube is held in a slanting position very carefully and then concentrated sulphuric acid is poured down the sides of the test tube.
Concentrated sulphuric acid is denser than the solution and therefore sinks to the bottom.

Diagram

ii) Solid nitrate

A sample of the solid nitrate is strongly heated in the boiling tube; metallic nitrates liberate oxygen gas, a colourless gas that relights a glowing splint and this may be accompanied with a reddish-brown gas (nitrogen dioxide). This excludes metallic nitrates of group (I) metals.

SAMPLE QUESTIONS

a) With the aid of a labeled diagram, explain how a sample of nitric can be prepared in the laboratory.

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b) Write equation for the reaction leading to formation of nitric acid.

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c) Write equation to show the reaction between nitric acid and

i) Sodium hydrogen carbonate.

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ii) Sulphur.

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d) The following equations show the nitrates of metals X, R, and M.

$2XNO_3(s) \rightarrow 2X(s) + 2NO_2(g) + O_2(g)$

$2RNO_3(g) \rightarrow 2RNO_2(g) + O_2(g)$

Equation

Suggest one possible identity of

i) X

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ii) R

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iii) M

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a) Nitrogen is generally an inert element. However, under certain conditions it reacts with hydrogen to form ammonia.

(i) State two conditions other than temperature, under which the above reaction occurs.

High pressure and presence of iron as a catalyst.

(ii) Write the equation for the reaction leading to the formation of ammonia

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(iii) State the practical application of the reaction in a(i)

Manufacture of ammonia.

b) (i) Write the equation for the reaction that takes place during the laboratory preparation of ammonia and state the condition(s) for the reaction

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(ii). Explain why the evolution of ammonia is possible as indicated by the reaction in (b)(i)

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(iii). Name the drying agent for ammonia and explain why it is preferred to the other commonly available drying agents.

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(iv) State the method for collecting ammonia and give a reason for using the method.

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c) Write an equation for the reaction in which ammonia behaves as a reducing agent

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d) State two;

(i) Uses of ammonia as alaboratory reagent.

Testing hydrogen chloride.

(ii) Industrial uses of ammonia.

- ✓ Manufacture of fertilizers.
- ✓ Manufacture of nitric acid.

(a) Under suitable condition(s), a dry sample of ammonia can be prepared in the laboratory using ammonium chloride mixed with calcium hydroxide according to the following equation.

$$Ca(OH)_2(s) + 2NH_4Cl(s) \longrightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(l)$$

(i) State;

- The condition(s) for the reaction leading to the formation of ammonia.
  The reaction mixture must be heated.
- How ammonia is collected and give a reason for your answer.
  Ammonia is collected by upward delivery since it is less dense than air.

(ii) Briefly explain why ammonia is not dried using fused calcium chloride or concentrated sulphuric acid.

Ammonia is a base; concentrated sulphuric acid is an acid, so the base reacts with it to form ammonium sulphate.

Ammonia reacts with anhydrous calcium chloride to form a complex salt.

(iii) Name the substance, which is usually used as a drying agent for ammonia.

Calcium oxide.

(b) When **X**g of ammonium chloride were used in the preparation of ammonia as shown by the equation in (a). 3.40g of pure and dry calcium chloride were obtained.

(i) Determine the value of **X**$[\boldsymbol{H = 1, N = 14, Cl = 35.5, Ca = 40}]$

(ii) Calculate the volume of dry ammonia gas, measured at room temperature.(1 mole of a gas occupies $24.0dm^3$ at room temperature)

(c) State the conditions under which dry ammonia can react with oxygen and write equation for the reaction(s) that take(s) place.

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(d) Write the equation to show how ammonia reacts with chlorine.

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(a) Write an equation in each case for the reaction in which nitric acid behaves as;

(i) An acid

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(ii) An oxidizing agent.

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(b) State the conditions for the reactions in (a).

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(c) Excess lead(II) oxide was added to warm dilute nitric acid and the mixture was stirred. After cooling, the mixture was filtered and a solution of sodium chloride was added to the filtrate.

(i) Write an equation for the reaction betweenlead(II) oxide and nitric acid.

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(ii) State what was observed when sodium chloride was added to the filtrate.

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

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(iv) Describe what happens when the mixture in (ii) is heated.

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(a) Describe how a dry sample of ammonia can be prepared in the laboratory (diagram not required).

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(b) Name a reagent that can be used to test for ammonia and state what would be observed if ammonia is tested with the reagent.

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(c) (i) Draw a labeled diagram of set up of the apparatus that can be used to show that ammonia can burn in oxygen.

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(ii). Write an equation for the combustion of ammonia in oxygen.

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(d) Dry ammonia was passed over heated copper(II) oxide.

(i) State what was observed.

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(ii) Write an equation for the reaction.

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(a) Dry ammonia gas was passed over heated lead(II) oxide.

(i) State what was observed.

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(ii) Write the equation for the reaction that took place.

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(b) Describe how ammonia can be converted to nitric acid. Use equations to illustrate your answer.

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(c) Nitrogen can react with hydrogen in the presence of a catalyst which is finely divided to produce ammonia in the Haber process.

(i) State the source of nitrogen.

- Air/atmosphere/liquid air

(ii) Name the catalyst used in the reaction.

- Iron.

(iii) Explain why the catalyst is finely divided.

- Reaction takes place only at the surface of the catalyst. Finely divided iron provides a large surface area. This ensures maximum yield of ammonia.

(iv) Write the equation for the reaction leading to the formation of ammonia.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(v) State two factors that can affect the yield of ammonia in the Haber process.

- High pressure.
- Low temperature.

(d) Write equation for the reaction to show that ammonia can;

(i) Act as a reducing agent.

$3CuO(s) + 2NH_3(g) \longrightarrow 3Cu(s) + 3H_2O(l) + N_2(g)$

(ii) Burn in oxygen.

$4NH_3(g) + 3O_2(g) \longrightarrow 6H_2O(l) + 2N_2(g)$

(e) Ammonia obtained by the Haber process can be converted to nitrogen(II) oxide.

(i) Write the equation for the reaction leading to the conversion of ammonia to nitrogen(II) oxide.

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(ii) State the conditions for the reaction.

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(f) Write equation(s) to show how nitrogen(II) oxide can be converted to nitric acid.

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(g) When aqueous ammonia was added drop wise until in excess to a solution of copper(II) nitrate, a blue precipitate,**P**, which dissolved in excess ammonia to give a deep blue solutionwas formed.

- Identify **P**.

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- Write the formula and name of the cation in the deep blue solution.

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Ammonia can react with lead(II) oxide according to the following equation.

$3PbO(s) + 2NH_3(g) \longrightarrow 3Pb(s) + 3H_2O(l) + N_2(g)$

(a) State;

i. The condition(s) under which the reaction takes place.

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ii. The property of ammonia shown in this reaction.

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(b) $3.1g$ of lead was obtained when ammonia reacted with lead(II) oxide

($Pb = 207,\ O = 16, 1\ mole\ of\ gas\ occupies\ 22.4dm^3\ at\ s.t.p$)

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(a) **With the help of equation, explain how a dry sample of ammonia gas can be prepared in the laboratory starting from ammonium chloride.(diagram not required)**

Solid ammonium chloride and calcium hydroxide are placed into a round bottomed flask which is clamped in a slanting position so that condensed water does not run back to the hot reactants and crack the flask.

The mixture of solids is heated and ammonia produced is passed through calcium oxide which dries the it. The gas is then collected by upward delivery because it is less dense than air.

$Ca(OH)_2(s) + 2NH_4Cl(s) \longrightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(l)$

(b) **Briefly explain why when dry ammonia is passed over strongly heated copper(II) oxide, a colourless liquid is formed and a brown solid residue is obtained. Write equation to illustrate your explanation.**

Ammonia is a reducing agent. At high temperatures, it removes oxygen from copper(II) oxide leaving copper which is a brown residue and itself oxidized to nitrogen and water which is the colourless liquid formed.

$3CuO(s) + 2NH_3(g) \longrightarrow 3Cu(s) + 3H_2O(l) + N_2(g)$

(c) **One of the large scale uses of ammonia is manufacture of fertilizers**

(i). Briefly explain what is meant by a fertilizer.

A fertilizer is a substance which when added to the soil improves the crop yield.

(ii) Name two fertilizers obtained from ammonia.

Ammonium sulphate.

Sodium nitrate.

(d) Ammonium nitrate dissolves in water according to the following equation.

$NH_4NO_3(s) + H_2O(l) \longrightarrow NH_4OH(aq) + HNO_3(aq)$

Explain using equations, why extensive use of ammonium nitrate as a fertilizer can make the soil acidic.

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(a) Write an equation for the reaction between oxygen and;

i. Ammonia in presence of heated platinum.

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ii. Nitrogen monoxide.

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(b) State how the product in (a)(ii) can be converted to nitric acid.

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(c) Write an equation and state the conditions for the reaction between nitric acid and

i. Sulphur.

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ii. Lead(II) oxide

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(d) In each case, state what was observed and write equation for the reaction that took place when, sodium nitrate was heated strongly;

i. Alone.

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ii. As a mixture with concentrated sulphuric acid.

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(e) Calcium nitrate was strongly heated.

i. State what was observed.

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ii. Write equation for the reaction that took place.

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iii. Name the gas that can be dried using the solid residue.

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iv. Calculate the total volume of the gaseous products formed at room temperature when 4.5g of calcium nitrate is heated strongly.

$(H = 1, N = 14, Cl = 35.5, Ca = 40,$
$1\ mole\ of\ gas\ occupies\ 24.0dm^3\ at\ room\ temperature)$

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(f) The residue in (e) was dissolved in water. Write equation for the reaction that took place.

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(g) Excess carbon dioxide was bubbled through solution in (f). State;

i. What was observed and write the equation(s) for the reaction(s) that took place.

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ii. One application of this reaction in gas analysis.

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(h) To the solution in (f) soap solution was added. State what was observed.

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(a) Vanadium(V) oxide and platinum-Rhodium are industrial catalysts used in the manufacture of two laboratory acids,**R**and **W** respectively. Name acid

i. **R**………………………………………………………………………………

ii. **W**……………………………………………………………………………...

(b) Write down the equation of the gaseous reaction catalyzed in each case of acid.

i. **R**

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…………………………………………………………………………

ii. **W**

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(c) Starting from the reaction products in (b), describe how the acids **R** and **W** can be produced. Illustrate your answer with equations.

i. Acid **R**

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ii. Acid **W**

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(d) Write the equation of the reaction between;

i. Lead(II) oxide and dilute acid **R**.

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ii. Copper turnings and concentrated acid **W** on heating the reaction mixture.

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(e) Give one use of acid.

i. **R**

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ii. **W**

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(a) Copper(II) nitrate was heated until there was no further change

i. State what was observed.

The blue-green crystals melt, form brown fumes and black residue remains.

ii. Write the equation for the reaction that took place.

$2Cu(NO_3)_2(s) \longrightarrow 2CuO(s) + 4NO_2(g) + O_2(g)$

(b) Concentrated nitric acid was added to copper(II) nitrate and the mixture heated.

i. Write an ionic equation for the reaction that took place.

$NO_3^-(s) + H_2SO_4(l) \longrightarrow HSO_4^-(s) + HNO_3(l)$

ii. State the practical application of the reaction in (b) (i)

Laboratory preparation of nitric acid.

The table below shows the effect of heat on the carbonates and nitrates of two metals **W** and **Y.**

metal	*carbonates*	*Nitrates*
W	*Do not decompose at all*	*Decomposes giving oxygen and a residue only.*
Y	*Decomposes leaving a yellow residue on cooling*	*Decomposes leaving a yellow residue on cooling.*

(a) Suggest one metal in the category of;

i. ***W***………………………………………………………………………………

ii. ***Y***………………………………………………………………………………

(b) Write the equation for the decomposition of the nitrate of the metal you have stated in (a) above.

i. ***W***………………………………………………………………………………

ii. ***Y***………………………………………………………………………………

(c) State what is observed during the process of heating the nitrate of the metal you have stated in category ***Y***.

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(a) Sulphuric acid can react with sodium nitrate to form nitric acid.

i. State the conditions for the reaction.

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ii. Write the equation for the reaction in (a) (i) above.

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(b) Sulphur was warmed with concentrated nitric acid.

i. State what was observed.

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ii. Write equation for the reaction.

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(a) Lead(II) nitrate was heated until there was no further change.

i. State what was observed.

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ii. Write equation for the reaction that took place.

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(b) Dilute hydrochloric acid was added to a solution of lead(II) nitrate and the resultant solution warmed.

i. State what was observed.

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ii. Write the equation for the reaction that took place.

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iii. What can you deduce from your observation.

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(a) Zinc oxide reacts with dilute nitric acid.

i. Write the equation for the reaction that takes place.

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ii. Briefly describe how dry crystals of the product of the reactoin in (a) (i) can be obtained in the laboratory.

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(b)

(a) State what would be observed if aqueous lead(II) nitrate was added to;

i. Dilute sulphuric acid.

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ii. Sodium iodide solution.

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(b) Write ionic equation for the reaction in;

i. (a) (i)

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…………………………………………………………………………………….

ii. (a) (ii)

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(c) State what would be observed when the following are reacted.

i. Potassium nitrate and concentrated sulphuric acid.

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ii. Lead(II) nitrate and sodium carbonate solution.

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(d) State the condition for the reaction in © (i)

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(e) Write the equation for the reaction in;

i. C) (i)

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ii. C) (ii)

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(a) Describe how nitric acid can be manufactured using hydrogen and nitrogen as raw materials.(illustrate your answer with equations) $(10\frac{1}{2}\ marks)$

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(b) Write equations to show the effect of heat on;

i. NH_4NO_3

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ii. $Hg(NO_3)_2$

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iii. $AgNO_3$

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(c) The gaseous product in (b) (i) was reacted with burning magnesium. Write the equation for the reaction.

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(d) Excess dilute nitric acid was added to the solid residue in (c) above. Aqueous ammonia was added to the resultant solution.

i. State what was observed when ammonia was added to the resultant solution.

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ii. Write the equation for the reaction.

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(a) When dilute nitric acid was reacted with copper, a colourless gas, **R** which turned brown when exposed to air was evolved.

i. Name gas **R**.

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ii. Write the equation for the leading to the formation of the brown gas.

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(b) Write an equation for the reaction that would take place if the brown gas was dissolved in water.

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(c) State what would be observed if concentrated nitric acid was heated with iron(II) sulphate solution.

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(a) Describe how you would prepare pure crystals of lead(II) nitrate in the laboratory starting from lead(II) oxide. Write an equation for the reaction that takes place.

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(b) State what happens when lead(II) nitrate is strongly heated.

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(c) State what is observed if ammonia solution is gradually added to a solution of lead(II) nitrate until the alkali is in excess. Write the equation for the reaction that takes place.

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(d) Lead(II) ions react with iodide ions according to the following equation.

$Pb^{2+}(aq) + 2I^{-}(aq) \longrightarrow PbI_2(s)$

$100cm^3$of 1M iodide ions was added to a solution containing excess lead(II) ions. Calculate the mass in grams of lead(II) iodide formed.$(Pb = 207, I = 127)$

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A mixture containing 3.90g of silver nitrate and silver chloride was shaken with excess water, filtered and the residue dried.

(a) Identify the anion that was present in the;

i. Residue……………………………………………………………………..

ii. Filtrate……………………………………………………………………...

(b) State the test that can be carried out to confirm the anion in the filtrate.

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(c) The mass of the residue dried was 1.80g. Calculate the number of moles of silver ions contained in the filtrate.

$(Ag = 108, Cl = 35.5, N = 14, O = 16)$

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Explain the following observations;

(a) When magnesium is burnt in air and the residue dissolved in water, a gas that turns moist red litmus paper blue is evolved. (05 $marks$)

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(b) When ammonia solution is added drop wise until in excess to zinc nitrate solution, a white precipitate is formed. The precipitate dissolves in excess ammonia solution to form a colourless solution. (04 $marks$)

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(c) When lead(II) nitrate is heated strongly, a decrepitating sound is produced. (03 $marks$)

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(a) Complete the following equations

i. $NaNO_3(s) \xrightarrow{heat}$

ii. $NH_4NO_3(s) \xrightarrow{heat}$

iii. $AgNO_3(s) \xrightarrow{heat}$

(b) Concentrated nitric acid was added to copper metal and the mixture was heated.

i. State what was observed.

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ii. Write an equation for the reaction.

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(a) When a white solid **W** was heated with sodium hydroxide solution, a colourless gas **X** which formed dense white fumes with concentrated hydrochloric acid was evolved. Identify the cation in **W**

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(b) When aqueous solution of **W** was treated with lead(II) nitrate solution, a bright yellow precipitate was formed. Identify the anion in **W**.

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(c) Write ionic equation for the reaction leading to the formation of;

i. Gas **X**

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ii. The yellow precipitate in (b)

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(d) Chlorine was bubbled through an aqueous solution of **W**. State what was observed and write an ionic equation for the reaction that took place.

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(a) During laboratory preparation of nitric acid, a mixture of potassium nitrate and reagent,**R** , is heated.

i) Identify **R**

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ii) Write equation for the reaction, which leads to the formation of nitric acid.

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iii) State the property of **R,** which makes it possible for nitric acid to be prepared as shown by the reaction equation which you have written in (a)(ii)

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(b) Fuming nitric acid is yellow in colour.

i) Give a reason.

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ii) Write equation to show the effect of heat on fumes of nitric acid.

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(c) Nitric acid reacts with zinc, producing oxides of nitrogen instead of hydrogen. Give a reason.

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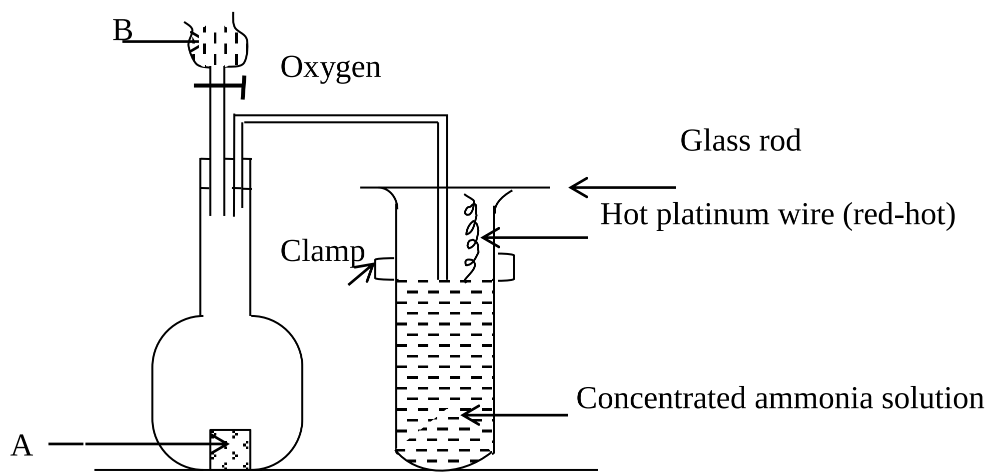
1. The following apparatus was set up to show the catalytic oxidation of ammonia in the laboratory.



(a) Name the chemicals A and B used to prepare oxygen:

A …………………………………………………………………………………….

B. ……………………………………………………………………………………

(b) State two observations that were made in the boiling tube.

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(c) (i) Write equation for the reaction of ammonia and oxygen in the presence of platinum.

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(ii) State one industrial application of the reaction in (c) (i)

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1. **5.0 g of lead (II) nitrate was strongly heated in a dry in a dry hard test tube till no further change.**

(a)(i) State what was observed. (1½ mks)
The white crystals(solid) melts and decompose with crackling sound; giving off reddish-brown fumes(brown fumes) and a solid residue which is reddish-brown when hot and yellow when cold.
*Reject: Residue without the word **solid**; cracking/hissing sound*
(ii) **Write equation for the reaction that took place.** (1½ mks)
$2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$
(b)(i) **Calculate the total volume of the gaseous product formed at s.t.p.** (1½ mks)

$$Rfm of Pb(NO_3)_2 = 207 + 2(14 + 48) = 331$$
$$No. of moles of Pb(NO_3)_2 heated = \frac{5.0}{331}$$
$$No. of moles of gaseou product = \frac{5}{2} No. of moles of Pb(NO_3)_2 heated$$
$$= \frac{5}{2} \times \frac{5.0}{331}$$
$$Total volume of gaseou products = \frac{5}{2} \times \frac{5.0}{331} \times 22.4 = 0.8/\ 0.85 dm^3$$

(ii) State two uses of one of the gaseous product in (a). (1 mk)

Nitrogen dioxide	Oxygen
Manufacture of • nitric acid • nitrogenous fertilizers	• Aid respiration. • To produce oxy-acetylene flame used for welding/cutting steel. • Liquid oxygen is used as fuel in space rockets.

CHLORINE AND ITS COMPOUNDS

Chlorine has atomic number 17.
It has electronic configuration of 2:8:7.
It belongs to group(VII) of the periodic table because it has seven electrons in its outer most energy level.
It belongs to period 3 of the periodic table because it has 3 energy levels containing electrons.
It belongs to a class of reactive elements called Halogens.
Chlorine exists as a diatomic molecule i.e. Cl_2

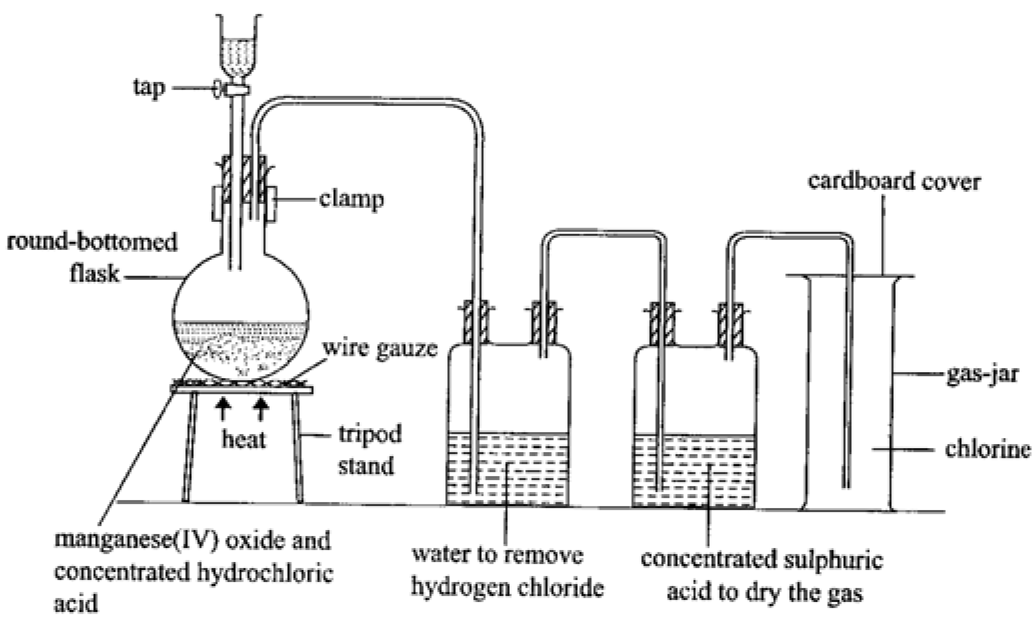
CHLORINE GAS ($\boldsymbol{Cl_2}$)

Preparation of chlorine gas

Chlorine gas can be prepared in the following methods;

(i) **Reacting potassium manganate(VII) with cold concentrated hydrochloric acid.**
$2KMnO_4(s) + 16HCl(aq) \longrightarrow 2KCl(aq) + 2MnCl_2(aq) + 5Cl_2(g) + 8H_2O(l)$
Potassium manganate(VII) in the reaction acts as an oxidizing agent.

(ii) **Reacting manganese(VI) oxide with hot concentrated hydrochloric acid.**



$MnO_2(s) + 4HCl(aq) \longrightarrow MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$
Note; $KMnO_4$ is a more powerful oxidizing agent thanMnO_2, that is why with $KMnO_4$ the reaction occurs in the cold unlike with MnO_2 where heating is required.

(iii) **Reacting concentrated sulphuric acid with a mixture of any chloride e.g. sodium chloride and manganese(IV) oxide.**

(iv) $2NaCl(s) + MnO_2(s) + 2H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + MnSO_4(aq) + 2H_2O(l) + Cl_2(g)$

In this reaction, sodium chloride first reacts with concentrated sulphuric acid to produce hydrogen chloride gas which is then oxidized by manganese(IV) oxide to chlorine.

(v) From bleaching powder.

Bleaching powder is calcium hypochlorite. It is reacted with dilute nitric acid or hydrochloric acid.

Equation;$CaOCl_2(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)2(aq) + H_2O(l) + Cl_2(g)$

$or \quad CaOCl_2(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + Cl_2(g)$

(vi) Preparation on large scale(industrial preparation of chlorine)

State and explain how chlorine is prepared on large scale using sodium chloride (5mks)

Chlorine is prepared on large scale by electrolyzing concentrated sodium chloride solution.

Graphite which is inert and resists corrosion by chlorine is used as electrodes.

Use of concentrated sodium chloride solution ensures preferential discharge of chloride ions at the anode despite of its position being higher than that of the hydroxide ion in the electro chemical series.

The ions transfer electrons to the anode resulting into chloride atoms which soon pair up giving chlorine.

$Cl^-(aq) \longrightarrow Cl + e$

$2Cl \longrightarrow Cl_2$

LABORATORY PREPARATION OF PURE AND DRY CHLORINE GAS.

Describe how a pure sample of chlorine can be prepared in the laboratory from potassium manganate(VII) crystals.(your answer should include a well labeled diagram and equation for the reaction) (06marks)

Diagram

Potassium manganate(VII) crystals which are solids are placed in a flat bottomed flask fitted a tap funnel and a delivery tube.

Concentrated hydrochloric acid which is a liquid is added onto potassium manganate(VII) crystals through the tap funnel at room temperature, chlorine gas is produced.

$$2KMnO_4(s) + 16HCl(aq) \longrightarrow 2KCl(aq) + 2MnCl_2(aq) + 5Cl_2(g) + 8H_2O(l)$$

Or $2MnO_4^-(s) + 16H^+(aq) + 10Cl^-(aq) \longrightarrow 2Mn^{2+}(aq) + 5Cl_2(g) + 8H_2O(l)$

The gas is passed through water to remove acid sprays (hydrogen chloride gas) and then through concentrated sulphuric acid to dry the gas because it is acidic.

The dry gas is collected by down ward delivery because its denser than air.

(a) State the role of the following reagents during the preparation of chlorine gas.

(i) Water.

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(ii) Concentrated sulphuric acid.

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(b) State the method used to collect the gas and give a reason for your answer.

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(c) When a mixture of concentrated hydrogen chloride solution in water and a black solid **J** was heated, a greenish-yellow gas was evolved.

(i) Identify **J** and name the greenish-yellow gas.

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(ii) Write the equation for the reaction that leads to the formation of the greenish-yellow gas.

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(d) State the conditions under which hydrochloric acid reacts with potassium manganate(VII) during the laboratory preparation of chlorine and write the equation for the reaction leading to the formation of chlorine.

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Manganese(IV) oxide can react with hydrochloric acid.

(a) State;

(i) the conditions for the reaction.

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(ii) what was observed?

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(b) Write the equation for the reaction between manganese(IV) oxide and hydrochloric acid.

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Physical properties of chlorine gas

- It is a yellowish-green gas.
- It is denser than water.
- It is slightly soluble in water.
- It is poisonous.
- It turns damp blue litmus paper red and bleaches.

Chemical properties of chlorine gas

1. REACTION WITH WATER.

Chlorine slightly dissolves in water forming a yellow-green solution/ pale yellow solution. The solution turns blue litmus paper red, implying that the solution is acidic. The resultant solution is normally referred to as chlorine water.

$Cl_2(g) + H_2O(l) \rightleftharpoons HCl(aq) + HOCl(aq)$

The bleaching action of chlorine.

When moist red or blue flowers are added to a gas jar containing chlorine gas, the red or blue colour of the flowers is removed and the flowers are turned to whitish i.e. they are bleached. This is due to hypochlorous acid formed as above.

The hypochlorous acid formed gives away its oxygen to the dye (blue or red colour) and the colour is removed.

$HOCl(aq) + dye \longrightarrow HCl(aq) + [dye + O]$

An aqueous solution of chlorine is regarded as a bleaching agent.

(i) Name the bleaching agent in the solution of chlorine.

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(ii) Write the equation for the reaction between the moist blue cloth and the bleaching agent.

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Damp blue litmus paper was dropped into a gas jar containing chlorine.

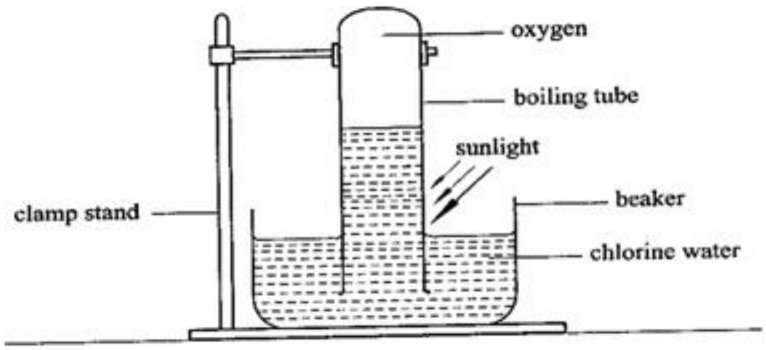
(i) State what was observed.

Blue litmus paper turned red and then white (bleached).

(ii) **Explain your observations above.**

Chlorine dissolves in water forming hydrochloric acid and hypochlorous acid. The blue litmus paper turned red because of hydrochloric acid and later bleached by hypochlorous acid.

Effect of sun light on chlorine water



Observation; when a boiling tube full of chlorine water is exposed to sun light for some time, the yellow-green chlorine water is turned to colourless and a colourless gas collects up the boiling tube.

Chlorine dissolves in water to form hydrochloric acid and hypochlorous acid. Sun light decomposes hypochlorous acid into hydrochloric acid and oxygen gas.

$2HOCl(aq) \longrightarrow 2HCl(aq) + O_2(g)$

A boiling tube filled with chlorine water was inverted into a beaker containing chlorine water and exposed to sun light for some time.

(a) **State what was observed.**

Colourless gas collects in the boiling tube and the yellow-green chlorine water turned colourless.

(b) **Explain with the aid of the equation(s) your observation(s) above.**

Chlorine water contains hypochlorous acid and hydrochloric acid. the hypochlorous acid in the presence of sun light decomposes to produce oxygen.

$2HOCl(aq) \longrightarrow 2HCl(aq) + O_2(g)$

Or $Cl_2(g) + 2H_2O(l) \longrightarrow 4HCl(l) + O_2(g)$

2. REACTION OF CHLORINE WITH METALS.

(i) Reaction with the Dutch metal(copper/zinc)

A thin sheet of Dutch metal is an alloy of copper and zinc burns in chlorine with a green flame forming copper(II) chloride and zinc chloride.

$Cu(s) + Cl_2(g) \longrightarrow CuCl_2(s)$

$Zn(s) + Cl_2(g) \longrightarrow ZnCl_2(s)$

(ii) Reaction with iron.

When dry chlorine is passed over heated iron wire in the apparatus below, the iron glows red-hot forming iron(III) chloride which sublimes and cools on the cooler parts to give a black solid.

$2Fe(s) + 3Cl_2(g) \longrightarrow 2FeCl_3(s)$

Chlorine was passed over heated iron wire

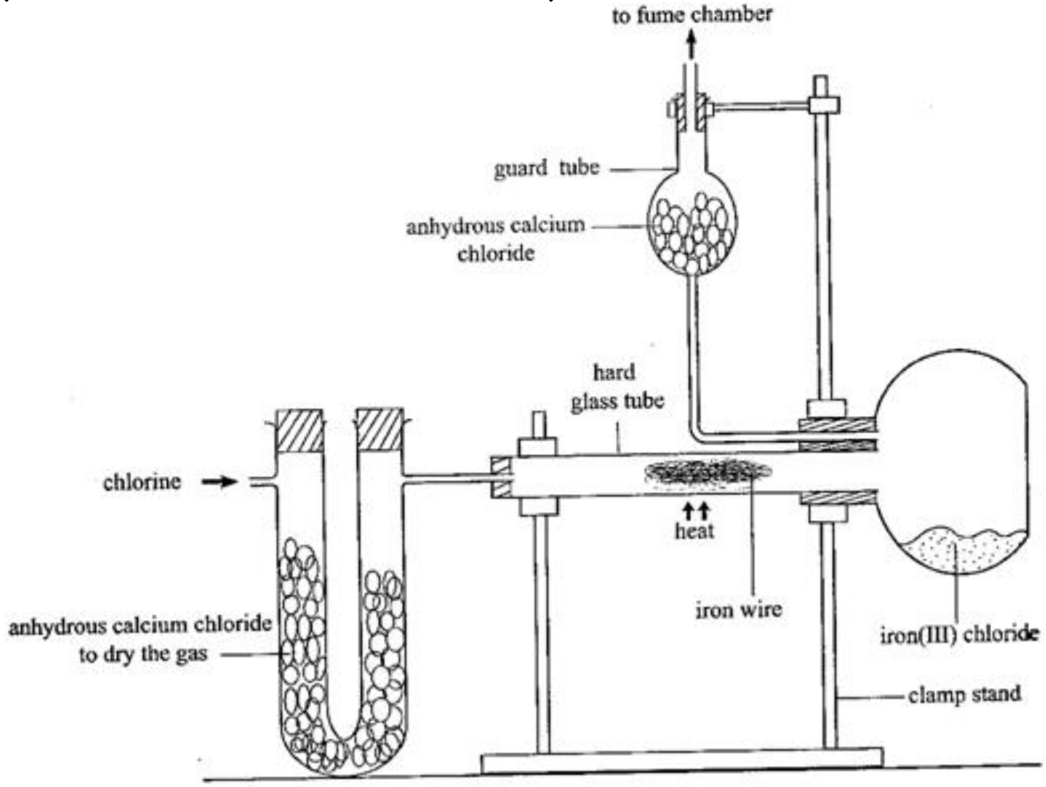
(a) State what was observed

Iron glowed red-hot and a black sublimate (solid) formed.

(b) Write the equation for the reaction that took place.

$2Fe(s) + 3Cl_2(g) \longrightarrow 2FeCl_3(s)$

Draw a fully labeled diagram for the set up of apparatus which can be used to prepare anhydrous iron(III) chloride in the laboratory.



Note; if hydrogen chloride gas is used instead of chlorine, iron(II) chloride is formed.

$Fe(s) + 2HCl(g) \longrightarrow FeCl_2(s) + H_2(g)$

Anhydrous iron(III) chloride was prepared using the set up of apparatus below.

Diagram

(a) Identify;

(i) X

Chlorine gas.

(ii) R

Anhydrous calcium chloride.

(b) Write the equation for the reaction leading to the formation iron(III) chloride.

$2Fe(s) + 3Cl_2(g) \longrightarrow 2FeCl_3(s)$

(c) (i) State what would be observed if iron(III) chloride is exposed to air.

The black crystals would slowly turn to a yellow solution.

(ii). Give a reason for your answer in c(i)

This is because anhydrous iron(III) chloride is deliquescent, and so absorbs water from the atmosphere forming a yellow solution of iron(III) chloride.

(iii) Reaction of chlorine with magnesium.

State what would be observed and write equation for the reaction that would take place if burning magnesium was lowered into a gas jar of dry chlorine.

Magnesium continues to burn with a bright white flame forming a white solid residue.

(iv) Reaction of chlorine with sodium.

(a) State what would be observed and write equation for the reaction that would take place if burning sodium was lowered into a jar of chlorine gas.

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(b) Explain your observation in (a)

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3. REACTION OF CHLORINE WITH NON METALS.

(i) Reaction with phosphorus.

Phosphorus burns spontaneously in chlorine to give white fumes which settle to form white solids.

$P_4(s) + 6Cl_2(g) \longrightarrow 4PCl_3(s)$
(phosphorous(III) chloride)

$P_4(s) + 10Cl_2(g) \longrightarrow 4PCl_5(s)$
(phosphorous(V) chloride)

(ii) Reaction with turpentine($C_{10}H_{16}$)

A violent reaction occurs accompanied by a red flash and black particles (deposits) of carbon are observed.

Also a colourless gas that forms misty fumes in moist air and forms dense white fumes with ammonia is given off.

$C_{10}H_{16}(l) + 8Cl_2(g) \longrightarrow 16HCl(aq) + 10C(s)$

Which one of the following gases is formed when turpentine is burnt in chlorine?

A. Methane.

B. Hydrogen.

C. Hydrogen chloride.

D. Carbon dioxide.

(iii) Reaction with hydrogen sulphide

When a gas jar of chlorine is inverted over one of hydrogen sulphide, yellow particles of sulphur are formed.

$H_2S(g) + Cl_2(g) \longrightarrow S(s) + 2HCl(g)$

(iv) Reaction with iron(II) chloride solution.

When chlorine is bubbled through a solution of iron(II) chloride, the solution turns from green to yellow (reddish-brown solution or brown solution)

$2FeCl_2(aq) + Cl_2(g) \longrightarrow 2FeCl_3(aq)$

$or\ Fe^{2+}(aq) + Cl_2(g) \longrightarrow 2Fe^{3+}(aq) + 2Cl^{-}(aq)$

State what would be observed if chlorine was bubbled through a solution of iron(II) ions and write equation for the reaction.

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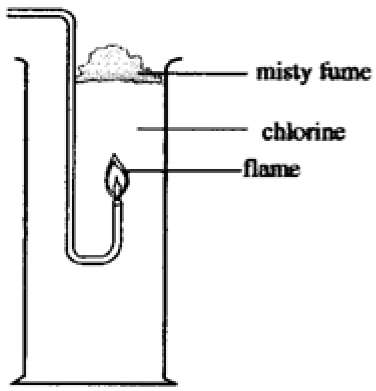
(v) Reaction with hydrogen.

When a jet of burning hydrogen is lowered into a gas jar full of chlorine, hydrogen continues to burn with a white flame forming white misty fumes



(vi) **Reaction with cold and dilute alkalis.**

Chlorine reacts with cold and dilute solution of either sodium or potassium hydroxide to form a pale yellow solution of sodium or potassium hypochlorite and sodium or potassium chloride.

$2NaOH(aq) + Cl_2(g) \longrightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$
$2KOH(aq) + Cl_2(g) \longrightarrow KOCl(aq) + KCl(aq) + H_2O(l)$

Ionic equation

$Cl_2(g) + 2OH^-(aq) \longrightarrow Cl^-(aq) + OCl^-(aq) + H_2O(l)$

State what would be observed and write equation for the reaction that would take place if chlorine was bubbled into aqueous sodium hydroxide solution.

- ✓ Aqueous sodium hydroxide turned from colourless solution to pale yellow(yellowish solution)

  $2NaOH(aq) + Cl_2(g) \longrightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$

DISPLACEMENT REACTIONS OF CHLORINE

(i) **Reaction with a solution of potassium bromide.**

State what would be observed if chlorine was bubbled through potassium bromide solution and write equation for the reaction.

- ✓ Colourless solution turned red and then a red liquid sinks to the bottom.

  Note; we can use reddish-brown instead of red but not brown instead of red.

  $2KBr(aq) + Cl_2(g) \longrightarrow 2KCl(aq) + Br_2(l)$ or
  $Cl_2(g) + 2Br^-(aq) \longrightarrow Br_2(aq) + 2Cl^-(aq)$

Explain your observation above.

- ✓ Chlorine being more reactive than bromine, displaces bromine from its solution forming a red liquid of bromine.

  Or chlorine oxidizes bromide ions to bromine which is a colourless liquid.

(ii) **Reaction with a solution of potassium iodide.**

State what would be observed if chlorine was passed through a solution of potassium iodide and write equation for the reaction.

- ✓ Potassium iodide solution turned from colourless to dark brown and finally a black solid settles at the bottom.

  $2KI(aq) + Cl_2(g) \longrightarrow 2KCl(aq) + I_2(s)$ or

  $Cl_2(g) + 2I^-(aq) \longrightarrow I_2(s) + 2Cl^-(aq)$

Explain your observation above.

- ✓ Chlorine being more reactive than iodine, displaces iodine from potassium iodide solution forming a dark brown solution of iodine which finally settled to a black solid of iodine.

  Or chlorine oxidizes the iodide ions to iodine which is a dark brown solution and settle to form a black solid of iodine.

State what would be observed when chlorine is bubbled through blue litmus solution.

- ✓ Blue litmus solution turns colourless.

4. TEST FOR CHLORINE GAS.

   Chlorine's presence is confirmed using moist blue litmus paper in which its turned red, and bleached.

   USES OF CHLORINE

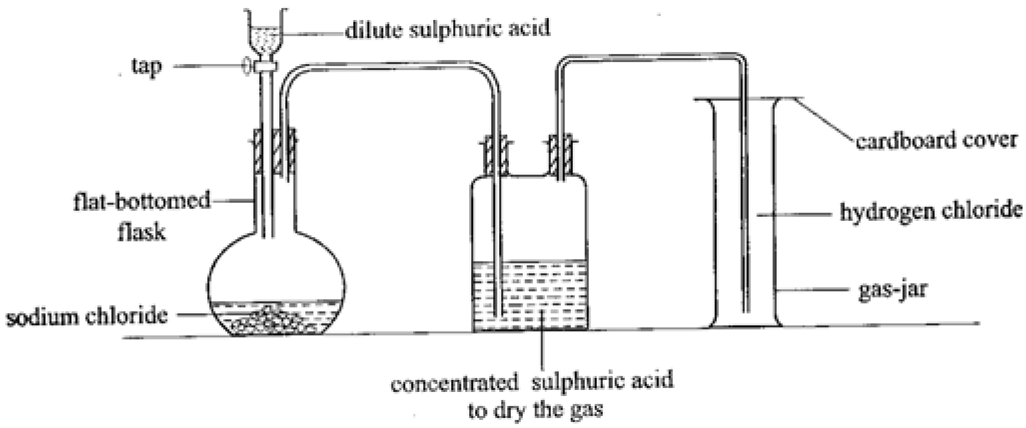
- ✓ Used as a disinfectant in treatment of water.
- ✓ Used as a bleaching agent (used to bleach wood pulp)
- ✓ Used in the manufacture of hydrochloric acid.
- ✓ Used in the manufacture of plastics.
- ✓ Used in the manufacture of chloroform.
- ✓ Used as a degreasing agent(dry washing)
- ✓ Used in manufacture of weed killers(herbicides)
- ✓ Used in manufacture of insecticides e.g. DDT used in fumigation.

  COMPOUNDS OF CHLORINE

  1. HYDROGEN CHLORIDE GAS, HCl

Briefly explain how a dry sample of hydrogen chloride can be prepared in the laboratory. (write equation to illustrate your answer and a diagram is required)

Diagram;



Sodium chloride which is a solid is placed in a flat bottomed flask fitted with a tap funnel and a delivery tube.

Concentrated sulphuric acid which is a liquid is added to sodium chloride through a tap funnel. The white solid (sodium chloride) dissolves readily at room temperature with effervescence of a colourless gas($Hydrogen\ chloridegas$). The gas is passed through concentrated sulphuric acid to dry it since the gas itself is acid. It is then collected by down ward delivery since it is denser than air.

$NaCl(s) + H_2SO_4(l) \longrightarrow NaHSO_4(s) + HCl(g)$

Physical properties of hydrogen chloride.

- ✓ It is denser than air.
- ✓ It is a colourless gas.
- ✓ Turns moist blue litmus paper red i.e its acidic.

Chemical properties of hydrogen chloride .

1. It is highly soluble in water.

   Hydrogen chloride is the second most soluble gas, ammonia being the most soluble and its solubility is demonstrated by the fountain experiment.

   Fountain experiment to demonstrate the very solubility of hydrogen chloride gas in water.

   Diagram

A thick walled round bottomed flask is filled with hydrogen chloride gas and then inverted in water as shown above.

Clip **B** is then opened for a short so as to allow some little water in the flask.

Clip **A** is then opened where water rises by capillarity and comes out of the delivery tube in form of a jet called a fountain.

Explanation;

The little water that is allowed in when clip **B** is opened, absorbs all the hydrogen chloride gas. This creates a vacuum in the flask so that the atmospheric pressure forces the water in the trough to rise up when clip **A** is opened and comes out in form of a jet called fountain.

2. Reaction of hydrogen chloride with ammonia(test for hydrogen chloride gas)

   When a gas jar of hydrogen chloride gas is inverted over that of ammonia, dense white fumes are formed which settle to a white solid.

   $NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$

(a) Name the reagent that can be used to test for hydrogen chloride gas.

- ✓ Concentrated ammonia.

(b) State the observation made above and write the equation for the reaction that would occur

- ✓ Dense white fumes are formed which settle to a white solid.

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$$

3. Reaction of hydrogen chloride with iron.

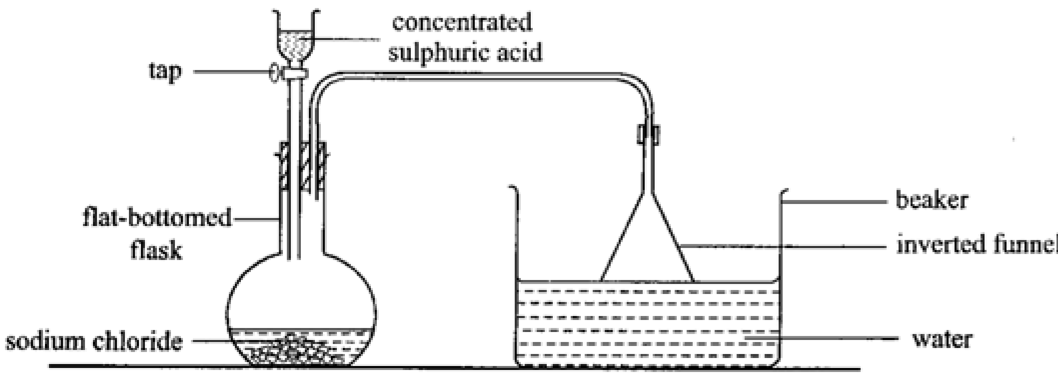
   When dry hydrogen chloride gas is passed over heated iron wire, a white solid and a colourless gas are formed

   $Fe(s) + 2HCl(g) \longrightarrow FeCl_2(s) + H_2(g)$

PREPARATION OF HYDROCHLORIC ACID

Hydrochloric acid is prepared by dissolving hydrogen chloride gas in water. The gas is bubbled through water by means of an inverted funnel to increase the surface area over which the dissolution process takes place and to avoid a problem of sucking back.

Draw a labeled diagram of the set up of apparatus that can be used to prepare a solution of hydrogen chloride in water.



Uses of hydrochloric acid.

- ✓ Used in the production of chloride fertilizers.
- ✓ Used in electroplating.
- ✓ Used in the photographic, textile and rubber industries.
- ✓ Used in removing scales from boilers or for pickling and cleaning of metal products (removing oxides from metal surfaces)

Reactions of dilute hydrochloric acid.

(i) Reaction with iron.

Iron dissolves in dilute nitric acid with effervescence of a colourless gas forming a green solution.

$Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$

(ii) Reaction with carbonates and hydrogen carbonates.

When dilute hydrochloric acid is reacted with carbonates or hydrogen carbonates, they dissolve with effervescence of a colourless gas forming salts and water. E.g

Dilute hydrochloric acid was added to zinc carbonate. State what was observed and write equation for the reaction.

The white solid (powder) dissolves with effervescence of a colourless gas forming a colourless solution.

$ZnCO_3(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + CO_2(g) + H_2O(l)$

(iii) Reaction with oxides.

Dilute hydrochloric acid reacts with basic and amphoteric oxides to form a salt and water. E.g

Dilute hydrochloric acid was added to zinc oxide. State what was observed and write equation for the reaction.

The white solid (powder) dissolved forming a colourless solution.

$ZnO(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2O(l)$

(iv) Reaction with metals

Dilute hydrochloric acid reacts with metals higher than hydrogen in the reactivity series liberating a salt and hydrogen gas. E.g

Zinc metal was added to dilute hydrochloric acid. State what was observed and write the equation for the reaction that took place.

The grey metal dissolved with effervescence of a colourless gas forming a colourless solution.

Dilute hydrochloric acid was added to zinc carbonate. State what was observed and write equation for the reaction.

The white solid (powder) dissolves with effervescence of a colourless gas forming a colourless solution.

$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$

Note;

Hydrogen chloride ionizes only in polar solvents like water but in non polar solvents like benzene, methylbenzene or carbon tetrachloride, it does not and therefore in such solvents hydrogen chloride does not conduct electricity and has no effect on litmus, does not react with metals, carbonates etc.

Aqueous hydrogen chloride reacts with magnesium producing hydrogen, whereas a solution of hydrogen chloride in methylbenzene has no effect on magnesium. Explain this observation.

Being a polar solvent, water causes ionization and ultimately dissociation of hydrogen chloride releasing hydrogen ions and chloride ions into solution.

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

The hydrogen ions are responsible for the reaction of aqueous hydrogen chloride with magnesium forming hydrogen gas.

$Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$

However, methylbenzene is a non polar solvent. It does not cause ionization of hydrogen chloride (i.e. hydrogen chloride remains in its molecular form in methylbenzene).

Aqueous sodium hydrogen carbonate was added separately to solutions of hydrogen chloride in methylbenzene and in water respectively. State what was observed in each case and explain your observations.

With methylbenzene, there is no observation change whereas the aqueous solution gave effervescence.

In methylbenzene, hydrogen chloride exists as a covalent molecule. In aqueous solution, water enhances ionization of hydrogen chloride producing hydrogen ions as follows

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

It is the hydrogen ions that decompose the hydrogen carbonate ions forming carbon dioxide which is the reason for effervescence.

$H^+(aq) + HCO_3^-(aq) \longrightarrow H_2O(l) + CO_2(g)$

Aqueous hydrogen chloride conducts electricity while hydrogen chloride in methyl benzene (toluene) does not. Explain this observation.

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Concentrated hydrochloric acid is commonly used for removing oxides from metal surfaces (pickling). Explain why concentrated nitric acid is not used for the same purpose.

Concentrated nitric acid is a strong oxidizing agent. It would remove oxides from metal surfaces and oxidizes the metal as well.

TEST FOR CHLORIDE ION (Cl^-)

1. **Using lead(II) nitrate solution.**

   To a solution suspected to contain a chloride ion, lead(II) nitrate solution is added followed by dilute nitric acid and the mixture warmed.

   Observation;

   A white precipitate is formed which is insoluble in the acid.

   On warming, the white precipitate dissolves and recrystallizes on cooling.

   Equation;

   $Pb^{2+}(aq) + 2Cl^-(aq) \longrightarrow PbCl_2(s)$

2. **Using silver nitrate solution.**

   To a solution containing a suspected chloride ion, silver nitrate solution is added followed by dilute nitric acid.

   Observation;

   A white precipitate is formed which is insoluble in the acid.

   Equation;

   $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$

   Note;

   The precipitate formed if excess ammonia solution is added, it dissolves forming a colourless solution.

   $AgCl(s) + 2NH_3(aq) \longrightarrow Ag(NH_3)_2^+(aq) + Cl^-(aq)$

SAMPLE QUESTIONS

(a) **Hydrochloric acid reacts with potassium manganate(VII) during the laboratory preparation of chlorine gas.**

   (i) **State the conditions for the reaction and write the equation leading to the formation of chlorine gas.**

   - ✓ Concentrated acid at room temperature.

   Equation for the reaction;

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   ………………………………………………………………………………

(ii) Explain how a pure dry sample of chlorine gas can be obtained using its preparation as stated in (a) (i) above.(No diagram is required)

Chlorine which is produced is bubbled through water, then through concentrated sulphuric acid, which dries the gas before it is collected by down ward delivery.

Water removes the traces of hydrogen chloride because this gas readily dissolves in water.

The concentrated sulphuric acid is hygroscopic, hence absorbs water from chlorine gas which acidic, leaving it as a dry gas

Dry chlorine is collected as stated because it is denser than air.

(b) State and explain how chlorine is prepared on large scale using sodium chloride.(No diagram is required)

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(c) Dilute hydrogen chloride was added drop wise to lead(II) oxide until in small excess and the resultant mixture allowed to stand.

(i) State what was observed and write equation for the reaction that took place.

The yellow solid turned into white crystals.

$$PbO(s) + 2HCl(aq) \longrightarrow PbCl_2(s) + H_2O(l)$$

(ii) From the reaction in © (i) , deduce any conclusion that can be made concerning the composition of hydrogen chloride.

Hydrogen chloride consists of hydrogen and chlorine atoms in the mole ratio 1:1.

(d) Write equation for the reaction between chlorine and;

(i) Heated iron

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(ii) Cold dilute sodium hydroxide solution.

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(a) State what would be observed if chlorine was bubbled through;

(i) Water.

A pale yellow solution formed.

(ii) A solution of potassium bromide.

The colourless solution turned red (or reddish-brown)

(b) (i) Explain your answer in (a) (ii)

Chlorine being more reactive than bromine displaces bromine from its solution forming a red liquid.

Or Chlorine oxidizes bromide ions to bromine which is a red liquid.

(c) Write an equation to show how chlorine can react with;

(i) Dilute potassium hydroxide solution.

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(ii) Turpentine,$C_{10}H_{16}$

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(d) Briefly describe a test you would carry out to confirm the presence of chlorine ions in solution.

Add acidified silver nitrate solution. A white precipitate forms.

$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$

Or $AgNO_3(aq) + Cl^-(aq) \longrightarrow AgCl(s) + NO_3^-(aq)$

(a) Briefly describe how a dry sample of hydrogen chloride can be prepared in the laboratory.(Diagram not required)

Concentrated sulphuric acid is run from a tap funnel onto sodium chloride crystals in a flat bottomed flask with a delivery tube and the mixture heated.

The gas is passed through concentrated sulphuric acid to dry it.

The gas is then collected by down ward delivery since its denser than air.

$$NaCl(aq) + H_2SO_4(l) \longrightarrow NaHSO_4(s) + HCl(g)$$

(b) Hydrogen chloride was bubbled into a solution of lead(II) nitrate.

(i) State what was observed and explain your answer.

White precipitate was formed.

Hydrogen chloride ionises in aqueous solution releasing hydrogen ions and chloride ions. The chloride ions react with lead(II) ions to form lead(II) chloride which is insoluble in water thus precipitated out.

(ii) Write an equation for the reaction that took place.

$Pb(NO_3)_2(aq) + 2HCl(g) \longrightarrow PbCl_2(s) + 2HNO_3(aq)$

Or $Pb^{2+}(aq) + 2HCl(g) \longrightarrow PbCl_2(s) + 2H^+(aq)$

Or $Pb^{2+}(aq) + 2Cl^-(g) \longrightarrow PbCl_2(s)$

(c) Hydrogen chloride is prepared in the laboratory by action of concentrated sulphuric acid on solid **X**.

(i) Identify **X**.

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(ii) State the conditions for the reaction.

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(d) State what would be observed and write equation for the reaction that would take place if hydrogen chloride was;

(i) Held near a bottle containing concentrated ammonia solution.

Observation

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Equation.

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(ii) Passed through silver nitrate solution.

Observation.

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Equation

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(a) When a mixture of concentrated hydrogen chloride in water and a black solid **J** was heated, a greenish-yellow gas was evolved.

(i) Identify **J** and write the name of the greenish-yellow gas

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(ii) Write equation for the reaction that leads to the formation of greenish-yellow gas.

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(b) Write equation only, to show how anhydrous sample of the following iron salts can be prepared.

(i) Iron(II) chloride.

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(ii) Iron(III) chloride

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(c) Manganese(IV) oxide can react with hydrochloric acid . state;

(i) The conditions for the reaction

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(ii) What is observed.

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(d) Write equation for the reaction between manganese(IV) oxide and hydrochloric acid.

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(e) Aqueous solution of the gaseous product obtained in (d) is regarded as ' a bleaching agent'

(i) Name the bleaching agent in the solution of the gaseous product.

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(ii) Write equation for the reaction between a moist blue cloth and the bleaching agent.

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Iron(II) chloride reacts with silver nitrate to form silver chloride according to the equation
$FeCl_2(aq) + 2AgNO_3(aq) \longrightarrow AgCl(s) + Fe(NO_3)_2(aq)$

(a) State what would be observed if silver nitrate solution was added to a solution of iron(II) chloride.

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(b) State what would be observed if the reaction mixture in (a) above was;

(i) Exposed to sun light.

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(ii) Mixed with excess ammonia.

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To an aqueous solution of salt **E** was added silver nitrate solution followed by ammonia solution. In this reaction a white precipitate formed which dissolved in excess ammonia solution and formed a colourless solution.

(a) Identify the anion in **E**

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(b) Write an ionic equation for the reaction;

(i) Between the solution of **E** and silver nitrate solution.

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(ii) Leading to the formation of the colourless solution when the precipitate dissolved in ammonia solution.

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(c) Explain the observation; An aqueous solution of hydrogen chloride gives a white precipitate with silver nitrate, whereas a solution of hydrogen chloride in tetrachloromethane shows no observation change, when treated with silver nitrate solution.

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(a) Dilute hydrochloric acid was added to a clean piece of iron wire. State what was observed.

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(b) The experiment in (a) above was repeated using copper turnings

(i) State what was observed

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(ii) ex plain your observations in (a) and (b)(i)

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(a) state what would be observed and write equation that would take place if hydrogen chloride was bubbled through aqueous;

(i) sodium hydrogen carbonate.

Observation.

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Equation.

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(ii) Silver nitrate.

Observation

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Equation.

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(b) When red flowers were put in a gas jar containing chlorine gas, the flowers turned white. Explain this observation.

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(c) Write equation for the reaction by which hydrogen chloride is prepared in the laboratory and explain why the reaction takes place.

$NaCl(s) + H_2SO_4(l) \quad NaHSO_4(s) + HCl(g)$

Sulphuric acid is stronger acid than hydrochloric acid. It displaces hydrochloric acid, the weaker and more volatile acid from its salt readily.

(d) Chlorine gas was bubbled through iron(II) sulphate solution.

(i) State what was observed.

The green solution turned yellow(Reddish-brown).

(ii) Write the molecular and ionic equation for the reaction

Molecular equation.

$6FeSO_4(aq) + 3Cl_2(g) \longrightarrow 2FeCl_3(aq) + 2Fe_2(SO_4)_3(aq)$

Ionic equation.

$2Fe^{2+}(aq) + Cl_2(g) \longrightarrow 2Fe^{3+}(aq) + 2Cl^{-}(aq)$

(a) Both nitric acid and hydrogen chloride gas can be prepared in the laboratory by reacting sodium salts with sulphuric acid under similar conditions.

(i) State the conditions for the reactions.

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(ii) Write equation for each of these preparations.

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(iii) What property of sulphuric acid is demonstrated in the (a)(ii)?

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(b) Name the substance formed when hydrogen chloride is dissolved in water.

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(c) Explain why aqueous hydrogen chloride is an electrolyte whereas a solution of hydrogen chloride in methylbenzene is a non-electrolyte.

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(a) What is meant by the term ‘halogens’

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(b) Describe the laboratory experiment to show how a dry pure sample of chlorine is prepared from manganese(IV) oxide. (diagram is required)

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(c) Describe the reactions of chlorine with;

(i) Hot concentrated potassium hydroxide solution.

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(ii) Water.

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(iii) Hydrogen sulphide.

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(d) Draw a well labeled diagram for the set up of apparatus that can be used to prepare hydrogen chloride in the laboratory and write equation for the reaction leading to the formation of hydrogen chloride.

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(e) State how you would test for hydrogen chloride.

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(f) Hydrogen chloride was dissolved in tetrachloromethane and water and the solutions tested separately with litmus papers. State what was observed in each case and briefly explain your observation(s). (No equations required).

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(g) Chlorine can be prepared by the reaction of hydrochloric acid with potassium manganate(VII) according to the following equation.

$$2KMnO_4(s) + 16HCl(aq) \longrightarrow 2KCl(aq) + 2MnCl_2(aq) + 5Cl_2(g) + 8H_2O(l)$$

Calculate the mass of potassium manganate(VII) that would be required to react with hydrochloric acid to produce $1120.0cm^3$ of dry chlorine, measured at s.t.p.

$1\ mole\ of\ potassium\ manganate(VII)\ weighs\ 158.0g\ and\ 1\ mole\ a\ gas\ occupies\ 22.4dm^3\ at\ s.t.p$

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(a) A pure dry sample of hydrogen chloride was prepared in the laboratory by adding concentrated sulphuric acid onto a crystalline solid,**Q**, in a flask and then warming the mixture. The gas evolved was passed through a liquid,**Z**, before it was collected;
   i) Identify **Q**
   ii) Name one suitable piece of apparatus by means of which concentrated sulphuric acid was added onto **Q**.
   iii) Name **Z** and state its role.
   iv) Give a reason why **Z** was preferred for its role, which you have stated in (iii)
   v) State the method by which hydrogen chloride was collected and give a reason.

(b) State;
   i) What an aqueous hydrogen chloride is called.
   ii) A suitable procedure for preparing a sample of aqueous hydrogen chloride in the laboratory.

(c) Two equal masses of magnesium powder were added separately to solutions of hydrogen chloride in water and methylbenzene, respectively. State what was observed in each case; and give reasons for each observation that you have stated.

(d) Dry hydrogen chloride was bubbled into silver nitrate solution that was acidified with nitric acid. Write ionic equation for the reaction that took place.

(e) A mixture of manganese(IV) oxide and a concentrated hydrogen chloride solution was heated.
   i) Write equation for the reaction that took place.
   ii) State one practical application of the reaction in (e)(i)

(a) When hydrogen chloride gas was passed through a solution **X,** a white precipitate was formed. The precipitate dissolved when the mixture was heated, but reappeared on cooling the solution to room temperature.
   i) Identify solution **X**
   ii) Write an ionic equation for the reaction that took place between hydrogen chloride and **X**

(b) Silver nitrate solution can react with sodium chloride to form silver chloride according to the following equation;

$Ag^{+}(aq) + Cl^{-}(aq) \longrightarrow AgCl(s)$

Calculate the maximum mass of silver chloride that would be formed if excess sodium chloride solution was added to 20.0cm^3 of a 0.5M silver nitrate solution.

(c) Hydrogen chloride gas was dissolved in two separate test tubes one containing methylbenzene and the other containing water. Then little solid sodium carbonate was added to each test tube mentioned above. State what was observed in the test tube containing

i) Methylbenzene

ii) water

(d) Explain the differences in the observation you have made in © (i) and (ii) above.

(a) A pure dry sample of chlorine was prepared in a fume cupboard in the laboratory by adding concentrated hydrochloric acid from a tap funnel onto a solid, **R** in a flask and then heating the mixture. The gas evolved, was passed through water, then through liquid, **T**, before it was collected.

i) Identify **R**

ii) State why the preparation of chlorine was carried out in fume cupboard.

iii) Name **T** and state its role.

iv) Give a reason why **T** was preferred for its role, which you have stated in (iii)

v) Why was chlorine passed through water?

vi) State, giving a reason, a method by which chlorine was collected.

vii) Write equation for the reaction that led to the formation of chlorine.

(b) Chlorine was bubbled through saturated potassium iodide solution, which was containing tetrachloromethane and the mixture shaken, and left to stand for some time.

i) State what was observed.

ii) Write equation for the reaction that took place.

(c) When exposed to bright sun light, chlorine water produces a colourless gas.

i) Name the gas

ii) Explain briefly, how the gas was formed.

(d) Write equation for the reaction that can take place between iron and chlorine.

(e) Give a reason why the reaction in (d) above is regarded as oxidation.

(a) Write equation for the synthesis of the chloride of;

i) Hydrogen

ii) Magnesium

(b) At room temperature hydrogen chloride is a gas, whereas magnesium chloride is a solid. Give a reason.

(c) Some drops of acidified silver nitrate solution were added separately into test tubes containing aqueous hydrogen chloride and magnesium chloride.

i) State what was observed in each case.

ii) Give an account of what was observed.(No diagram is reqiured)

(a) Write equation for the reaction that takes place when chlorine is bubbled into water.

(b) A glass tube filled with aqueous solution of chlorine was inverted in a beaker of water and left to stand for some time in ultraviolet light.

i) State what was observed.

ii) Explain your observation in (b)(i)

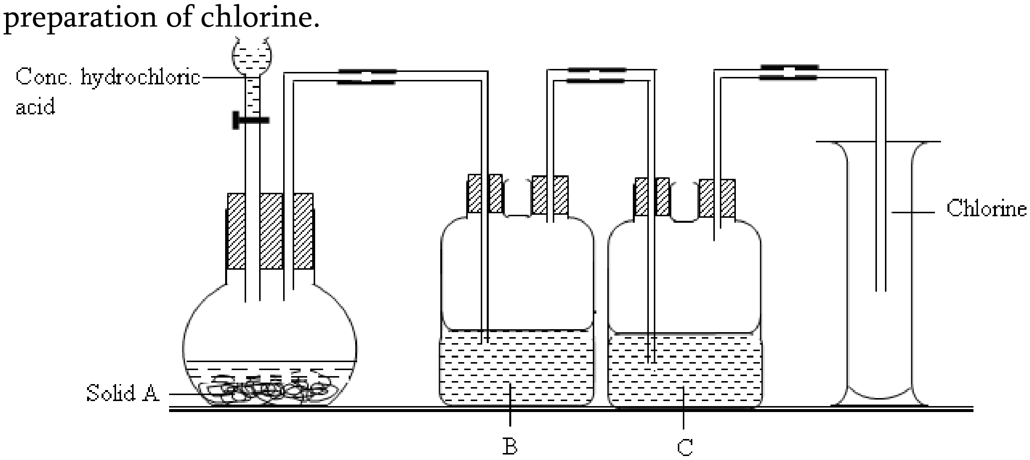
(c) State the condition(s) in each case and write equation for the reaction of chlorine with;

i) Sulphur.

ii) turpentine

(d) write an ionic equation for the reaction which can show that chlorine is more reactive than bromine.

(a) The diagram below shows an arrangement of the apparatus for the laboratory preparation of chlorine.



(i) Identify liquids

B

C

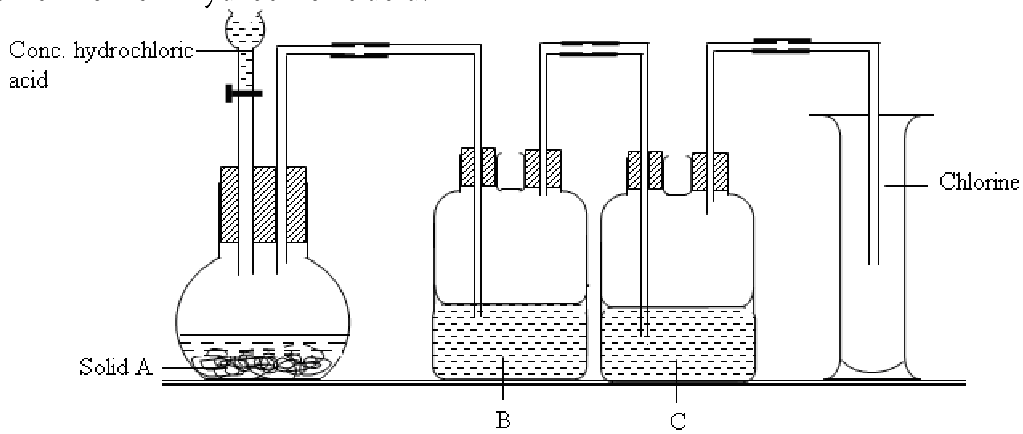
(ii) What is the function of liquid C?

(iii)Why is chlorine collected as shown?

(b) Write an equation for the reaction between chlorine and aqueous iron (II) chloride.

(c) State one use of chlorine.

The diagram in Fig.1 shows a set-up of the apparatus for the laboratory preparation of dry chlorine from hydrochloric acid.



(a) (i) Name substances A, B and C.

A.

B.

C.

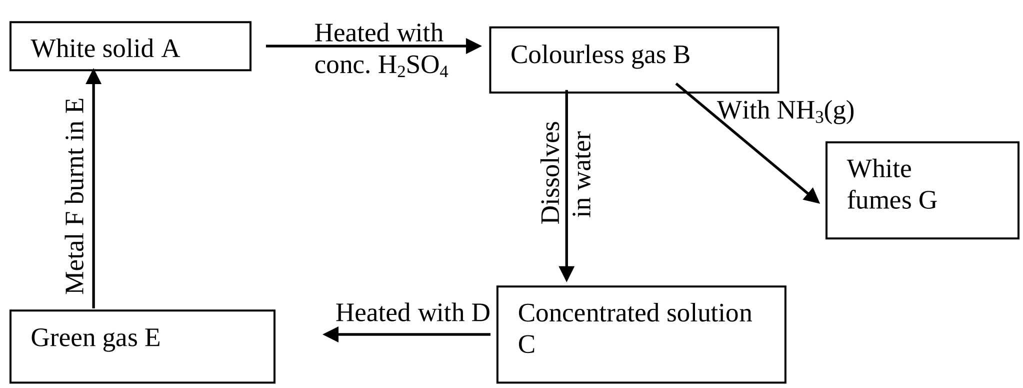
(ii) State the role of substance B.

(b) State the conditions for the reaction.

(c) Write equation for the reaction.

(d) A solution of hydrogen chloride gas in methylbenzene does not turn litmus red but a solution of the same gas in water turns litmus red. Explain this observation (03 marks)

(e) The reaction scheme shows a series of reactions.



Identify A, B, C, D, E, F and E giving reasons. (05 marks)

(b) A white solid **W** sublimed when heated. **W** reacted with concentrated sulphuric acid yielding a colourless gas **X,** which gave dense white fumes with concentrated ammonia solution. An aqueous solution of **W** reacted with both dilute solutions of sodium hydroxide and ammonia forming white precipitates. The precipitate formed with dilute sodium hydroxide dissolved in excess alkali whereas the precipitate formed with dilute ammonia solution did not dissolve in excess ammonia.

Identify

(i) Solid **W** (½mark)

……………………………………………………………………………………………

(ii) gas **X** (½ mark)

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(c) Write an ionic equation to show the reaction of **W** with

(i) dilute ammonia solution (1 ½ marks)

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(ii) concentrated sulphuric acid (1 ½ marks)

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2 .Manganese (IV) oxide is used in the laboratory preparation of chlorine and oxygen.

(a) Name one substance that when treated with manganese (IV) oxide can be used in the laboratory preparation of

(i) Chlorine (½ mark)

……………………………………………………………………………………………

(ii) oxygen. (½ mark)

……………………………………………………………………………………………

(b) Write equation to show the reaction in which manganese (iv) oxide together with the substance that you have named in (a)produce

(i) oxygen (1 ½ marks)

……………………………………………………………………………………………

(ii) chlorine (1 mark)

……………………………………………………………………………………………

(c) When heated in a current of dry oxygen or chlorine, iron undergoes oxidation. Write equation for the oxidation of iron by

(i) oxygen

……………………………………………………………………………………………

(ii) chlorine

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a) Chlorine gas can be prepared in the laboratory by heating concentrated hydrochloric acid and substance **Z**.

i. Identify **Z**.

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ii. Write the equation for the reaction leading to the formation of chlorine.

b) Dry chlorine gas was passed separately over dry and damp red litmus paper. State what is observed with;

i. Dry red litmus paper.

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ii. Damp red litmus paper.

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c) Write equation for the reaction in b(ii) above.

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SULPHUR AND ITS COMPOUNDS.

SULPHUR

Sulphur is a yellow solid with atomic number 16 and mass number32.

Its electronic configuration is 2: 8: 6.

Therefore it belongs to group(VI) of the periodic table because it has six electrons in its outer most energy level.

It belongs to period 3 of the periodic table because it has three energy levels containing electrons.

EXTRACTION OF SULPHUR

Describe the Frasch's process of extraction of sulphur (Diagram is required)

- Three concentric pipes are lowered underground through hole that has been drilled into sulphur deposits.
- Super heated water is forced down through the outer pipe.
- The water melts sulphur. Hot compressed air is then pumped down through the inner most pipe.

- Molten sulphur, mixed with air and water is forced up through the central pipe. The mixture is run into tanks from where is solidifies into roll sulphur, yellow in colour.

VULCANISATION OF RUBBER

Thisis the process of hardening of rubber by heating it with sulphur.

(a) Describe briefly the process of vulcanization of rubber.

- Natural rubber is mixed with the required amount of sulphur and the mixture is boiled.
- Sulphur adds to the double bonds in the rubber forming vulcanized rubber which is hard, elastic and durable.

(b) What is the importance of vulcanization of rubber?

- To make rubber hard, elastic and durable.

(c) State the uses of vulcanized rubber.

- Used to make shoe soles.
- Used to make tyres of cars.
- Used to make insulators.

ALLOTROPES OF SULPHUR.

Define the following terms;

(i) Allotropy.

- This is the existence of an element in two or more different forms without changing the physical state.

(ii) Allotropes.

- These are various forms of an element which exist in more than one form without change of state.

(a) List the allotropes of sulphur.

- Amorphous sulphur.
- Monoclinic sulphur.
- Rhombic sulphur.
- Plastic sulphur.
- Colloidal sulphur.

(b) State two crystalline allotropes of sulphur.

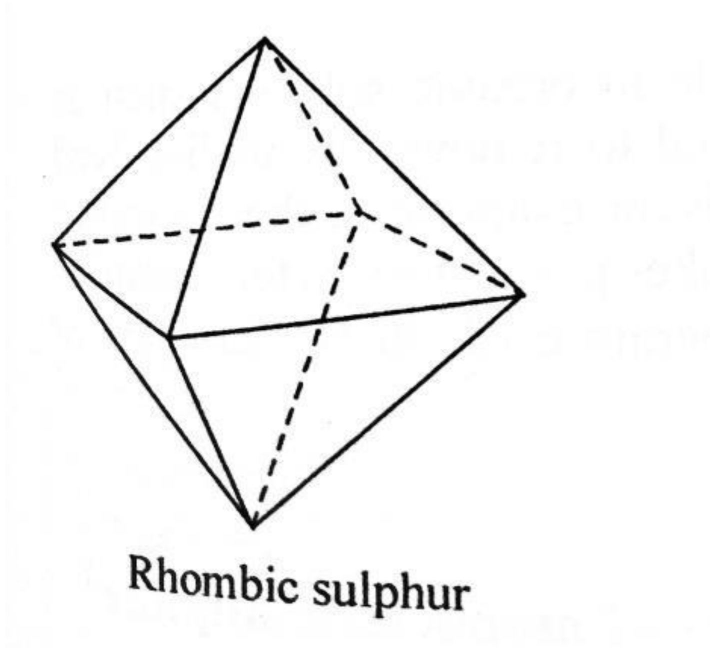
- Monoclinic sulphur.
- Rhombic sulphur.

(c) State the differences between rhombic sulphur and monoclinic sulphur.

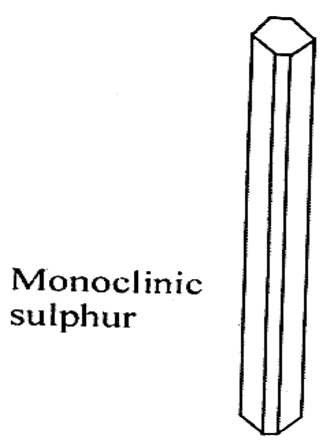
Rhombic sulphur	***Monoclinic sulphur***
➢ Crystals are in octahedral form.	Crystals are in needle shaped form.
➢ Has a density of $2.08gcm^{-3}$.	Has a density of $1.98gcm^{-3}$.
➢ Crystals are stable below 96^0C.	Crystals are stable above 96^0C(unstable at a temperature below 96^0C).
➢ Has a melting point of 114^0C.	Has a melting point of 119^0C.
➢ Its bright yellow.	Its pale yellow.

STRUCTURES OF RHOMBIC SULPHUR AND MONOCLINIC SULPHUR.

Rhombic sulphur.



Monoclinic sulphur.



PREPARATION OF MONOCLINIC AND RHOMBIC SULPHUR

Describe how a sample of monoclinic sulphur can be prepared in the laboratory.

Diagram.

Sand is placed on a sand bath and heated strongly. A boiling tube containing a saturated solution of sulphur and methylbenzene is placed in the sand bath that is being heated.
A boiling tube is fitted with a long tube to carry away a vapour of methylbenzene. The mixture is left to cool. A pale yellow needle-like structure crystallizes out of the solution.
The pale yellow solid formed is a pure sample of monoclinic sulphur.

Describe how a sample of Rhombic sulphur can be prepared. (Diagram not required).

Some powdered sulphur is dissolved in carbon disulphide in a boiling tube. Its then placed in a beaker after extinguishing all the flames in the area around. The solution is filtered into another dry beaker and a piece of clean filter paper is placed on top of the beaker.
Some small holes are pierced in the filter paper and the setup is placed near a window for a day to allow the carbon disulphide to evaporate. Large rhombic crystals of sulphur are formed having an octahedral shape.

PROPERTIES OF SULPHUR

1. **Physical properties.**
    - ✓ It's a yellow non-metal.
    - ✓ It's insoluble in water but soluble in organic solvents like carbon disulphide.
    - ✓ It is a poor conductor of heat and electricity. This is because sulphur lacks mobile electrons.
2. **Chemical properties.**

    Reaction with metals.

    i) **Reaction with iron.**

A mixture of iron filings and sulphur was heated strongly.

(a) **State what was observed**

- The mixture glowed red hot and a black solid formed.

(b) **Write the equation for the reaction.**

- $Fe(s) + S(s) \longrightarrow FeS(s)$

(c) **Name the product formed.**

- Iron(II) sulphide.

ii) **Reaction with zinc.**

A mixture of zinc and sulphur was heated strongly.

(a) State what was observed.

-

(b) Write the equation for the reaction.

- $Zn(s) + S(s) \longrightarrow ZnS(s)$

iii) **Reaction with copper.**

Copper was heated strongly with sulphur.

(a) State what was observed.

-

(b) Write the equation for the reaction.

- $Cu(s) + S(s) \longrightarrow CuS(s)$

REACTION OF SULPHUR WITH NON METALS

1. REACTION WITH OXYGEN.

Sulphur was burnt in air.

(a) State what was observed.

- The yellow solid burnt with a blue flame and leaves misty fumes of the gas.
  Note; The mist is due to traces of sulphur trioxide formed simultaneously.

(b) Write the equation for the reaction that took place.

- $S(s) + O_2(g) \longrightarrow SO_2(g)$

2. REACTION WITH HYDROGEN.

Hydrogen gas was reacted with sulphur.

(a) State what was observed.

- A colourless gas with rotten egg smell was produced.

(b) Write the equation for the reaction that took place.

- $H_2(g) + S(s) \longrightarrow H_2S(g)$

(c) State the condition under which sulphur reacts with oxygen.

- Burning sulphur in oxygen.

3. REACTION WITH CARBON.

Carbon was heated with sulphur.

(a) State what was observed.

-

(b) Write equation for the reaction that took place.

- $C(s) + 2S(s) \longrightarrow CS_2(l)$

4. REACTION WITH ACIDS.

(A) WITH NITRIC ACID

Nitric acid was added to sulphur powder in a test tube and the mixture warmed.

(a) State the condition(s) for the reaction.

- Concentrated acid.

(b) State what was observed.

- The powder dissolved with effervescence of reddish-brown fumes.

(c) Write the equation for the reaction that took place.

- $S(s) + 6HNO_3(aq) \longrightarrow H_2SO_4(aq) + 6NO_2(g) + 2H_2O(l)$

(d) Explain your observation above.

- Concentrated nitric acid is an oxidizing agent, so it oxidizes sulphur to sulphuric acid and its self reduced to nitrogen dioxide seen as reddish-brown fumes.

(B) WITH SULPHURIC ACID.

Sulphuric acid was reacted with sulphur.

(a) State the condition(s) for the reaction.

- Sulphuric acid must be concentrated.

(b) State what was observed.

- The yellow solid dissolved with effervescence of a colourless gas with irritating smell.

(c) Write the equation for the reaction.

- $S(s) + 2H_2SO_4(l) \longrightarrow 3SO_2(g) + 2H_2O(l)$

(d) **Explain your observations above.**

- Concentrated sulphuric acid is an oxidizing agent, so it oxidizes sulphur to sulphur dioxide seen as bubbles of a colourless gas and its self reduced to water, a colourless liquid.

USES OF SULPHUR

- ✓ Used in manufacture of sulphuric acid.
- ✓ Used in vulcanization of rubber.

- ✓ Used to make fungicides.
- ✓ Used in production of detergents.
- ✓ Used in manufacture of gun powder, fireworks.
- ✓ Used to manufacture carbon disulphide, sodium thiosulphate used in photography.
- ✓ Used in manufacture of ointments which is used to treat skin diseases.

Describe an experiment to show that rhombic sulphur and monoclinic sulphur are allotropes of sulphur.

OR

Describe briefly, an experiment in the laboratory to show that rhombic sulphur and monoclinic sulphur consists of sulphur atoms only.

- Equal masses of rhombic and monoclinic sulphur are separately burnt in pure oxygen. They yield equal masses of sulphur dioxide.

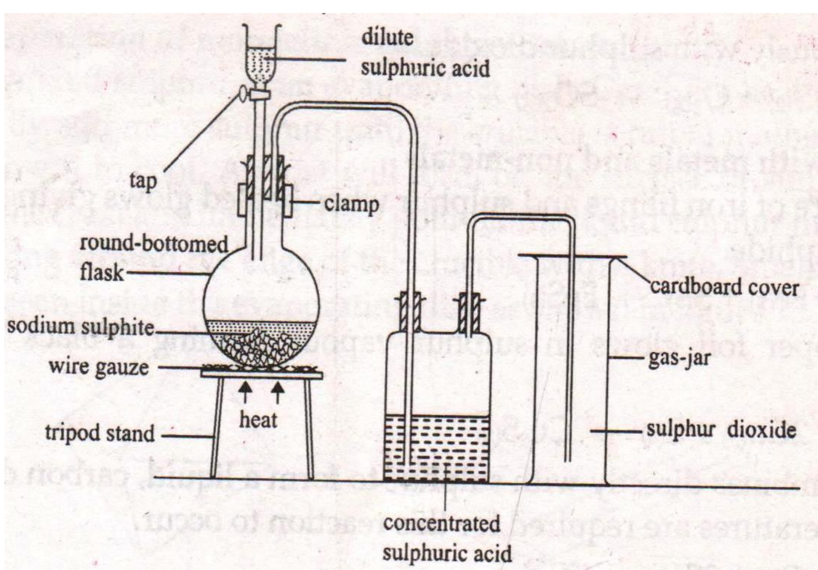
  $S(s) + O_2(g) \longrightarrow SO_2(g)$

  A test is carried out with a reagent such as acidified potassium dichromate, to confirm that the product is sulphur dioxide.

COMPOUNDS OF SULPHUR

1. ***SULPHUR DIOXIDE GAS, SO_2***

(a) With the aid of a labeled diagram, explain how a pure dry sample of sulphur dioxide can be prepared in the laboratory.



- Dilute sulphuric acid is added from a tap funnel because it is a liquid to sodium sulphite in a flat bottomed flask because it is a solid and sulphur dioxide gas is produced at room temperature.
- The gas is passed through concentrated sulphuric acid to dry it because the gas is acidic.
- **The** dry gas is collected by down ward delivery because it is denser than air.

(b) Write the equation for the reaction that took place.

- $Na_2SO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + SO_2(g) + H_2O(l)$
  OR
- $Na_2SO_3(s) + 2H^+(aq) \longrightarrow 2Na^+(aq) + SO_2(g) + H_2O(l)$
  OR
- $SO_3^{2-}(s) + 2H^+(aq) \longrightarrow SO_2(g) + H_2O(l)$

Note; Dilute hydrochloric acid can be used instead of dilute sulphuric acid.
Instead of using sodium sulphite, it is also possible to prepare the gas by using copper turnings and concentrated sulphuric acid.

Procedure:

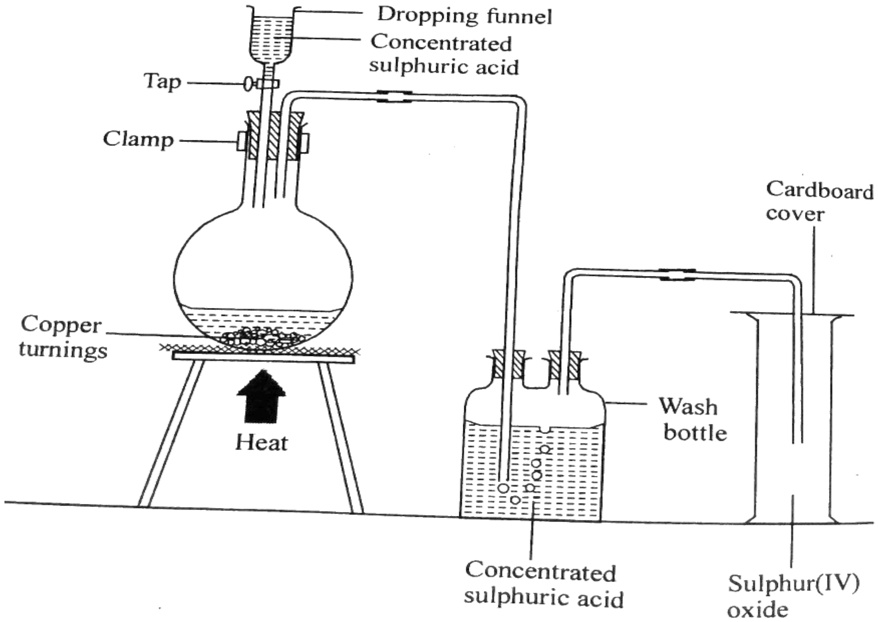
Copper turnings are placed in a round bottomed flask and the apparatus set up as shown above.

Concentrated sulphuric acid is poured into the flask using a dopping funnel until copper turnings are covered.

The flask is then heated.

When the reaction mixture in the flask gets hot, effervescence is observed and a colourless gas is produced.

The gas is passed through concentrated sulphuric acid to remove any moisture, thus drying it. It is collected by downward delivery since it is denser than air.



$Cu(s) + 2H_2SO_4(l) \longrightarrow CuSO_4(aq) + SO_2(g) + 2H_2O(l)$

Hydrochloric acid reacts with sodium sulphite to form a gas **Q**

(a) Identify Q.

- Sulphur dioxide gas.

(b) State the condition(s) under which the reaction takes place.

- Dilute acid.
- Heat or room temperature.

(c) Write the equation leading to the formation of Q

- $Na_2SO_3(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + SO_2(g) + H_2O(l)$

TEST FOR SULPHUR DIOXIDE GAS

State the reagents that can be used to identify sulphur dioxide and state the corresponding observations.

Reagent;

(i) Acidified potassium dichromate solution.

Observation; Acidified potassium dichromate solution turns from orange to green.

(ii) Acidified potassium manganate(VII) solution.

Observation; Acidified potassium manganate(VII) solution turns from purple to colourless.

USES OF SULPHUR DIOXIDE

- ✓ Used in the manufacture of sulphuric acid by the contact process.
- ✓ Used as a bleaching agent in the paper industries.
- ✓ Used as a fumigant for houses.
- ✓ Used as a coolant in refrigerators.
- ✓ Used as a preservative of some liquids such as orange juice where it reacts with oxygen and prevents oxidation of the liquid.

PHYSICAL PROPERTIES OF SULPHUR DIOXIDE GAS.

- ✓ It's a colourless gas.
- ✓ Has an irritating smell.
- ✓ Is denser than air.
- ✓ It's fairly poisonous.
- ✓ Turns moist blue litmus paper red and later bleaches it. This means that sulphur dioxide is acidic and a bleaching agent.

CHEMICAL PROPERTIES OF SULPHUR DIOXIDE GAS.

1. BLEACHING ACTION OF SULPHUR DIOXIDE GAS.

Sulphur dioxide is a bleaching agent, thus its solution in water would bleach the dye by taking the oxygen from it.

The dye is therefore converted to a colourless compound.

$SO_2(g) + 2H_2O(l) + dye \longrightarrow H_2SO_4(aq) + (dye + 2H)$

Alternatively

Sulphur dioxide dissolves in water to form sulphurous acid.

$SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$

The sulphurous acid formed reduces the coloured flower (dye) by removing oxygen atom, hence dye bleached.

$dye + H_2SO_3(aq) \longrightarrow (dye - O) + H_2SO_4(aq)$

2. REACTION SULPHUR DIOXIDE GAS WITH BURNING MAGNESIUM.

(a) **State what would be observed if burning magnesium is lowered into a gas jar containing sulphur dioxide.**

- The grey solid (magnesium) continues to burn with a bright flame forming a white solid and a yellow solid formed.

(b) **Write the equation for the reaction.**

- $2Mg(s) + SO_2(g) \longrightarrow 2MgO(s) + S(s)$

(c) **Explain your observation in (a) above.**

- Burning magnesium produces a lot of heat energy that decomposes sulphur dioxide into sulphur, a yellow powder and oxygen. The oxygen reacts with magnesium forming magnesium oxide, a white solid.

N.B. This reaction shows that sulphur dioxide is an oxidizing agent. Magnesium is oxidized to magnesium oxide while sulphur dioxide is reduced to sulphur.

3. REACTION OF SULPHUR DIOXIDE GAS WITH HYDROGEN SULPHIDE GAS.

A gas jar containing sulphur dioxide gas was inverted over one of hydrogen sulphide.

(a) **State what was observed.**
   - A yellow solid and a colourless condensate formed.

(b) **Write the equation for the reaction that took place.**
   - $SO_2(g) + 2H_2S(g) \longrightarrow 3S(s) + 2H_2O(l)$

(c) **Explain your observation above.**
   - Sulphur dioxide is an oxidizing agent. It oxidizes hydrogen sulphide to sulphur, a yellow solid and its self reduced water, a colourless condensate.

4. REACTION OF SULPHUR DIOXIDE GAS WITH SODIUM HYDROXIDE SOLUTION.

   Sodium hydroxide reacts with sulphur dioxide under two conditions; excess sulphur dioxide and limited.
   In limited addition, sodium sulphite is formed.
   $2NaOH(aq) + SO_2(g) \longrightarrow Na_2SO_3(aq) + H_2O(l)$
   In excess addition, sodium hydrogen sulphite is formed.
   $Na_2SO_3(aq) + H_2O(l) + SO_2(g) \longrightarrow 2NaHSO_3(aq)$
   over all equation.
   $NaOH(aq) + SO_2(g) \longrightarrow NaHSO_3(aq)$

5. SULPHUR DIOXIDE AS A REDUCING AGENT.

   (i) **Reaction with acidified potassium dichromate solution.**

Sulphur dioxide was bubbled through a solution of acidified potassium dichromate.

(a) **State what was observed and explain your observation.**
   - Sulphur dioxide turns acidified potassium dichromate solution from orange to green.
   - Sulphur dioxide is a reducing agent. It reduces orange potassium dichromate to chromium(III) sulphate which is green.
   OR
   - Potassium dichromate(VI) oxidizes sulphur dioxide in the presence of water to sulphuric acid, being its self reduced to green chromium(III) sulphate.

$3SO_2(g) + Cr_2O_7^{2-}(aq) + 2H^+(aq) \longrightarrow 3SO_4^{2-}(aq) + 2Cr^{3+}(aq) + H_2O(l)$

When sulphur dioxide reacts with acidified potassium dichromate solution, there was a colour change from orange to green.
Name the ions responsible for;

i) **Orange colour.**
- Chromium(VI) ion.

ii) **Green colour.**
- Chromium(III) ion.

(ii) **Reaction with iron(III) sulphate solution.**

State what would be observed and explain your what happens if sulphur dioxide is passed through iron(III) sulphate solution.

- Iron(III) sulphate solution turned from brown to green.
- Sulphur dioxide reduces brown iron(III) sulphate solution to pale green iron(II) sulphate solution and its self oxidized to sulphuric acid.
  $Fe_2(SO_4)_3(aq) + SO_2(g) + 2H_2O(l) \longrightarrow 2FeSO_4(aq) + 2H_2SO_4(aq)$
  OR
  $2Fe^{3+}(aq) + 2H_2O(l) + SO_2(g) \longrightarrow 2Fe^{2+}(aq) + SO_4^{2-}(aq) + 4H^+(aq)$

(iii) **Reaction of sulphur dioxide with concentrated nitric acid.**

State what would be observed and explain what happen if sulphur dioxide is passed through concentrated nitric acid.

- Brown fumes are formed.
- Concentrated nitric acid oxidizes sulphur dioxide in the presence of water to sulphuric acid and its self reduced to nitrogen dioxide, the brown fumes.
  $SO_2(g) + 2HNO_3(aq) \longrightarrow H_2SO_4(aq) + 2NO_2(g)$

(iv) **Reaction of sulphur dioxide with potassium manganate(VII)**

State what would be observed and explain what happens if sulphur dioxide is bubbled through potassium manganate(VII)

- The solution turns from purple to colourless.
- Potassium manganate(VII) oxidizes sulphur dioxide in the presence of water to sulphuric acid and its self reduced to manganese(II) sulphate, a colourless solution.

$5SO_2(g) + 2MnO_4^-(aq) + 2H_2O(l) \longrightarrow 5SO_4^{2-}(aq) + 2Mn^{2+}(aq) + 4H^+(aq)$

6. ***REACTION OF SULPHUR DIOXIDE WITH HALOGENS***

(a) **State what would be observed if sulphur dioxide was bubbled through aqueous solutions of the following and in each case write the equation for the reaction.**

(i) **Chlorine.**

- The greenish-yellow solution turns to colourless.
- $SO_2(g) + 2H_2O(l) + Cl_2(g) \longrightarrow H_2SO_4(aq) + 2HCl(aq)$

(ii) Bromine.

- The reddish-brown solution turns to colourless.
- $SO_2(g) + 2H_2O(l) + Br_2(l) \longrightarrow H_2SO_4(aq) + 2HBr(aq)$

(iii) Iodine.

- The brown solution turned to colourless.
- $SO_2(g) + 2H_2O(l) + I_2(s) \longrightarrow H_2SO_4(aq) + 2HI(aq)$

(b) State the property shown by sulphur dioxide above.

- Reducing property.

Sulphur dioxide was reacted with oxygen gas.

(a) State what was observed.

- Misty fumes are formed. Or white fumes.

(b) Write the equation for the reaction.

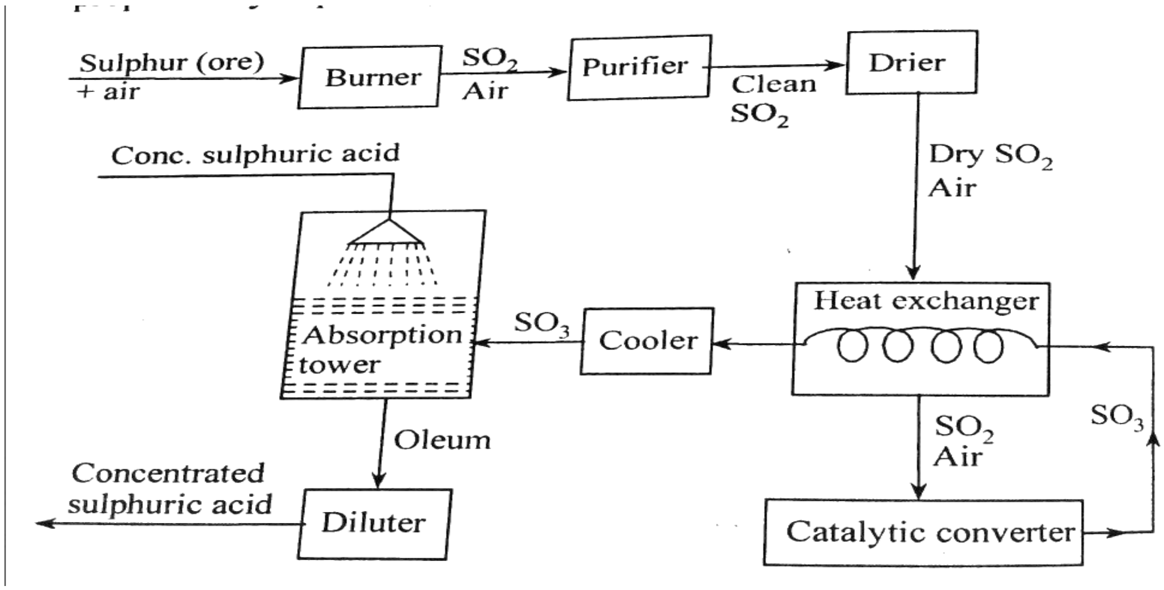
- $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

SULPHURIC ACID, H_2SO_4

Sulphuric acid is a dibasic mineral acid.
It is a dense oily liquid when concentrated with a density of $1.83gcm^{-3}$.
It decomposes at its boiling point of 330^0C forming white fumes.
$H_2SO_4(l) \rightleftharpoons H_2O(l) + SO_3(g)$
Note; A dibasic acid is an acid which produces two hydrogen ions when one mole of it is dissolved in water.
Or
A dibasic acid is an acid when produces two hydrogen ions when one mole of it is ionized in aqueous solution.

INDUSTRIAL PREPARATION OF SULPHURIC ACID

Describe briefly how sulphuric acid can be manufactured on large scale. (Diagram is required)



Sulphuric acid is manufactured on large scale by the contact process.
Sulphur is burnt in excess air to produce sulphur dioxide.
$S(s) + O_2(g) \longrightarrow SO_2(g)$
The mixture of sulphur dioxide and excess air is purified. This is done so as to remove the impurities e.g. dust that would poison the catalyst. I.e. making the catalyst ineffective.
The gas is then passed over vanadium(V) oxide. This occurs at low temperature and high pressure ($temperature\ of 450^0C\ and\ pressure\ of\ 2\ atmospheres$) where sulphur trioxide is formed.
$2SO_2(s) + O_2(g) \rightleftharpoons 2SO_3(g)$
The sulphur trioxide is then dissolved in concentrated sulphuric acid to produce a fuming liquid called **oleum.**
$SO_3(g) + H_2SO_4(l) \longrightarrow H_2S_2O_7(l)$
The oleum formed is diluted with correct amounts of distilled water to form ordinary concentrated sulphuric acid.
$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(l)$
State the conditions for the maximum yield of sulphur trioxide.

- Low temperature(temperature of about $450^0C - 500^0C$)
- High pressure(pressure of about 2-3 atmospheres)

Why is vanadium(V) oxide preferred as a catalyst in the contact process instead of platinised asbestos.

- Vanadium(V) oxide is less expensive.
- It is not easily poisoned by impurities.

Explain why during the manufacture of sulphuric acid, sulphur trioxide is not dissolved directly in water.

- Sulphur trioxide dissolves in water to give out a lot of heat because the reaction is exothermic. The heat is enough to vapourise liquid sulphuric acid formed into sulphuric acid vapour which is dangerous.

Note; During the contact process, sulphur dioxide can also be prepared by burning hydrogen sulphide obtained from crude oil or burning coal in air.
It can also be obtained by roasting sulphide ores e.g. zinc sulphide, iron pyrites.
$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$
$4FeS_2(s) + 11O_2(g) \longrightarrow 2Fe_2O_3(s) + 8SO_2(g)$

(a) In the manufacture of sulphuric acid, sulphur trioxide is not dissolved in water, but another solvent.

(i) State why water is not used as a solvent.

Reaction is exothermic and there is formation of misty fumes of sulphuric acid (sulphuric acid vapour) which are dangerous.

(ii) Write equation(s) to show the formation of sulphuric acid from sulphur trioxide.

$SO_3(g) + H_2SO_4(l) \longrightarrow H_2S_2O_7(l)$
$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(l)$

(b) Write the equation for the reaction between sulphuric acid and hydrogen bromide.

$2HBr(g) + H_2SO_4(l) \longrightarrow Br_2(aq) + SO_2(g) + 2H_2O(l)$

Note;
When mixing concentrated sulphuric acid with water, it is very important to add the acid to the water and **NOT** water to the acid. This is because heat is given out changes some of the water explosively to steam and scatters the acid.
The flow chart below shows the steps used in the manufacture of sulphuric acid by the contact process.

The following flow chart shows the steps in the manufacture of sulphuric acid by the contact process.

(a) Write an equation for the reaction that takes place in STEP I.

$S(s) + O_2(g) \longrightarrow SO_2(g)$

(b) Why is STEP II necessary?

It is necessary to remove the impurities from sulphur dioxide, which may poison the catalyst and prevent it from working.

(c) Name the;

(i) Drying agent in STEP III.

Concentrated sulphuric acid.

(ii) Catalyst in STEP IV.

Vanadium(V) oxide.

(d) Describe the process that takes place in STEP V.

Sulphur trioxide is dissolved in concentrated sulphuric acid to produce a fuming liquid, oleum.

$SO_3(g) + H_2SO_4(l) \longrightarrow H_2S_2O_7(l)$

Oleum is diluted with correct amount of water to give concentrated sulphuric acid.

$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(l)$

USES OF SULPHURIC ACID

- ✓ Used in car batteries and accumulators as an electrolyte.
- ✓ Used in the manufacture of fertilizers e.g. ammonium sulphate.
- ✓ Used in extraction of metals and also cleaning them prior to plating.
- ✓ Used in manufacture of paint.
- ✓ Used in manufacture of detergents.

PROPERTIES OF SULPHURIC ACID

Concentrated sulphuric acid is a colourless liquid, which does not show any acidic properties unless water is added.

1. *SULPHURIC ACID AS A STRONG ACID.*

Sulphuric acid behaves as a strong acid in dilute concentration.

i) Electropositive metals liberate hydrogen from dilute sulphuric acid.

$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$

$Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$

ii) It reacts with bases to form salt and water only.

$ZnO(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2O(l)$

$2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$

iii) Reacts with carbonates and hydrogen carbonates with effervescence of a colourless gas, carbon dioxide.

$$Na_2CO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$$
$$2NaHCO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$$

2. *SULPHURIC ACID AS AN OXIDISING AGENT.*

When concentrated and hot, it acts as an oxidizing agent to both metals and non metals and it is reduced to sulphur dioxide.

(a) It oxidizes copper to copper(II) sulphate.

$$Cu(s) + H_2SO_4(l) \longrightarrow CuSO_4(aq) + 2H_2O(l) + SO_2(g)$$

Reaction with zinc and iron produces similar results.

Sulphuric acid was reacted with copper

(i) State the condition(s) for the reaction.

- Concentrated acid.
- Hot acid.

(ii) State what was observed.

- The brown solid dissolved with bubbles of a colourless gas forming a blue solution.

(iii) Write the equation for the reaction that took place.

- $Cu(s) + H_2SO_4(l) \longrightarrow CuSO_4(aq) + 2H_2O(l) + SO_2(g)$

(iv) Explain your observation in (ii) above.

- Concentrated sulphuric acid is an oxidizing agent. It oxidizes brown copper to copper(II) sulphate, a blue solution and itself is reduced to sulphur dioxide, seen as bubbles of a colourless gas.

(b) It oxidizes sulphur and carbon to their oxides.

$$S(s) + 2H_2SO_4(l) \longrightarrow 2H_2O(l) + 3SO_2(g)$$
$$Cu(s) + 2H_2SO_4(l) \longrightarrow CO_2(g) + 2H_2O(l) + 2SO_2(g)$$

(c) Reaction with Hydrogen sulphide.

Hydrogen sulphide was bubbled through concentrated sulphuric acid.

(i) State what was observed.

- A yellow solid and bubbles of a colourless gas.

(ii) Write the equation for the reaction.

- $H_2S(g) + H_2SO_4(l) \longrightarrow S(s) + 2H_2O(l) + SO_2(g)$

(iii) Explain your observation in (i) above.

- Concentrated sulphuric acid is an oxidizing agent. It oxidizes hydrogen sulphide to sulphur, a yellow solid and its self reduced to sulphur dioxide which is seen as colourless bubbles.

3. *SULPHURIC ACID AS A DEHYDRATING AGENT*.

It behaves as a dehydrating agent when concentrated. Concentrated sulphuric acid has a very high affinity for water and can remove water from substances including air i.e. hygroscopic. It can be used as a drying agent for most gases.

(a) *REACTION WITH SUGAR(SUCROSE)*

When concentrated sulphuric acid is poured onto sugar (sucrose) in a beaker. The sugar turns yellow, then brown and finally a black spongy mass of carbon rises filling the beaker. Steam is given off and the whole mass becomes very hot.

$C_{12}H_{22}O_{11}(s) \longrightarrow 12C(s) + 11H_2O(l)$

Similar reactions take place when other carbohydrates are used.

$C_6H_{12}O_6(s) \longrightarrow 6C(s) + 6H_2O(l)$

a) State the conditions under which sulphuric acid react with;

(i) Sucrose, $C_{12}H_{22}O_{11}$

- Concentrated acid.

(ii) Zinc oxide.

- Dilute acid.

b) Write the equation for the reaction of sulphuric acid with;

(i) Sucrose.

$C_{12}H_{22}O_{11}(s) \longrightarrow 12C(s) + 11H_2O(l)$

(ii) Zinc oxide.

$ZnO(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2O(l)$

c) State the property of sulphuric acid which is shown by its reaction with;

(i) Sucrose.

- Dehydrating property.

(ii) Zinc oxide.

- Acidic property.

(b) *REACTION WITH HYDRATED COPPER(II)SULPHATE*

When concentrated sulphuric acid is added to blue crystals of copper(II) sulphate and warmed, they turn to white solid of anhydrous copper(II) sulphate after water of crystallization being removed.

$CuSO_4.5H_2O(s) \longrightarrow CuSO_4(s) + 5H_2O(l)$

Sulphuric acid was added to a beaker containing hydrated copper(II) sulphate.

(a) State the conditions for the reaction.

- Concentrated acid.
- Warming.

(b) State what was observed.

- The blue crystals turned to white and a colourless condensate formed.

(c) Write the equation for the reaction.

- $CuSO_4.5H_2O(s) \longrightarrow CuSO_4(s) + 5H_2O(l)$

(d) State the property shown by sulphuric acid above.

- Dehydrating property.

(c) ***REACTION WITH ETHANOL***

a) State the conditions under which sulphuric acid reacts with ethanol.

- Concentrated acid.
- A temperature of170^0C.
- Excess concentrated sulphuric acid.

b) Write the equation for reaction.

- $C_2H_5OH(l) \xrightarrow{-H_2O} C_2H_4(g)$

c) **Name the reagent used to test gaseous product**.

- Bromine

d) **State the observation made if the reagent above is treated with the gaseous product**.

- Bromine liquid turns from red to colourless.

CHEMICAL TEST FOR A SULPHATATE ION , SO_4^{2-}

Name the regents which can be used to test for the presence of a sulphate ion in solution and each case state the observations that can be made and write the equation for the reaction.

Reagent; Acidified barium nitrate solution (or Barium nitrate solution followed by dilute nitric acid)

Observation; A white precipitate forms.

Equation; $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

Reagent; Acidified barium chloride solution (or Barium chloride solution followed by dilute hydrochloric acid)

Observation; A white precipitate forms.

Equation; $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

A mixture of zinc sulphate and zinc carbonate was shaken with excess water in a beaker and filtered.

(a) Identify the substance in the residue.

- Zinc carbonate.

(b) The residue was dried and then heated strongly.

(i) State what was observed.

- The white solid turned yellow on heating and white on cooling.

- A colourless gas was evolved.

(ii) **Write the equation for the reaction that took place.**

- $ZnCO_3(s) \longrightarrow ZnO(s) + CO_2(g)$

(c) Name the reagent that can be used to identify the anion in the filtrate.

- Aqueous barium nitrate and dilute nitric acid.

(d) State the observation made if the reagent in c) is treated with the anion in the filtrate.

- A white precipitate forms.

(e) Write the equation for the reaction in (d)

$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

Name one reagent that can be used to distinguish between the following pair of anion s and state what would be observed if the reagent is separately reacted with each member.

$$\boldsymbol{SO_3^{2-}(aq)\ \ and\ \ SO_4^{2-}(aq)}$$

Reagent; Acidified barium nitrate solution.
Observation;
With $\boldsymbol{SO_3^{2-}(aq)}$; Bubbles of a colourless gas.
With $\boldsymbol{SO_4^{2-}(aq)}$; A white precipitate forms.

Concentrated sulphuric acid was added to sugar in a beaker.

(i) **State what was observed.**

- A spongy black mass of charcoal rises and fills the beaker.
- Steam is given off and a lot of heat is produced.

(ii) **State the term that describes this type of reaction.**

- Dehydration.

(iii) **Write the equation for the reaction that occurred.**

- $C_{12}H_{22}O_{11}(s) \longrightarrow 12C(s) + 11H_2O(l)$

(iv) **Write equations to show how sugar can be converted to ethanol.**

- $C_{12}H_{22}O_{11}(s) + H_2O(l) \longrightarrow 2C_6H_{12}O_6(aq)$
- $C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(l) + 2CO_2(g)$

(a) State the conditions under which sulphur dioxide is produced from, and include equation for the reaction.

(i) **Sulphur.**

- Burning sulphur in oxygen.
- $S(s) + O_2(g) \longrightarrow SO_2(g)$

(ii) **Sodium sulphite.**

- Dilute acid.
- $SO_3^{2-}(s) + 2H^+(aq) \longrightarrow SO_2(g) + H_2O(l)$

(b) State the application of the reaction in (a)(i) and that in (a)(ii)

- In (a) (i) manufacture of sulphuric acid in the contact process.
- In (a) (ii) laboratory preparation of sulphur dioxide.

(c) State what would be observed and in each case, give a reason for your observation if;

(i) Sulphur dioxide was bubbled through an acidified solution of potassium dichromate(VI).

- Orange solution turns green because sulphur dioxide reduced chromium(VI) ion to chromium(III) ion.

(ii) A blue coloured flower was dropped into a wet gas jar containing sulphur dioxide.

- Blue coloured flower was bleached. Sulphur dioxide dissolves in water to form sulphurous acid which removes oxygen the flower hence turning it to colourless.

(d) Write an equation only, to show the reaction in which sulphuric acid acts as;

(i) A dehydrating agent.

- $C_2H_5OH(l) \xrightarrow{-H_2O} C_2H_4(g)$
- Or $CuSO_4.5H_2O(s) \longrightarrow CuSO_4(s) + 5H_2O(l)$

(ii) An acid.

- $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$

(iii) An oxidizing agent.

- $Cu(s) + 2H_2SO_4(aq) \longrightarrow CuSO_4(aq) + SO_2(s) + 2H_2O(l)$

Sulphuric acid reacts with zinc and copper metals as shown in the equations below;

(i) $Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$

(ii) $Cu(s) + 2H_2SO_4(aq) \longrightarrow CuSO_4(aq) + SO_2(s) + 2H_2O(l)$

(a) Which property was illustrated by sulphuric acid when;

(i) The acid reacted with zinc.

- Acidic property.

(ii) The acid reacted with copper metal.

- Oxidizing property.

(b) State the conditions under which the reactions in equation (i) and equation (ii) above will take place.

(i) Dilute acid
No heating.

(ii) Concentrated acid.
Heating.

(c) A piece of carbon was heated with concentrated sulphuric acid in a test tube.

(i) **State what was observed.**

- Effervescence of a colourless gas which has an irritating smell.

(ii) **Explain your observation in c)(i) above.**

- Concentrated sulphuric acid oxidizes carbon to carbon dioxide and the acid is reduced to sulphur dioxide gas.
- $C(s) + H_2SO_4(aq) \longrightarrow CO_2(g) + 2H_2O(l) + 2SO_2(g)$

(d) Sulphur dioxide gas was bubbled through a test tube containing concentrated nitric acid.

(i) **State what was observed.**

- Bubbles of reddish-brown fumes.

(ii) **Write the equation for the reaction.**

- $SO_2(g) + 2HNO_3(aq) \longrightarrow H_2SO_4(aq) + 2NO_2(g)$

(e) With the aid of equation, give one example of how sulphur dioxide gas reacts as an oxidizing agent.

- Sulphur dioxide oxidizes burning magnesium to magnesium oxide and its self reduced to sulphur.
- $2Mg(s) + SO_2(g) \longrightarrow 2MgO(s) + S(s)$

During the manufacture of sulphuric acid by the contact process, sulphur dioxide and oxygen are passed over a catalyst at $450 - 500^0C$

(i) Name the catalyst.

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(ii) Write the equation for the reaction that occurs on the surface of the catalyst.

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(iii) With the aid of equation explain how sulphur dioxide can be converted to sulphuric acid.

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4. ***HYDROGEN SULPHIDE***, $\boldsymbol{H_2S}$

Note; The laboratory preparation of hydrogen sulphide gas is not required including the diagram of the set up of apparatus. This is because it's poisonous.

However it is prepared by reacting iron(II) sulphide with dilute hydrochloric acid.

$$FeS(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2S$$

Dilute sulphuric acid may be used instead of dilute sulphuric acid.

$$FeS(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2S$$

Or $S^{2-}(s) + 2H^+(aq) \longrightarrow H_2S(g)$

(a) A mixture of iron filings and sulphur was heated strongly. Write the equation for the reaction that took place.

- $Fe(s) + S(s) \longrightarrow FeS(s)$

(b) Dilute sulphuric acid was added to the product in (a)

(i) State what was observed.

- The black solid dissolved with effervescence of a colourless gas with rotten egg smell.
- A green solution formed.

(ii) Write the equation for the reaction that took place.

- $FeS(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2S$
- Or $S^{2-}(s) + 2H^+(aq) \longrightarrow H_2S(g)$

(c) One the substances formed in the reaction (b)(ii) pollutes the air.

(i) Identify the substance.

- Hydrogen sulphide.

(ii) Give one reason why the substance pollutes air.

- Has a bad smell.
- Has a bad rotten egg smell.
- It's poisonous.
- It is irritating and causes breathing problems.

PHYSICAL PROPERTIES OF HYDROGEN SULPHIDE.

- It's poisonous.
- Has a bad rotten egg smell.
- Denser than air.
- Slightly soluble in water.
- Has an irritating smell.

TEST FOR HYDROGEN SULPHIDE

Describe a test for hydrogen sulphide gas.

Hydrogen sulphide is tested by inserting/lowering a strip of filter paper soaked in lead(II) ethanoate solution in a gas jar containing hydrogen sulphide. The paper turns black. The colour change is caused by the formation of lead(II) sulphide which is black.

Or

By bubbling the gas through lead(II) ethanoate solution. A black precipitate forms.
$(CH_3COO)_2Pb(aq) + H_2S(g) \longrightarrow 2CH_3COOH(aq) + PbS(s)$
Or $Pb^{2+}(aq) + S^{2-}(g) \longrightarrow PbS(s)$

CHEMICAL PROPERTIES OF HYDROGEN SULPHIDE GAS

1. **Hydrogen sulphide as a powerful reducing agent.**

   It reduces oxidizing agents and its self oxidized to sulphur which appears as a pale yellow precipitate or solid.

State what would be observed and write the equation for the reaction that takes place if hydrogen sulphide is bubbled into;

(i) Iron(III) chloride solution.

- The yellow solution turns green and a yellow solid is formed.
- $H_2S(g) + 2FeCl_3(aq) \longrightarrow S(s) + 2FeCl_2(aq) + 2HCl(g)$

(ii) Dilute nitric acid.

- A reddish-brown gas is liberated.
- $H_2S(g) + 8HNO_3(aq) \longrightarrow H_2SO_4(aq) + 8NO_2(g) + 4H_2O(l)$

Hydrogen sulphide was bubbled through concentrated sulphuric acid.

(a) State what was observed.

- A yellow precipitate was formed.

(b) Write the equation for the reaction that took place.

- $H_2SO_4(aq) + 3H_2S(g) \longrightarrow 4H_2O(l) + 4S(s)$

(c) Explain why hydrogen sulphide cannot be dried using concentrated sulphuric acid.

- It's because hydrogen sulphide reacts with concentrated sulphuric acid to form water and sulphur.
- $H_2SO_4(aq) + 3H_2S(g) \longrightarrow 4H_2O(l) + 4S(s)$

(d) Explain your observation in (a) above.

- Hydrogen sulphide is a reducing agent. It reduces concentrated sulphuric acid to water and its oxidized to sulphur, a yellow solid.

Hydrogen sulphide was bubbled through acidified potassium manganate(VII) solution.

(a) State what was observed.

- The purple solution turned colourless and a yellow solid was formed.

(b) Write the equation for the reaction that took place.

- $2MnO_4^-(aq) + 5H_2S(g) + 6H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5S(s)$

(c) Explain your observation above.

- Hydrogen sulphide is a reducing agent. It reduces manganate(VII) ion which are purple to manganese(II) ion which are colourless and its oxidized to sulphur, a yellow solid.

Hydrogen sulphide was bubbled through acidified potassium dichromate(VI) solution.

(a) State what was observed.

- The orange solution turned to green and a yellow solid was formed.

(b) Write the equation for the reaction that took place.

- $Cr_2O_7^{2-}(aq) + 3H_2S(g) + 8H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3S(s)$

(c) **Explain your observation in (a) above.**

- Hydrogen sulphide is a reducing agent. It reduces orange dichromate(VI) ion to chromium(III) ion which are green and its self oxidized to sulphur, a yellow solid.

2. **Combustion of Hydrogen sulphide.**

Hydrogen sulphide burns in air under two conditions i.e. in excess air and in limited supply of air.

(i) In excess supply of air.

It burns with a blue flame forming water and sulphur dioxide.

$2H_2S(g) + 3O_2(g) \longrightarrow 2SO_2(g) + 2H_2O(l)$

(ii) In limited supply of air.

Burns and forms a yellow solid of sulphur. Due to limited oxygen, sulphur is not completely oxidized to sulphur dioxide.

$2H_2S(g) + O_2(g) \longrightarrow 2S(s) + 2H_2O(l)$

3. **Reaction with salts of metals.**

Hydrogen sulphide was bubbled through copper(II) sulphate solution.

(a) State what was observed.

- A dark brown precipitate is formed.

(b) **Write the equation for the reaction that occurred**.

- $CuSO_4(aq) + H_2S(g) \longrightarrow CuS(s) + H_2SO_4(aq)$

Hydrogen sulphide was bubbled through lead(II) nitrate solution.

(a) State what was observed.

- A black precipitate was formed.

(b) Write the equation for the reaction that took place.

- $Pb(NO_3)_2(aq) + H_2S(g) \longrightarrow PbS(s) + 2HNO_3(aq)$

A solid substance P is non metallic; it burns in air to form a colourless gas Qwhich bleaches moist litmus paper.

(a) Will the aqueous solution of the gas have a PH greater or less than 7?

- The PH will be less than 7.

(b) P combines directly with iron metal when heated together to give a black solid R which reacts with dilute hydrochloric acid to give a colourless gas S with rotten egg

smell. When the gas is passed through the yellow solution, the solution turns green and a pale yellow precipitate is formed.

(i) **Identify**;

R- iron(II) sulphide.

S- Hydrogen sulphide.

(ii) **Write the equation for the reaction between R and the acid.**

- $FeS(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2S(g)$

(iii) **Write the equation for the reaction between S and iron(III) chloride solution.**

- $FeCl_3(aq) + H_2S(g) \longrightarrow S(s) + 2FeCl_2(aq) + 2HCl(aq)$

EFFECT OF HEAT ON SULPHATES.

1. Hydrated iron(II) sulphate, $FeSO_4.7H_2O$

(a) **State what would be observed when iron(II) sulphate-7-water is heated strongly**.

- The green crystals give off a colourless vapour and a dirty yellow anhydrous solid.
- When strongly heated, the solid turns reddish-brown.

(b) Write the equation(s) for the above reaction.

- $FeSO_4.7H_2O(s) \longrightarrow FeSO_4(s) + 7H_2O(l)$
- $2FeSO_4(s) \longrightarrow Fe_2O_3(s) + SO_3(g) + SO_2(g)$

2. Hydrated magnesium , $MgSO_4.7H_2O$

(a) State what would be observed when magnesium sulpate-7-water is strongly heated.

- The white crystals turn to white powder; a colourless vapour is formed and on strong heating white fumes is formed.

(b) Write the equation(s) for the reaction(s) that took place.

- $MgSO_4.7H_2O(s) \longrightarrow MgSO_4(s) + 7H_2O(l)$
- $MgSO_4(s) \longrightarrow MgO(s) + SO_3(g)$
-

3. Hydrated copper(II) sulphate, $CuSO_4.7H_2O$

(a) **State what would be observed when copper(II) sulphate-7-water is heated strongly**.

- The blue crystals give off a colourless vapour and a white powder is formed.
- The white powder turns black and white fumes formed on strong heating.

(b) Write equation(s) for the reaction(s) that took place.

- $CuSO_4.7H_2O(s) \longrightarrow CuSO_4(s) + 7H_2O(l)$
- $CuSO_4(s) \longrightarrow CuO(s) + SO_3(g)$

PREPARATIONS OF SULPHATES.

Describe how a pure sample of copper(II) sulpate-5-water can be prepared in the laboratory from copper(II) oxide.

- To warm dilute sulphuric acid in a beaker is added copper(II) oxide, little at a time while stirring.
  $CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$
- Addition of the oxide is continued until no more dissolves and a little excess remains.
- The excess oxide is filtered off. The filtrate which is aqueous copper(II) sulphate is heated and allowed to evaporate to saturation point.
- The saturated solution is cooled, covered and allowed to stand for few days for the crystals to grow.
  $CuSO_4(aq) + 5H_2O(l) \longrightarrow CuSO_4.5H_2O(s)$
- The crystals are filtered, washed and dried.

Describe briefly how magnesium sulphate can be prepared (equations required).

- To warm dilute sulphuric acid in a beaker is added little magnesium oxide and the mixture is stirred. Magnesium sulphate is formed.
  $MgO(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2O(l)$
- Addition of magnesium oxide is continued until some magnesium oxide remains un dissolved.
- The un dissolved magnesium oxide is filtered off. The filtrate is heated to saturation point.
- The saturated solution is cooled to allow crystals to form. The mixture is filtered and the residue which is magnesium sulphate crystals is washed with a little cold distilled water and dried.

Describe briefly how iron(II) sulphate-7-water can be prepared in the laboratory(Diagram not required but equations required).

- To warm dilute sulphuric acid is added iron filings and the mixture is stirred. Iron(II) sulphate is formed.
  $Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$
- More iron filings are added until some iron filings remain un dissolved.
- The un dissolved iron filings are filtered off. The filtrate is heated to saturation point.
- The saturated solution is cooled, covered and allowed to stand for some days for crystals to grow.
  $FeSO_4(aq) + 7H_2O(l) \longrightarrow FeSO_4.7H_2O(s)$
- The crystals are filtered off, washed and dried.

Explain what is observed when sulphur is heated gently until it boils.

- The yellow solid melts at about 110⁰c to a clear amber liquid which flows easily like water.
- Solid and liquid sulphur contains rings of 8 atoms (S_8). This liquid is not viscous because these sulphur rings flow readily over one another.
- The colour darkens on further warming. At about 160⁰c, the sulphur becomes reddish-brown and viscous. It remains like a syrup in the tube even when inverted.
- The change is caused by the breaking up of the rings of 8 atoms and formation of long chains.
- The liquid is viscous because the chain twists over one another.
- On further warming, the liquid becomes black and mobile again. The chain breaks and becomes shorter therefore can flow more readily.
- The sulphur boils at 444⁰c and forms brownish vapour.

Sulphur dioxide gas was passed into water using the set up shown below.

(i) Explain what is observed when a blue litmus paper is dropped into the solution.

- The blue litmus paper turned to red and then bleached.
- Sulphur dioxide dissolves in water to form sulphurous acid. The paper turned red because of sulphurous acid and later bleached by the same acid.

(ii) Why is this method used for dissolving sulphur dioxide into water?

- Sulphur dioxide is very soluble in water. The inverted funnel is used to prevent “sucking back”.

Moist coloured flower petals were placed in a gas jar of sulphur dioxide gas and the set up left for some time.

(a) State what was observed.

- The coloured moist flowers were bleached.

(b) Explain your observation in (a) above.

- Sulphur dioxide dissolves in water to form sulphurous acid.
  $SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$
- The sulphurous acid formed reduces the coloured flower(dye) by removing oxygen atom, hence the dye is bleached.

$$dye + H_2SO_3(aq) \longrightarrow (dye - O) + H_2SO_4(aq)$$

What is chemical pollution?

- This is the introduction of toxic substances to the environment which reduces the ability of the environment to sustain life.

Briefly describe how sulphur compounds cause pollution in the atmosphere.

- Burning of sulphur impurities in crude oil liberates sulphur dioxide, sulphur trioxide and hydrogen sulphide into the atmosphere. These are the main pollutants in the atmosphere.
- Sulphur dioxide and sulphur trioxide dissolve in rain water to form acidic solution. The solution is what comes down as acid rain.

What harmful effects does pollution have on the environment?

- **It causes** respiratory diseases.
- **It** accelerates corrosion of metallic structures and buildings in case of acidic rain.
- It bleaches plants and affects the PH of the soil and crop production.

What are the steps taken to reduce the pollution caused by sulphur compounds?

- Burning less fossil fuels containing sulphur.
- Pollutants like sulphur should be removed from fuels before they are burnt.

(a) When dilute hydrochloric acid was added to iron(II) sulphide, a gas X was evolved. Write the equation for the reaction.

- $FeS(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2S(g)$

(b) State;

(i) How the gas X was identified.

-

(ii) Why the gas is normally prepared in a fume cup board.

- It is poisonous.

(c) A gas jar containing gas X was inverted over a gas jar containing moist sulphur dioxide.

(i) State what was observed.

- A yellow solid and a colourless condensate formed.

(ii) Give a reason for your answer in (i)

- Sulphur dioxide oxidizes hydrogen sulphide to water and its reduced to sulphur.

(iii) Write the equation for the reaction that took place.

- $2H_2S(g) + SO_2(g) \longrightarrow 2H_2O(l) + 3S(s)$

(d) Sulphur dioxide was passed into a beaker containing a red flower and water.

(i) State what was observed.

- The flower was bleached.

(ii) Give a reason for your answer.

- Sulphur dioxide dissolves in water to form sulphurous acid which is a bleaching agent that removed oxygen from the red flower hence bleaching them.

(a) The structure of sulphur is known to be made up of sulphur molecules(S_8) joined together by strong covalent bonds.

(i) The structure is referred to as a molecular structure. Draw this structure.

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(ii) What forces hold these molecules in the molecular structure?

....

(iii) Name one commercial use of sulphur.

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....

(b) Sulphur dioxide can be converted in the presence of a catalyst to sulphur trioxide which is used to produce oleum during the manufacture of sulphuric acid by the contact process.

(i) Name the catalyst.

- Vanadium(V) oxide.

(ii) Write equation for the conversion of sulphur dioxide to sulphur trioxide and state giving reasons, the conditions for the reaction other than the catalyst you have named in (b)(i).

- $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
- Conditions;

  Low temperature; the reaction is exothermic and sulphur trioxide is unstable to heat.

  High pressure; because formation of sulphur trioxide is accompanied by a reduction in volumes from 3 to 2.

(iii) Write the formula of oleum and state how it is produced during the manufacture of sulphuric acid.

- $H_2S_2O_7$
- It is produced by dissolving sulphur trioxide in concentrated sulphuric acid.

(c) When concentrated sulphuric acid was added to a crystal of copper(II) sulphate-5-water, a white powdered solid appeared. Give a reason for this observation.

- The crystal was dehydrated by the acid.

(a) State one difference between iron(II) sulphide and a mixture of iron and sulphur Other than their reactions with dilute acids.

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(b) Write equation to show the reaction of dilute sulphuric acid with;

(i) Iron(II) sulphide.

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(ii) A mixture of iron and sulphur.

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(c) (i) Indicate which one of the reactions in (b) should not be carried out in the open.

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(ii).Suggest one reason why the reaction you have indicated in c(i) should not be carried out in the open.

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When element **P** was heated in limited supply of oxygen, a colourless gas **X** that turned acidified potassium manganate(VII) solution from purple to colourless was formed. When**X** wasmixed with excess oxygen and the mixture passed over heated platinum catalyst, another acidic gas **Y** that formed a white precipitate with acidified barium nitrate solution but had no effect on acidified potassium manganate(VII) solution was formed.

(a) Identify;

(i) **P**…………………………………………………………………………………
(ii) **X**…………………………………………………………………………………
(iii) **Y**…………………………………………………………………………………

(b) Write equation for the reaction that takes place between **P** and oxygen.

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(c) Explain why gas **Y** formed a white precipitate with acidified barium nitrate solution. (No equations required)

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Concentrated sulphuric acid is used in the laboratory preparation of both ethene and sulphur dioxide.

(a) Name one substance that when treated with sulphuric acid can be used in the laboratory preparation of;

(i) Ethene.

……………………………………………………………………………………

(ii) Sulphur dioxide.

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(b) State the property of sulphuric acid shown during the laboratory preparation of;

(i) Ethene.

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(ii) Sulphur dioxide.

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(c) Write equation to show the reaction in which sulphuric acid together with the substance that you have named in (a) to produce;

(i) Ethene.

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(ii) Sulphur dioxide.

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Concentrated sulphuric acid was added to copper(II) nitrate and the mixture heated.

(i) Write an ionic equation for the reaction that took place.

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(ii) State the practical application for the reaction in (i) above.

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(a) State the conditions under which sulphur dioxide can be produced from; and write equation for the reaction in each case leading to the formation of sulphur dioxide.

(i) Sulphur.

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(ii) Sodium sulphite.

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(b) State the application of the application of the reaction in (a)(i) and that in (a)(ii).

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(c) State what would be observed and in each case, give a reason for your observation if;

(i) Sulphur dioxide was bubbled through an acidified potassium dichromate(VI) solution.

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....

(ii) A blue coloured flower was dropped into a wet jar containing sulphur dioxide.

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....

(d) Write an equation only, to show the reaction in which sulphuric acid acts as;

(i) A dehydrating agent.

....
....

(ii) An acid.

....
....

(iii) An oxidizing agent.

....
....

Both carbon and sulphur can burn in air to form oxides.

(a) Name the products of complete combustion of;

(i) Sulphur.

....

(ii) Carbon.

....

(b) The products of combustion in (a) above were carefully collected into separate boiling tubes and burning magnesium introduced in each. State what was observed in the boiling tube containing the products of combustion of;

(i) Sulphur.

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....

(ii) Carbon.

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....

(c) Write equation to illustrate your observation in;

(i) b(i)

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(ii) b(ii)

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(a) A piece of burning sulphur was lowered into a gas jar of oxygen.

(i) State what was observed.

(ii) Write the equation for the reaction that took place.

(b) Water was added to the gaseous product in (a) and to the resultant solution a red rose flower was immersed.

(i) State what was observed.

(ii) Write the equation for the reaction between water and the gaseous product in (a)

(iii) Explain your observation in b(i)

(c) State how the gaseous product in (a) can be identified in the laboratory.

(a) Describe with the aid of a diagram how a dry sample of hydrogen sulphide gas can be prepared in the laboratory.

(b) (i)State how hydrogen sulphide can be identified in the laboratory.

(ii)Write equation to support your answer in b(i) above.

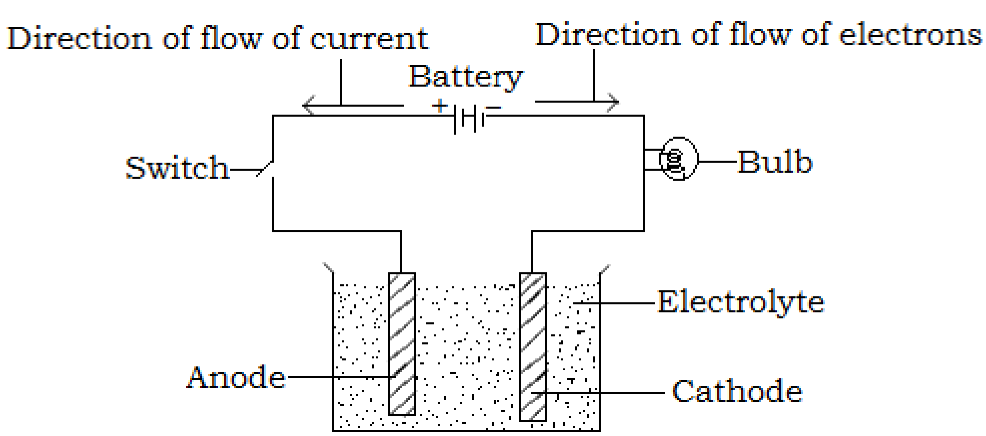
(c) A gas jar of hydrogen sulphide was inverted over one with sulphur dioxide.

(i) Name the solid product formed.

(ii) Write equation for the reaction that took place.

(d) With the aid of equations, show how sulphur can be converted to sulphuric acid.

EFFECT OF ELECTRICITY ON SUBSTANCES.



Define the following terms, giving examples where applicable

a) Electrolysis
   - This is the decomposition of an electrolyte by passing electricity through it .
   - Or is the decomposition of a compound when in aqueous or molten form by passing electricity through it.

b) Electrolyte
   - Is a compound which in solution or molten state conducts an electric current or electricity and decomposes at the electrodes as it does so.

     Examples of electrolytes;
     - ✓ Dilute sulphuric acid.
     - ✓ Dilute hydrochloric acid.
     - ✓ Dilute nitric acid.
     - ✓ Sodium hydroxide solution.
     - ✓ Sodium chloride solution.
     - ✓ Copper(II) sulphate solution.
     - ✓ E.t.c

TYPES OF ELECTROLYTES

c) Strong electrolyte
   - This is an electrolyte which ionises completely when in aqueous solution or molten form.

     Examples of strong electrolytes;
     - ✓ Dilute sulphuric acid.
     - ✓ Dilute hydrochloric acid.
     - ✓ Dilute nitric acid.
     - ✓ Sodium hydroxide solution.
     - ✓ Sodium chloride solution.
     - ✓ Copper(II) sulphate solution
     - ✓ Dilute potassium hydroxide solution

$N.B$; All dilute solutions of strong acids, bases and normal salt solutions are examples of strong electrolytes.

d) Weak electrolyte
   - Is an electrolyte which slightly ionises when in aqueous or molten states.

     Examples of weak electrolytes are;
     - ✓ Dilute ammonia solution.
     - ✓ Dilute ethanoic acid.
     - ✓ Dilute carbonic acid.
     - ✓ Dilute propanoic acid.

$N.B$; All dilute weak acids (organic acids) and weak bases are examples of weak electrolytes.

e) Non electrolytes

- Is a solution or molten compound which cannot be decomposed by an electric current.

  Examples of non electrolytes;
  - ✓ Ethanol
  - ✓ Cane sugar
  - ✓ Trichloromethane
  - ✓ Urea.

Define the following terms giving examples in each case.

a) A non conductor;

- Is a substance in solid state that does not allow electricity to pass through it.

  Examples of non conductors()

b) Electrodes

- These are pieces of metal or graphite through which electrons leave or enter the electrolyte.

c) Electrode.

- This is a piece of metal or graphite through which electrons leave or enter the electrolyte.

TYPES OF ELECTRODES

d) Anode;

- This is a positive electrode through which electrons leave the electrolyte. Or
- This is a positive electrode where current enters the electrolyte from the external circuit. Or
- This is the positive electrode where anions move to. Or
- This is a positive electrode where oxidation occurs.

e) Cathode;

- This is a negative electrode through which electrons enter the electrolyte. Or
- This is a negative electrode where current leaves the electrolyte to the external circuit. Or
- This is a negative electrode where cations move to. Or
- This is a negative electrode where reduction occurs.

CONDUCTION OF ELECTRICITY

Conduction of electricity in solid substances like metals is by use of mobile electrons while in molten or aqueous solutions, conduction of electricity is by use of mobile ions.

1. Name the conducting particles in the following;

a) Copper wire.

…………………………………………………………………………………………

b) Copper(II) sulphate solution.

…………………………………………………………………………………………

c) Graphite.

…………………………………………………………………………………………

d) Dilute ammonia solution.

2. Explain the following observations;

a) Graphite conducts electricity where as diamond does not

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b) Solid calcium chloride does not conduct electricity whereas aqueous calcium chloride conducts electricity.

c) ………………………………………………………………………………
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d) Molten sodium chloride conducts electricity whereas sodium chloride crystals do not.

- In molten sodium chloride, heat breaks down the electrostatic forces of attraction setting the ions free to move hence conduct electricity. However, sodium chloride crystals are in solid form where sodium ions and chloride ions are firmly held together by strong electrostatic forces of attraction, so they are not mobile to conduct electricity.

e) Copper(II) chloride in solid form does not conduct electricity whereas in molten state it does.

- In solid form, the copper(II) ions and the chloride ions are firmly held together by strong electrostatic forces of attraction, so they are not free and mobile to conduct electricity. However, in molten form, heat breaks the electrostatic forces of attraction setting the ions free and mobile to move hence conduct electricity.

f) Magnesium sulphate in solid state does not conduct electricity whereas in aqueous form it does.
   - In solid form, the magnesium ions and the sulphate ions are firmly held together by strong electrostatic forces of attraction, so they are not free and mobile to conduct electricity. However, in aqueous form, magnesium sulphate dissolves forming free mobile magnesium ions and sulphate ions which conduct electricity.

Explain the following;

a. Sodium conducts electricity when in solid state and when dissolved in water but copper(II) sulphate only conducts electricity when dissolved in water but not in solid state.
   - ✓ Sodium being a metal, conducts electricity by use of mobile electrons. When dissolves in water, sodium reacts with water forming sodium hydroxide solution which ionises to form mobile ions (sodium ions and hydroxyl ions) which conduct electricity.
     $2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$
     $NaOH(aq) \longrightarrow Na^+(aq) + OH^-(aq)$
   - ✓ In solid form, the copper(II) ions and the sulphate ions are firmly held together by strong electrostatic forces of attraction, so they are not free and mobile to conduct electricity. However, when copper(II) sulphate is dissolved in water, water breaks the electrostatic forces of attraction setting the ions free and mobile to move hence conduct electricity.

MIGRATION OF IONS

During electrolysis, positively charged ions (cations) in the electrolyte move towards the negative electrode (cathode) whereas the negatively charged ions (anions) in the electrolyte move towards the positive electrode (anode)

The migration of ions towards the respective electrodes can be remembered by the following statements.

"Cat" at "cat" : $Meaning$, $cations\ move\ to\ the\ cathode$.
"An" at "An" : $Meaning$, $Anions\ move\ to\ the\ anode$.

FACTORS THAT AFFECT ELECTROLYSIS

There are majorly three factors that affect electrolysis and these are;

- ✓ Position of the ions in the electrochemical series (preferential discharge)
- ✓ Concentration of the ions (concentration of the electrolyte)
- ✓ Nature of the electrode.

1) *POSITION OF THE ION IN THE ELECTROCHEMICAL SERIES.*

   This factor mainly affects dilute solutions of electrolytes. If two ions of similar charge are present at a given electrode, only one will be selected for discharge.
   Under this factor an ion which is below in the electrochemical series is the one that is preferentially discharged instead of the one higher in the electrochemical series.
   Below are electrochemical series for both cations and anions.

   Electrochemical series for cations.
   K^+
   Ca^{2+}
   Na^+
   Mg^{2+}
   Al^{3+}
   Zn^{2+}
   Fe^{2+}
   Pb^{2+}
   H^+
   Cu^{2+}
   Hg^{2+}
   Ag^+
   Electrochemical series for Anios
   SO_4^{2-}
   NO_3^-
   Cl^-
   Br^-
   I^-
   OH^-

For example; in dilute sodium hydroxide solution, there are;

- Sodium ions
- Hydrogen ions and
- Hydroxide ions.

At the cathode, both the sodium ions and the hydrogen ions are attracted but the hydrogen ions are selected for discharge in preference to sodium ions which are higher in the electrochemical series.

$N.B$: In any aqueous or dilute solution, water provides the hydroxide ions and hydrogen ions.
$E.g$: copper(II) sulphate solution was electrolysed using graphite electrodes. Identify all the ions present in the electrolyte;

- Copper(II) ions
- Sulphate ions
- Hydrogen ions and
- Hydroxide ions.

Note: The hydrogen ions and hydroxide ions are provided by water since its water which is used as a solvent when making a dilute or aqueous solution.
You are provided with the following solutions, identify the ion that will be discharged at the cathode and anode;

a. Dilute sulphuric acid.
   At anode ………………………………………………………………………………...
   At cathode……………………………………………………………………………….
b. Dilute calcium chloride solution.
   At anode ………………………………………………………………………………...
   At cathode ……………………………………………………………………………….
c. Dilute copper(II) sulphate solution
   At anode ………………………………………………………………………………
   At cathode ……………………………………………………………………………..
d. Dilute silver nitrate solution.
   At anode ………………………………………………………………………………..
   At cathode ……………………………………………………………………………….

2) *CONCENTRATION OF THE IONS OR CONCENTRATION OF THE ELECTROLYTE*
   This factor affects concentrated electrolytes. Ions in the electrolyte which are in much higher concentrations are discharged in preference to those in lower concentrations. E.g.
   In concentrated calcium chloride solution, calcium ions and chloride ions are in higher concentrations;
   At cathode, calcium ions will be discharged.
   At anode, chloride ions will be discharged.
   You are provided with the following solutions. Identify the ions at the cathode and anode that will be discharged.

a. Concentrated sodium chloride solution.
   At anode ……………………………………………………………………………..
   At cathode ……………………………………………………………………………
b. Concentrated sodium hydroxide solution.

At anode …………………………………………………………………………………..
At cathode …………………………………………………………………………………
c. Concentrated potassium chloride solution.
At anode …………………………………………………………………………………
At cathode …………………………………………………………………………………..

3) *NATURE OF ELECTRODES*.
This may sometimes influence the choice of the ion for discharge. The most important example to consider is the electrolysis of sodium chloride solution using mercury as the cathode and then using platinum as the cathode.
With platinum, the hydrogen ion is discharged in accordance with the order of the reactivity series, sodium ion being higher in the electrochemical series. In this case, the cathode product is hydrogen gas.
If the mercury cathode is used, there is a possibility of discharging sodium ion to form sodium amalgam with mercury. This is because it requires less energy than the discharge of hydrogen ions to form hydrogen gas and so it occurs in preference.

Questions

1) (a) State two factors that can determine the product formed at an electrode during electrolysis.
……………………………………………………………………………………………
……………………………………………………………………………………………
(b) Explain why aqueous solution of copper(II) chloride conducts electric current whereas solid copper(II) chloride does not.
   - ✓ In the solid state, copper(II) and chloride ions are firmly held together by strong electrostatic forces of attraction and therefore are not free to move.
   - ✓ In aqueous state, water breaks the forces between the ions thus setting them free to move.

2) (a)A dilute solution of copper(II) chloride was electrolysed using graphite electrodes.
   i. State what was observed at the cathode and write equation for the reaction that took place.
      - ✓ Cathode was coated with a brown solid.
        $Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$
   ii. Name the substance that was produced at the anode.
      - ✓ Oxygen.
   iii. Explain how the product you have named in (ii) above is formed at the anode and write equations to illustrate your answer.

- ✓ The chloride and hydroxide ions both migrate to the anode. The hydroxide ion is preferentially discharged by electron loss since it is lower than the chloride ions in the electrochemical series.

  $OH^-(aq) \longrightarrow OH + e$

  The hydroxyl radicals combine forming oxygen atom and water. The oxygen atoms soon combine to form oxygen gas.

  $2OH \longrightarrow H_2O(l) + O$

  $2O \longrightarrow O_2(g)$

(b) The electrolysis of copper(II) chloride was repeated using copper electrodes. State what was observed at the anode and briefly explain your answer.

- ✓ The anode becomes smaller in size.

  Copper is reactive. It therefore ionises in preference to chloride or hydroxide ions.

  Ionization of copper is by loss of electrons which result into reduction in the mass of the anode.

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

3) (a)(i) State three factors that affect selective discharge of an ion during electrolysis

- Position of the ions in the electrochemical series.
- Concentration of the ions in the aqueous solution.
- Nature of the electrode used during electrolysis.

(b) Concentrated sodium chloride was electrolysed using graphite anode and platinum cathode

i. State what was observed at the anode and cathode respectively (02mks)

- At the anode: Bubbles (effervescence) of a greenish-yellow gas.
- At the cathode: Bubbles (effervescence) of a colourless gas.

ii. Write the half equation(s) for reaction(s) at the anode and cathode respectively

- At the anode: $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e$
- At the cathode: $2H^+(aq) + 2e \longrightarrow H_2(g)$

iii. Write the overall equation for the reaction(s) at the electrodes.

- $2Cl^-(aq) + 2H^+(aq) \longrightarrow H_2(g) + Cl_2(g)$

(c) The product collected at the anode was passed through dilute iron (II) sulphate solution.

i. State what was observed

- Pale green solution turns to a yellow solution (or reddish brown solution)

ii. Write the ionic equation for the reaction that took place (1.5mks)

- $2Fe^{2+}(aq) + Cl_2(g) \longrightarrow 2Fe^{3+}(aq) + 2Cl^-(aq)$

iii. State the chemical property exhibited by the product collected at the anode in c(ii)

- Oxidizing property.

(d) The dry sample of the product formed at the cathode was passed over heated copper (II) oxide

i. state what was observed

- Black powder (solid) turns to a brown solid and a colourless condensate is observed.

ii. Write the ionic equation for the reaction that took place

- $CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$

iii. State the chemical property exhibited by the product collected at the cathode in d(ii)

- Reducing property.

(e) State one industrial application of electrolysis

- Extraction of very reactive metal e.g. sodium, potassium.
- Purification or refining of impure copper.
- Electroplating for example silver plating, chromium plating

$\boldsymbol{ELECTROLYSIS\ OF\ LEAD(II)\ BROMIDE}$

Molten lead(II) bromide was electrolysed using graphite electrodes.

a) State what was observed at the;

i. Anode.

- Reddish- brown fumes.

ii. Cathode.

- Cathode was coated with a grey solid.

b) Write the equation for the reaction at both electrodes;

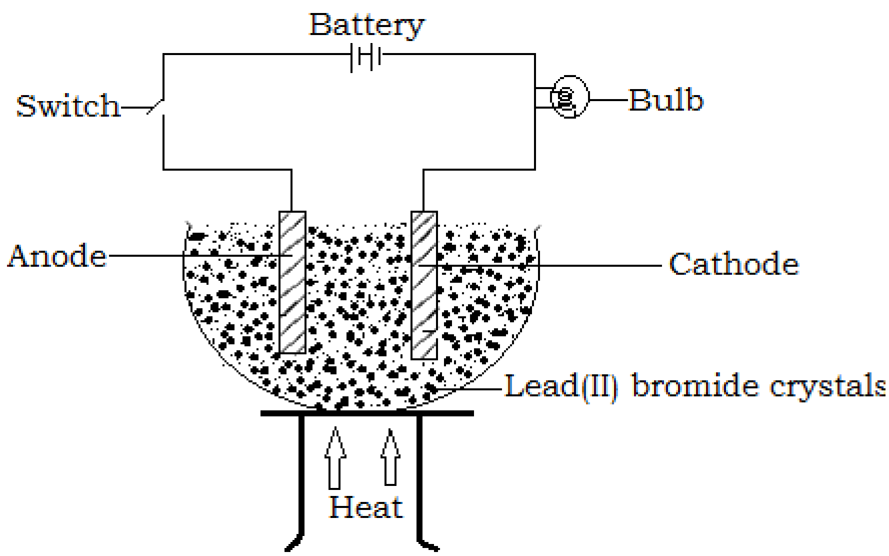
i. Anode.

- $2Br^-(l) \longrightarrow Br_2(g) + 2e$

ii. Cathode.

- $Pb^{2+}(l) + 2e \longrightarrow Pb(s)$

The circuit shown below was used in an experiment to study the effect of electricity on lead(II) bromide.



a. State what would be observed;

   i. Before lead(II) bromide had melted.
      - There was no observable change
      - Or the bulb did not give out light

   ii. After lead(II) bromide had completely melted.
      - The bulb gave out light, a grey solid coated electrode X and reddish brown fumes were observed at electrode Y.

b. Explain your answers in (a) (i) and (ii)
   - ❖ Before lead(II) bromide had melted, the lead(II) ions and the bromide ions were held together firmly by strong electrostatic forces which prevent free mobility of the ions hence no conduction of electricity.
   - ❖ However, after it had melted the lead(II) ions and the bromide ions were free to move since heat broke down the electrostatic forces of attraction.

c. Write the equation for the reaction that took place at the;

   i. *Y*
      - $2Br^{-}(l) \longrightarrow Br_2(g) + 2e$

   ii. *X*
      - $Pb^{2+}(l) + 2e \longrightarrow Pb(s)$

EXERCISE.

1) Graphite and lead(II) bromide are conductors of electricity.

Name the particles which are responsible for conducting electricity in;

i. Graphite.

....

ii. Lead(II) bromide.

....

(b) (i) Draw a labeled diagram of the set up of the apparatus that can be used to electrolyze lead(II) bromide.

(ii) State what is observed at the anode.

....

....

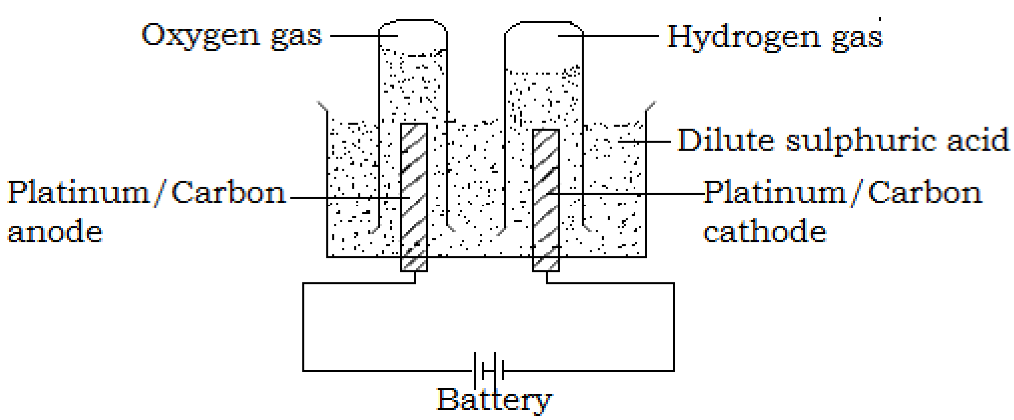
(iii) Write the equation for the observation in (ii) above.

....

....

2)

ELECTROLYSIS OF DILUTE SULPHURIC ACID (***ACIDIFIED WATER***)



or

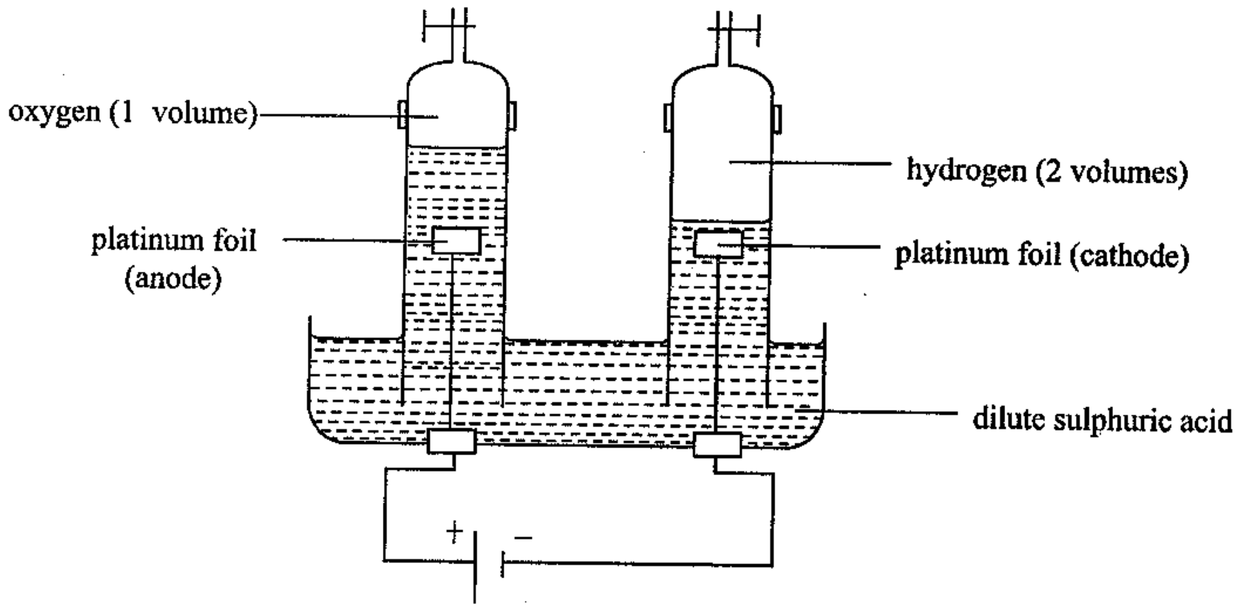


Fig 7.4 Electrolysis of dilute sulphuric acid

Dilute sulphuric acid ionises as follows;

$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$

$H_2O(l) \longrightarrow H^+(aq) + OH^-(aq)$

Reaction at the cathode.

At the cathode, hydrogen ions are attracted where they gain electrons to form hydrogen gas. i.e.

$2H^+(aq) + 2e \longrightarrow H_2(g)$

Observation.

Bubbles of a colourless gas that burns with a pop sound

Reaction at the anode.

At the anode, sulphate ions and the hydroxide ions are attracted but the hydroxide ions are discharged in preference to the sulphate ions because it is a dilute solution. Oxygen gas is formed as the main product at the anode.

$4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e$

Observation.

Bubbles of a colourless gas that relights a glowing splint

N.B

The volume of hydrogen gas at the cathode is twice the volume of oxygen gas at the anode.

Questions.

1. Hydrogen and oxygen can be prepared simultaneously by electrolysis.
   a) Name the substance used as;
   i. Electrolyte.
      - Dilute sulphuric acid.

ii. Electrodes.
   - Graphite (carbon) electrodes.

b) Identify the substance that is produced at the ;
   i. Anode.
   - Oxygen gas
   ii. Cathode.
   - Hydrogen gas.

c) Write the equation for the reaction that occurs at;
   i. The cathode.
   - $2H^+(aq) + 2e \longrightarrow H_2(g)$
   ii. The anode.
   - $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e$

d) State the;
   i. The relative quantities of products at the anode and cathode respectively.
   - One volume of oxygen at the anode for every two volumes of hydrogen at the cathode.
   ii. Any conclusion that can be drawn from your answer in (d) (i) above.
   - A water molecule consists of hydrogen and oxygen atoms in the ratio of 2:1 respectively.

2. The diagram below shows an electrolytic cell in which electrolysis of dilute sulphuric acid occurs.

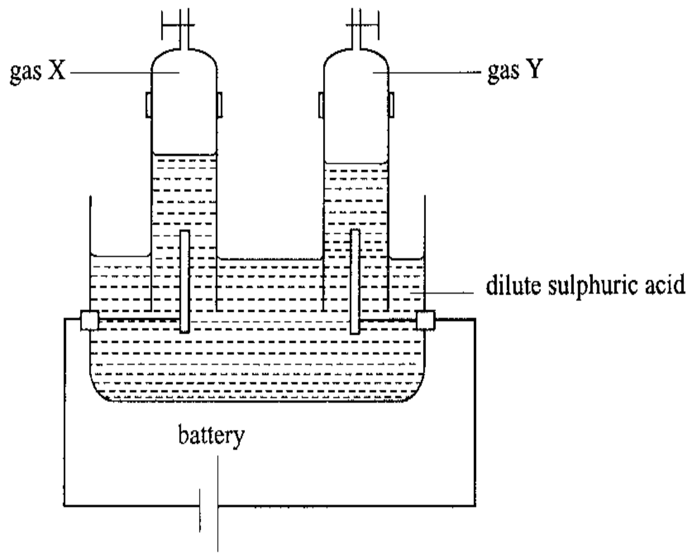


Fig 7.10

a) Name the gases *X and Y* that are evolved during electrolysis at ;

   i. *X*

   ……………………………………………………………………..

   ii. *Y*

   ……………………………………………………………………..

b) Write the equation for the reaction occurring at the anode.

………………………………………………………………………………
………………………………………………………………………………

c) Indicate the direction of electron flow in the circuit.

3. Study the electrolytic diagram below showing electrolysis of acidified water.

a) Identify an electrode which is the;

   i. Anode.

   ………………………………………………………………………

   ii. Cathode.

…………………………………………………………………………

b) Identify the gas;

i. *X*

…………………………………………………………………………..

ii. *Y*

…………………………………………………………………………

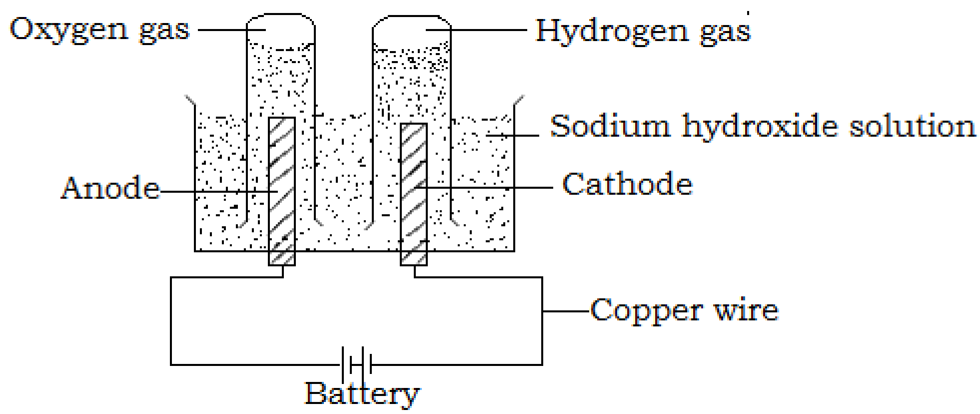
c) Name the ion that is discharged at the electrode B and write the equation for the reaction that occurred.

………………………………………………………………………………………

………………………………………………………………………………………

4. Bb

ELECTROLYSIS OF SODIUM HYDROXIDE SOLUTION



a. Identify the electrodes used in the above set up.

……………………………………………………………………………………………

……………………………………………………………………………………………

b. Name the product that is formed at the;

i. Cathode.

- Hydrogen gas.

ii. Anode.

- Oxygen gas.

c. State how the above products can be tested;

i. Product at cathode.

- By inserting a burning splint in the gas jar containing the gas; it burns with a pop sound.

ii. Product at anode.

- By inserting a glowing splint into the gas jar containing the gas, it relights a glowing splint.

d. Write equation for the reaction occurring at the;
   i. Anode.
      - $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e$
   ii. Cathode.
      - $2H^+(aq) + 2e \longrightarrow H_2(g)$

N.B. **The process above is equivalent to the electrolysis of acidified water. The volume ratio of the gases is established by the same method as that used in electrolysis of dilute sulphuric acid. i.e. the ratio of hydrogen : oxygen is 2:1.**

ELECTROLYSIS OF DILUTE COPPER(II)SULPHATE SOLUTION

This can be carried out using a number of electrodes;

(a) Using graphite (carbon) electrodes.

(b) Using copper as the anode and carbon (or platinum) as cathode.

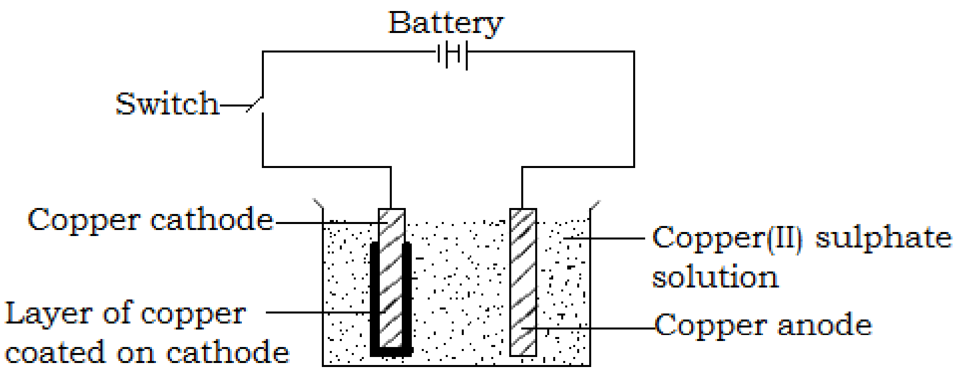
Using graphite (carbon) electrodes

a. State what is observed at the;
   i. Cathode.
      - A brown solid coated the cathode.
   ii. Anode.
      - Bubbles of a colourless gas that relights a glowing splint.

b. Write the equation for the reaction that occur at the;
   i. Cathode.
      - $Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$
   ii. Anode.
      - $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e$

N.B. When inert electrodes e.g. graphite are used, the blue colour of the electrolyte (copper(II) sulphate solution) fades because the copper(II) ions are being discharged at the cathode.

Electrolysis of dilute copper(II)sulphate solution using copper electrodes



(a) State what is observed at the;

i. Cathode.

- A brown solid is deposited and the electrode becomes bigger.

ii. Anode.

- The electrode decreases in size.

(b) Write the equation for the reaction at the;

i. Cathode.

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

ii. Anode.

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

(c) State one disadvantage of the set up of apparatus above.

- There is continuous replacement of the cathode.

EXERCISE

1. (a) Aqueous copper(II) chloride was electrolysed using graphite electrodes. State what was observed at the;

i. Cathode.

……………………………………………………………………………………………
……………………………………………………………………………………………

ii. Anode.

……………………………………………………………………………………………
……………………………………………………………………………………………

(b) Write the equation for the reaction that took place at the;

i. Cathode.

……………………………………………………………………………………
……………………………………………………………………………………

ii. Anode

……………………………………………………………………………………
……………………………………………………………………………………

(c) The above electrolysis was repeated using copper electrodes. State what was observed at;

i. Anode.

……………………………………………………………………………………
……………………………………………………………………………………

ii. Cathode.

……………………………………………………………………………………
……………………………………………………………………………………

(d) Write the equation for the reaction that took place at the;

i. Cathode.

……………………………………………………………………………………
……………………………………………………………………………………

ii. Anode.

……………………………………………………………………………………
……………………………………………………………………………………

2. Concentrated solution of copper(II) chloride was electrolysed using copper anode and copper cathode.

a. Write the equation for the reaction at the;

i. Anode.

……………………………………………………………………………………
……………………………………………………………………………………

ii. Cathode.

……………………………………………………………………………………
……………………………………………………………………………………

b. State what was observed at the;

i. Anode.

……………………………………………………………………………………
……………………………………………………………………………………

ii. Cathode.

……………………………………………………………………………………
……………………………………………………………………………………

a. Differentiate between the terms ‘ electrode’ and ‘electrolyte’

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

b. A dilute solution of copper(II) sulphate was electrolysed using graphite as electrodes. Write the equation for the reaction that took place at the anode.

…………………………………………………………………………………………
…………………………………………………………………………………………

c. Electrolysis of the copper(II) sulphate in (b) was repeated using strips of copper as electrodes instead of graphite and the experiment allowed to stand for some time. State what was observed at;

i. The cathode.

…………………………………………………………………………………………
…………………………………………………………………………………………

ii. The anode.

…………………………………………………………………………………………
…………………………………………………………………………………………

d. State one practical application of electrolysis of copper(II) sulphate solution as described in (c)

…………………………………………………………………………………………
…………………………………………………………………………………………

ELECTROLYSIS OF CONCENTRATED SODIUM CHLORIDE SOLUTION(BRINE) USING PLATINUM OR CARBON CATHODE AND CARBON ANODE.

$$NaCl(aq) \longrightarrow Na^{+}(aq) + Cl^{-}(aq)$$

$$H_2O(l) \longrightarrow H^{+}(aq) + OH^{-}(aq)$$

Sodium ions and hydrogen ions migrate to the cathode.
Hydrogen ions are discharged because they are less reactive than sodium ions.

Reaction at the anode

$2H^{+}(aq) \ + \ 2e \longrightarrow H_2(g)$

Reaction at the cathode

Chloride ions from the sodium chloride and the hydroxyl ions from water move to the anode, but the chloride ions are discharged because they are more concentrated than the hydroxyl ions thus chlorine gas (greenish-yellow gas) is liberated at the anode.

$2Cl^{-}(aq) \longrightarrow Cl_2(g) + 2e$

ELECTROLYSIS OF MOLTEN SODIUM CHLORIDE USING CARBON ELECTRODES

Molten sodium chloride was electrolysed using carbon electrodes.

a. State what was observed at the;

i. Anode

- A greenish-yellow gas was produced.

ii. Cathode.

- Cathode was coated with a grey metal(solid)

b. Write the equation for the reaction that took place at the;

i. Anode.

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

ii. Cathode.

- $Na^{+}(l) \quad + \quad e \longrightarrow Na(s)$

ELECTROLYSIS OF CONCENTRATED SODIUM CHLORIDE USING MERCURY CATHODE AND CARBON ANODE

Concentrated sodium chloride solution (brine) was electrolysed using graphite (carbon) anode and a mercury cathode

a. State what was observed at the;

i. Anode.

- A greenish-yellow gas was produced.

ii. Cathode.

- Cathode was coated with a grey metal(solid)

b. Write the equation for the reaction that took place at the;

i. Anode.

- $2Cl^{-}(aq) \longrightarrow Cl_2(g) + 2e$

ii. Cathode.

- $Na^{+}(aq) \quad + \quad e \longrightarrow Na(s)$

Concentrated hydrochloric acid was electrolysed using carbon cathode and carbon anode.

a. State what was observed at the;

i. Anode.

……………………………………………………………………………………
……………………………………………………………………………………

ii. Cathode.

……………………………………………………………………………………
……………………………………………………………………………………

b. Write the equation for the reaction at the;

i. Anode.

………………………………………………………………………………………
………………………………………………………………………………………

ii. Cathode

………………………………………………………………………………………
………………………………………………………………………………………

The set up of apparatus in the diagram below was used to find out what happens when an electrolyte is connected to a source of electric current.

a. State what was observed ;
   i. When the switch was closed.
- ➢ The blue colour moved towards the cathode.
   ii. If copper(II) sulphate crystal was replaced with potassium manganate(VII) crystal and the switch closed once again.
- ➢ Purple colour moves towards the anode.

b. Give a reason for your answer in a(i) and (ii)
- ➢ Copper(II) ions were attracted to the cathode while the manganate(VII) ions were attracted to the anode.

c. State any general conclusion that can be drawn following the reason you have given in (b)
- ➢ When an electrolyte is connected to source of electric current, ions migrate to the electrodes bearing opposite charges to the ions.

APPLICATION OF ELECTROLYSIS

1) *ELECTROPLATING.*

This is the process of coating a metal with another metal in order to improve its appearance and resistance to corrosion.
The metal to be electroplated is made the cathode and the electroplating material is made the anode.
The electrolyte used in this case must contain ions of the electroplating material e.g. during silver plating, the metal to be plated is made the cathode and silver salt solution as the electrolyte and pure silver is made the anode.

Qn. A ring made of iron can be protected by coating it with silver.
Draw a diagram of the set up of apparatus that can be used to coat an iron ring with silver.

The diagram below is used to show how a metallic fork was silver plated.

a. Identify the;
   i. Anode.
- Silver metal.
   ii. Cathode.
- Metallic fork.

b. State what was observed at the;
   i. Anode.
- The anode dissolved and reduced in size.
   ii. Cathode.
- The cathode was coated with a shinny grey solid.

c. Write the equation for the reaction that took place at;
   i. Anode.
- $Ag(s) \quad \longrightarrow Ag^{+}(aq) \; + e$
   ii. Cathode.
- $Ag^{+}(aq) \; + e \; \longrightarrow Ag(s)$

d. Identify the application of electrolysis being investigated.
- Electroplating.

a. Draw a well labeled diagram of the set up of apparatus that can be used to zinc plate an iron knife. $(2\ marks)$

b. State what was observed at the;
   i. Cathode.
   …………………………………………………………………………………………
   …………………………………………………………………………………………

   ii. Anode.
   …………………………………………………………………………………………
   …………………………………………………………………………………………

c. Write the equation for the reaction at the;
   i. Cathode.
   …………………………………………………………………………………………
   …………………………………………………………………………………………

   ii. Anode.
   …………………………………………………………………………………………
   …………………………………………………………………………………………

2) ***PURIFICATION OF METALS***

Metals such as copper and zinc may be refined (purified) by electrolysis. The impure metal is made the anode and the pure metal made the cathode. The electrolyte is a solution containing the metal ions. E.g.

Study the electrolytic set up below and answer the questions that follow.

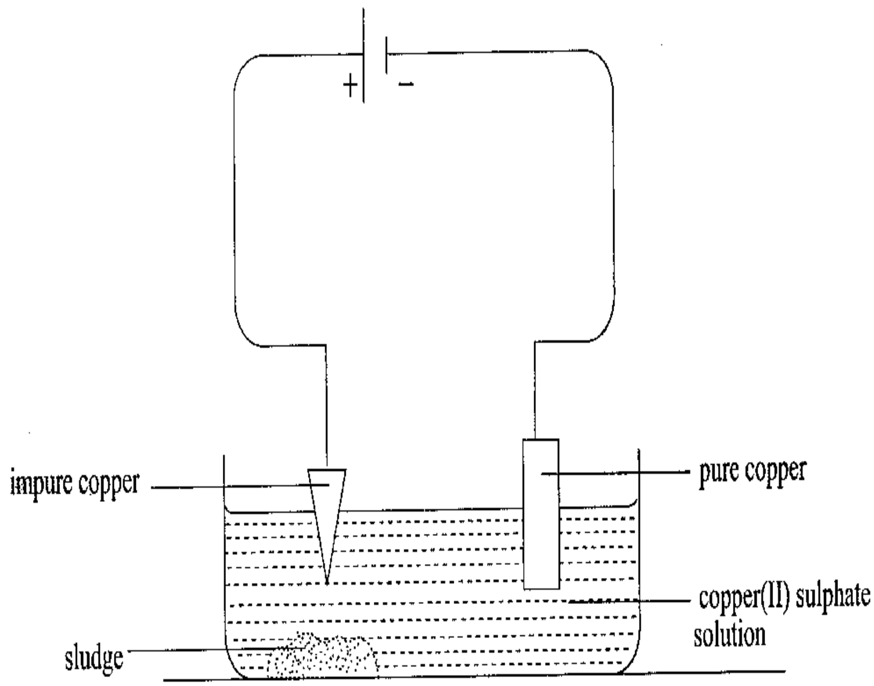


Fig 8.2 Purification of copper

a. State what was observed at the;

   i. Anode.

- The anode dissolves and decreases in mass.

   ii. Cathode.

- The brown solid is deposited.

b. Write the equation for the reaction at the;

   i. Cathode.

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

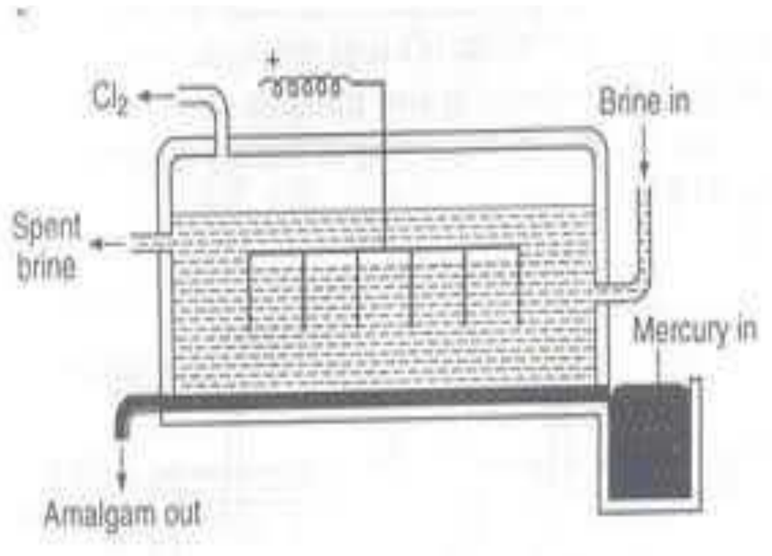
   ii. Anode.

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

c. State the application of electrolysis being investigated.

- Purification of copper.

3) ***MANUFACTURE OF CHEMICALS . e. g. Sodium hydroxide solution.***



In the manufacture of sodium hydroxide solution, concentrated sodium chloride solution (brine) is electrolysed using flowing mercury cathode and carbon anode.

Reaction at the anode

$2Cl^{-}(aq) \longrightarrow Cl_2(g) + 2e$

Reaction at the cathode.

$Na^{+}(aq) + e \longrightarrow Na(s)$

Sodium formed at the cathode dissolves in mercury forming mercury amalgam (Na/Hg) or ($Na.Hg$)

$Na(s) + Hg(l) \longrightarrow Na.Hg(l)$

The amalgam is mixed with water producing sodium hydroxide solution.

$2Na.Hg(l) + 2H_2O(l) \longrightarrow 2NaOH(aq) + 2Hg(l) + H_2(g)$

During the manufacture of sodium hydroxide, concentrated sodium chloride solution is electrolysed using mercury as the cathode.

a. Name the substance used as the anode.

....

b. Give a reason for the choice of the substance in (a) above.

....
....

c. Identify the product collected at the anode.

....

d. During the above process, sodium amalgam is formed at the cathode.

   i. State how the sodium amalgam is converted to sodium hydroxide.

   ....
   ....

ii. Write the equation for the reaction leading to the formation of sodium hydroxide.

………………………………………………………………………………………
………………………………………………………………………………………

ELECTROCHEMICAL CELLS

A cell is a device that converts chemical energy into electrical energy.

The reactions that take place in electrochemical cells are redox reactions.

A redox reaction is a type of reaction that involves both oxidation and reduction at the time(simultaneously).

Any cell that generates electric current by oxidation and reduction is called a voltaic cell or a galvanic cell.

GALVANIC OR VOLTAIC CELL

The common example of a voltaic cell is the Daniel's cell.

THE DANIEL'S CELL

With the aid of a labeled diagram, describe the Daniel's cell.

The Daniel's cell consists of the zinc rod dipped into a solution of zinc sulphate and copper rod dipped into copper(II) nitrate solution.

The solutions are connected using a salt bridge or porous partition which serves to complete the circuit.

The two rods are connected using a wire.

Electrons flow from the zinc rod which acts as the anode to the copper rod which acts as the cathode.

Equation at the anode.

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

Equation at the cathode.

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

overall equation

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

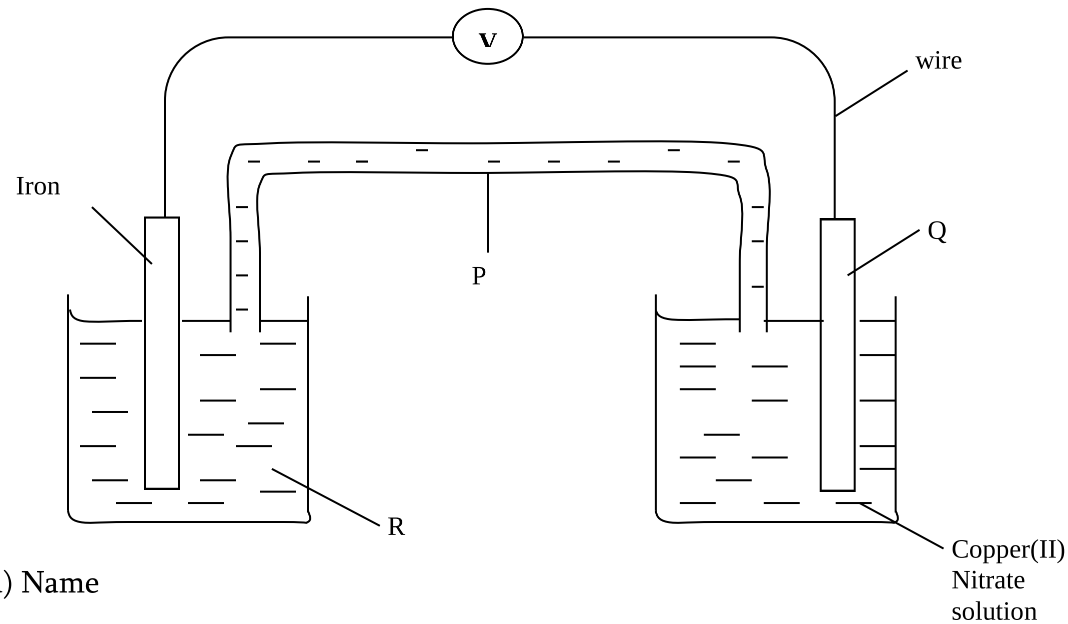
Define oxidation and reduction in terms of electrons.

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

The diagram below shows Copper-Iron electro-chemical cell



(a) Name

(i) P____________________________

(ii) Q____________________________

(iii) R____________________________

(b) (i) State the purpose of P.

____

____

(ii) Name one substance contained in P

____

(c) Indicate on the diagram the direction of flow of electrons.

(d) Write the equation of reaction at the cathode.

____

TEST QUESTIONS ON ELECTROLYTIC CELLS AND ELECTROCHEMICAL CELLS

1. (a) (i) Using examples, state the difference between **an electrolyte** and **an electrode** *(04 marks)*

(ii) Explain why aqueous solution of sodium chloride conducts electricity whereas solid sodium chloride does not. *(02marks)*

....

....

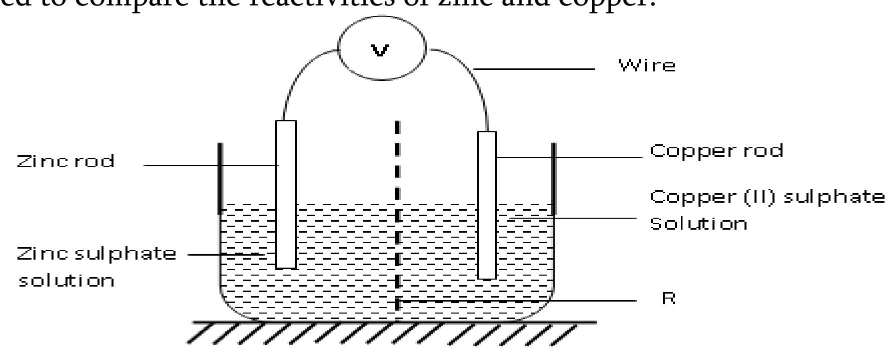
....

....

....

....

(b) The diagram below shows a set up of an electro-chemical cell which can be used to compare the reactivities of zinc and copper.



(i) Identify the rod that is positively charged. *(01 mark)*

....

(ii) Identify R and state its purpose. *(1½ marks)*

....

(iii) Write equations for the reactions taking place at the copper and zinc rods. *(03 marks)*

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(iv) Write equation for the overall reaction in the cell. *(1½ marks)*

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....

(v) State what would happen if zinc metal is dropped in a solution containing copper (II) ions. *(02marks)*

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2. Figure 2 shows the set – up of the apparatus in which electric current was produced by dipping two different metal rods A and B into dilute sulphuric acid.

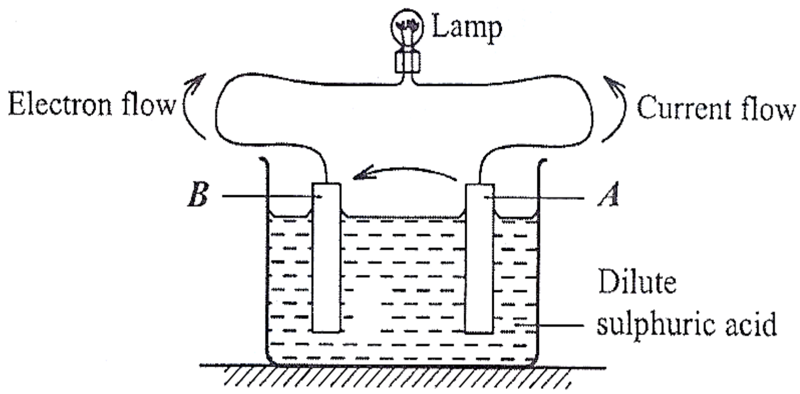

Fig. 2

(a) Name one metal that can be used as

(i) A

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(ii) B

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(b) State which of the metals A and B is the

(i) Anode

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(ii) Cathode

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(c) Both A and B are divalent metals.

Write equation for the reaction at

(i) Anode (1 ½ marks)

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(ii) Cathode (1 ½ marks)

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3. The cell convention for an electrochemical cell is shown below

$Zn(s)/Zn^{2+}(aq) \parallel Pb^{2+}(aq)/Pb(s)$

(a) Name two substances that could be used as electrolytes (1 mark)

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(b) State which one of the electrodes is the anode (½ mark)

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(c) Write equation for the reaction at

(i) the anode (1 mark)

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(ii) the cathode (1 mark)

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(d) Write an equation for the overall cell reaction (1 ½ marks)

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4. (a)Draw a diagram of a Daniel cell consisting of a zinc rod dipped in zinc sulphate solution and a copper rod dipped in copper(II) sulphate solution; the solutions separated by a porous wall; and the rods connected by a wire.

(b) Indicate;

(i) The charges on each electrode.

(ii) The direction of electron movement in the wire.

(c) Write;

(i) Equation for the reactions at each electrode.

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(ii) An equation for the overall reaction.

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Extraction of metals is the process of obtaining a metal from its naturally occurring ore.
An ore is a naturally occurring substance (or mineral) from which the metal can be extracted.
Most electropositive metals (higher in the electrochemical series) e.g. potassium, sodium, calcium, magnesium and aluminium occur mainly as **chlorides.** They are extracted by electrolysis.
Metals in the middle of the electrochemical series such as zinc, iron, lead and copper mainly occur as oxides, carbonates and sulphides. They are extracted by reduction of the ore.
Reduction is the addition of electrons to a chemical substance.
Chemical reduction involves the extraction of the metal from its ore by heating the ore with a strong reducing agent such as coke.
Metals lower in the electrochemical series such as mercury, silver and gold mainly occur as free metals in the Earth's crust. They are mainly dug up in the pure form.

SODIUM

The ores from which sodium can be extracted include the following;

- ✓ Sodium carbonate (soda ash)
- ✓ Sodium nitrate.
- ✓ Sodium chloride (Rock salt)

N.B. The chief ore from which sodium is extracted is **sodium chloride.**

EXTRACTION OF SODIUM

Sodium is extracted by electrolysis of **molten sodium chloride.**
It is done by the **Down's cell.**
The melting point of sodium chloride is lowered from $800°C\ to\ 600°C$ by addition of calcium chloride.
The anode is made up of circular steel (or iron) while the cathode is made up of graphite or carbon.
An iron gauze diaphragm is used to prevent the chlorine formed at the anode from mixing with sodium at formed at cathode.
The reactions at the electrodes are as shown below.

At the cathode

The sodium ions are attracted to the cathode and are discharged by electron gain to form liquid sodium.

Equation for the reaction

$Na^{+}(l)\ \ + e\ \ \longrightarrow Na(l)$

At the anode

The chloride ions are attracted there and are discharged by electron loss to give off chlorine gas.

Equation for the reaction

$2Cl^{-}(l) - 2e\ \ \longrightarrow\ Cl_2(g)$

Or
$2Cl^{-}(l) \longrightarrow Cl_2(g) + 2e$
The sodium metal collects under dry nitrogen in the inverted trough placed over the cathode.
Chlorine gas escapes through the hood.
Diagram to illustrate.

PROPERTIES OF SODIUM
Sodium is a white shiny silvery solid (or a grey shiny silvery solid)

a) ***Reaction with air (oxygen)***
Sodium first melts, then burns in excess oxygen or air with a bright yellow flame forming a yellow solid (sodium peroxide)
$2Na(s) + O_2(g) \longrightarrow Na_2O_2(s)$
Sodium first melts, then burns with a bright yellow flame in limited air to form a white solid (sodium oxide)
$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$
N.B.
    - ✓ The sodium and potassium tarnish rapidly in air because of formation of a thin layer of oxide.
    - ✓ Water vapour converts the oxide to a hydroxide which slowly absorbs carbon dioxide.
    - ✓ The final product is sodium or potassium hydrogen carbonate or sodium/potassium carbonate depending on the concentration of carbon dioxide.

$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$
$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$
$NaOH(aq) + CO_2(g) \longrightarrow NaHCO_3(s)$

- Potassium first melts, then burns in excess air with a lilac flame forming a deep yellow solid.
$2K(s) + O_2(g) \longrightarrow K_2O_2(s)$

b) ***Reaction with water.***

Sodium first melts into a silvery ball then darts/moves with a hissing sound on the surface of water giving off a colourless gas.

A colourless solution is formed.

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

c) ***Reaction with chlorine***.

Heated sodium burns with a yellow flame in chlorine forming white fumes that solidify into a white solid (sodium chloride)

$2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$

d) ***Reaction with hydrogen***

Heated sodium burns with a yellow flame in hydrogen forming white fumes which solidify into a white solid (sodium hydride)

$2Na(s) + H_2(g) \longrightarrow 2NaH(s)$

e) ***Reaction with mercury***

Sodium reacts with mercury forming sodium amalgam which quietly reacts with water to form sodium hydroxide, hydrogen and mercury.

$Na(l) + Hg(l) \longrightarrow NaHg(l)$

$2NaHg(l) + 2H_2O(l) \longrightarrow 2NaOH(aq) + 2Hg(l) + H_2(g)$

1. During the manufacture of sodium hydroxide, a concentrated sodium chloride solution (brine) is electrolysed using mercury cathode as shown in the diagram below.

a) Name the substance used as the anode.

✓ Carbon or graphite.

b) Identify substance;

i. Fed in at Q

✓ Concentrated sodium chloride solution (or brine)

ii. Taken out from;

R- Chlorine gas.

S- Used brine.

T- Sodium amalgam.

c) Name one other substance forming during the manufacture of sodium hydroxide.

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d) Describe briefly how solid sodium hydroxide can be obtained from the product of electrolysis.

- ✓ The sodium formed at the cathode dissolves in the mercury cathode to form sodium amalgam.
- ✓ The sodium amalgam then dissolves in water forming sodium hydroxide solution, mercury and hydrogen gas.
- ✓ Sodium hydroxide solution is then evaporated to dryness to obtain solid sodium hydroxide.

2. During the manufacture of sodium hydroxide, concentrated sodium chloride solution is electrolysed using mercury as the cathode.

a) (i) Name the substance that is used as the anode

- ✓ Graphite (carbon)

(ii) Give a reason for the choice of the substance.

- ✓ Graphite or carbon is unreactive and does not react with the product formed on it.

(iii) Identify the product collected at the anode.

- ✓ Chlorine.

b) During the electrolysis, sodium amalgam is formed at the cathode.

i. State how sodium amalgam is converted to sodium hydroxide.

- ✓ By dissolving sodium amalgam in a known volume of water.

ii. Write an equation for the reaction leading to the formation of sodium hydroxide.

- ✓ $2NaHg(l) + 2H_2O(l) \longrightarrow 2NaOH(aq) + 2Hg(l) + H_2(g)$

c) State two industrial uses of sodium hydroxide.

- ✓ Manufacture of soap.
- ✓ Manufacture of oxygen.

3. In the extraction of sodium from sodium chloride, calcium chloride is added to sodium chloride and the mixture is melted. The molten mixture is then electrolysed using graphite electrodes.

a) State the purpose of adding calcium chloride.

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b) Write the equation for the reaction that takes place at the;

i. Anode.

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ii. Cathode.

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c) Bromine vapour was passed over heated sodium. Write the equation for the reaction that took place.

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4. (a) Name the common ore of sodium and write its formula (1 mark)

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(b) Briefly describe how sodium can be extracted from the named ore in (a) and write equations(s) to illustrate your answer (5 marks)

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(c) State what would be observed and write equation when sodium metal

(i) reacts with oxygen (3 marks)

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(ii) is dropped in a beaker of cold water (3 ½ marks)

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(iii) reacts with chlorine gas (2 ½ marks)

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IRON

The following are the ores from which iron can be extracted;

	Chemical name	Chemical formula
1.	*Haematite* *Iron(III) oxide*	$\boldsymbol{Fe_2O_3}$
2.	*Spathic iron ore* *Iron(II)carbonate* *Siderite*	$\boldsymbol{FeCO_3}$
3.	*Iron(IV)sulphide* *Iron pyrites* *Iron disulphide*	$\boldsymbol{FeS_2}$
4.	*Magnetite* *Triirontetraoxide* *Iron(II, III) oxide*	$\boldsymbol{Fe_3O_4}$

N.B. The chief ore from which iron is extracted is Haematite

EXTRACTION OF IRON USING HAEMATITE

The haematite, limestone (calcium carbonate), coke and hot air are fed into a blast furnace.
Hot coke reacts with oxygen of the air to form carbon dioxide gas.

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

Carbon dioxide gas is then reduced by more hot coke to form carbon monoxide gas.

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

The carbon monoxide reduces the hot haematite to iron which is impure.

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

Molten iron runs to the bottom of the furnace.
Limestone is decomposed by heat to form calcium oxide (Quick lime) and carbon dioxide.

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

The basic calcium oxide reacts with acidic silicon(IV) oxide or sand or silicon dioxide or silica present as an impurity in the ore and forms a molten slag of calcium silicate.

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

Both iron and slag are molten and drop to the bottom of the furnace.

Slag (less dense) floats on the top of the iron and prevents oxidation of iron by the hot air blast.

ILLUSTRATION

EXTRACTION OF IRON USING SPATHIC IRON ORE

The spathic iron ore is first roasted or heated in air to convert it into iron(III) oxide.

Roasting also drives off the water from the ore.

$4FeCO_3(s) + O_2(g) \longrightarrow Fe_2O_3(s) + 4CO_2(g)$

The ore, limestone (calcium carbonate), coke and hot air are fed into a blast furnace.

Hot coke reacts with oxygen of the air to form carbon dioxide gas.

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

Carbon dioxide gas is then reduced by more hot coke to form carbon monoxide gas.

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

The carbon monoxide reduces the hot ore to iron which is impure.

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

Molten iron runs to the bottom of the furnace.

Limestone is decomposed by heat to form calcium oxide (Quick lime) and carbon dioxide.

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

The basic calcium oxide reacts with acidic silicon(IV) oxide or sand or silicon dioxide or silica present as an impurity in the ore and forms a molten slag of calcium silicate.

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

Both iron and slag are molten and drop to the bottom of the furnace.

Slag (less dense) floats on the top of the iron and prevents oxidation of iron by the hot air blast.

EXTRACTION OF IRON USING IRON PYRITES

Iron pyrites are first roasted in air to convert it into iron(III) oxide and sulphur dioxide and even remove some oxidizable impurities.

$4FeS_2(s) + 11O_2(g) \longrightarrow 2Fe_2O_3(s) + 8SO_2(g)$

The ore, limestone (calcium carbonate), coke and hot air are fed into a blast furnace.
Hot coke reacts with oxygen of the air to form carbon dioxide gas.
$C(s) + O_2(g) \longrightarrow CO_2(g)$
Carbon dioxide gas is then reduced by more hot coke to form carbon monoxide gas.
$CO_2(g) + C(s) \longrightarrow 2CO(g)$
The carbon monoxide reduces the hot ore to iron which is impure.
$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l) + 3CO_2(g)$
Molten iron runs to the bottom of the furnace.
Limestone is decomposed by heat to form calcium oxide (Quick lime) and carbon dioxide.
$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$
The basic calcium oxide reacts with acidic silicon(IV) oxide or sand or silicon dioxide or silica present as an impurity in the ore and forms a molten slag of calcium silicate.
$CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(l)$
Both iron and slag are molten and drop to the bottom of the furnace.
Slag (less dense) floats on the top of the iron and prevents oxidation of iron by the hot air blast.

EXTRACTION OF IRON USING MAGNETITE

The haematite, limestone (calcium carbonate), coke and hot air are fed into a blast furnace.
Hot coke reacts with oxygen of the air to form carbon dioxide gas.
$C(s) + O_2(g) \longrightarrow CO_2(g)$
Carbon dioxide gas is then reduced by more hot coke to form carbon monoxide gas.
$CO_2(g) + C(s) \longrightarrow 2CO(g)$
The carbon monoxide reduces the hot haematite to iron which is impure.
$Fe_3O_4(s) + 4CO(g) \longrightarrow 3Fe(l) + 4CO_2(g)$
Molten iron runs to the bottom of the furnace.
Limestone is decomposed by heat to form calcium oxide (Quick lime) and carbon dioxide.
$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$
The basic calcium oxide reacts with acidic silicon(IV) oxide or sand or silicon dioxide or silica present as an impurity in the ore and forms a molten slag of calcium silicate.
$CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(l)$
Both iron and slag are molten and drop to the bottom of the furnace.
Slag (less dense) floats on the top of the iron and prevents oxidation of iron by the hot air blast.

USES OF IRON

- Making iron bars.
- Making iron nails.
- Making doors and window frames.
- Making iron sheets.
- Making metallic beds.
- Making metallic chairs.

USES OF SLAG

- Manufacture of fertilizers.
- Road making material.
- Manufacture of cement.
- Used as a light building material.

CHEMICAL PROPERTIES OF IRON

a) ***Reaction of iron with water***

Iron does not react with cold water alone.
It reacts with water in form of steam when iron is strongly heated.
Heated iron glows red hot forming a blue-black solid (iron(II, III) oxide)
$3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$

b) ***Reaction of iron with air/oxygen***

Iron rusts in moist air forming a reddish-brown solid of hydrated iron(III) oxide called rust.
$4Fe(s) + 3O_2(g) + 2xH_2O(l) \longrightarrow 2Fe_2O_3.xH_2O(s)$

c) ***Reaction of iron with dilute acids e.g. dilute hydrochloric acid***

Iron dissolves in the acid with bubbles of a colourless gas forming a green solution.
$Fe(s) + 2H^+(aq) \longrightarrow Fe^{2+}(aq) + H_2(g)$

d)

1. One of the ores from which iron is extracted is spathic iron ore.
   i. Write the formula of the iron compound that is in the ore.
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   ii. Describe how impure iron is extracted from spathic iron ore. (Your answer should include equations) (07 *marks*)
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(b) Write equation(s) where possible and state the condition(s) for the reaction of iron with;

i. Water.

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ii. Chlorine

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(c) State three uses of iron.

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2. Haematite is one of the ores from which iron can be extracted.

a) Write the chemical formula of haematite.

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b) During the extraction of iron, roasted haematite is mixed with coke and limestone. The mixture is fed into the blast furnace and a blast of hot air blown into the furnace from the bottom.

i. Write equation(s) for the reaction(s) in the blast furnace that leads to the formation of iron $(4\frac{1}{2}\ marks)$

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ii. Explain the role of limestone $(4\frac{1}{2}\ marks)$

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c) Write equation for the reaction of iron with;

i. Water

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ii. Hydrochloric acid.

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d) To the resultant mixture in reaction (c)(ii) was added dilute ammonia solution until the alkali was in excess. State what was observed and write the equation for the reaction that took place.

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

- ✓ Air (or hot blast air)
- ✓ Coke.
- ✓ Limestone.
- ✓ Haematite (or magnetite, spathic iron ore, iron pyrites, limonite)

Note; chemical names are rejected for the ore in this case.

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

- ✓ Haematite is mixed with coke and limestone; and roasted in air in blast furnace to form the oxide.
- ✓ Hot air is passed from the base into the furnace.

- ✓ Coke burns in air forming carbon dioxide.
  $C(s) + O_2(g) \longrightarrow CO_2(g)$
- ✓ The carbon dioxide gas produced combines with more coke to form carbon monoxide.
  $CO_2(g) + C(s) \longrightarrow 2CO(g)$
- ✓ The carbon monoxide formed reduces the iron(III) oxide formed to iron.
  $Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l/s) + 3CO_2(g)$

(c) State what would be observed and write the equation for the reaction that would take place when the following gases are passed over heated iron.

i. Dry chlorine.
   - ✓ Heated iron glows red hot forming black crystals (sublimate) or solid.
   - ✓ $2Fe(s) + 3Cl_2(g) \longrightarrow 2FeCl_3(s)$

ii. Steam.
   - ✓ Heated iron glows red hot forming a blue-black solid.
   - ✓ $3Fe(s) + 4H_2O(g) \longrightarrow Fe_3O_4(s) + 4H_2(g)$

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

- ✓ $Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$

  or
- ✓ $Fe(s) + 2H^+(aq) \longrightarrow Fe^{2+}(aq) + H_2(g)$

4. In the extraction of cast iron using a blast furnace, spathic iron ore, which contains some impurities, is first roasted in air. It is then mixed with some other substances 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.

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b) (i) Give the chemical name of spathic iron ore.

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

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

i. From the top

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ii. From the bottom.

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d) Outline the reactions leading to;

i. The formation of cast iron.

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

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e) State the major components of steel.

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5. (a) Name one ore of iron and write its formula.

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(b) During the extraction of iron, limestone and coke are added into the blast furnace. Explain the role of;

i. Coke (05 *marks*)

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ii. Limestone. $(04\ marks)$

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$(Use\ equation(s) to\ illustrate\ your\ answers)$

(c) Write equation for the reaction leading to the formation of iron(II) sulphate.

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(d) Iron(II) sulphate was heated strongly.

i. State what was observed.

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ii. Write the equation for the reaction that occurred.

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6. a) Haematite is an ore of iron from which the metal is extracted. Write the chemical name and formula of haematite $(02\ marks)$

- $Iron(III) oxide$; Fe_2O_3

(b) During the extraction of iron in the blast furnace, carbon monoxide is formed which converts the ore into iron and slag is also produced.

i. Outline the reaction leading to the formation of carbon monoxide and subsequently to the conversion of the ore to iron $(06\ marks)$

- Coke burns in air forming carbon dioxide
  $C(s) + O_2(g) \longrightarrow CO_2(g)$
- The carbon dioxide gas produced combines with more carbon to form carbon monoxide.
  $CO_2(g) + C(s) \longrightarrow 2CO(g)$
- The carbon monoxide formed reduces the iron(III) oxide to iron.

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

ii. Write the chemical name of slag and explain how it is formed (05 $marks$)

- Calcium silicate.

  Limestone is decomposed into calcium oxide and carbon dioxide.
  $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$
  Calcium oxide, which is a base, reacts with silicon dioxide (acidic oxide), which is present as the major impurity in the ore; forming the slag.
  $CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(l)$

(c) Most of the iron that is extracted is used for making steel, which is more commonly used instead of pure iron. State what steel is and give two reasons why it is more commonly used instead of pure iron (02 $marks$)

- Steel is an alloy of iron with carbon present in small amounts.
- Steel is more durable than pure iron.
- Steel is stronger than pure iron.
- Steel resists rusting whereas pure iron rusts readily.
- Steel has an attractive appearance compared to pure iron.

6. Sodium and iron are extracted from their ores by electrolysis and reduction respectively

a) .

i. Define the term an ore.

✓ An ore is naturally occurring solid material from which a metal or valuable material can be extracted.

ii. State why sodium is extracted by Electrolysis whereas iron is extracted by reduction.

✓ The ionic bond in sodium chloride is much stronger than that in the oxides of iron; thus it requires a lot of heat energy to have it broken compared to the heat energy which favours chemical reduction.

b) .

i. Name one common ore of sodium.

✓ Sodium chloride.

ii. Write the chemical name and formula of one oxide and one carbonate, which are some of the major ores of iron

✓ Iron(III) oxide;Fe_2O_3 (or triiron tetraoxide; Fe_3O_4)

✓ Iron(II) carbonate; $FeCO_3$

c) Briefly describe how sodium can be extracted from its ore and write the equation(s) to illustrate your answer.

- ✓ Sodium is extracted by electrolysis of fused or molten concentrated, sodium chloride solution or brine to which calcium chloride has been added to lower its melting point from 800℃ to 600℃ in Down's cell. Iron cathode and graphite anode are used.
- ✓ The cell has steel gauze around the anode that prevents the sodium and chlorine from reacting.
- ✓ The sodium ions are reduced at the iron cathode and the sodium floats on top of the sodium chloride since its less dense.
- ✓ It is then collected in an inverted trough placed over the cathode and its tapped off through the iron storage tank containing nitrogen gas.

  $Na^{+}(l) \ + e \ \ \longrightarrow Na(s)$

d) Describe with the aid of equations, how sodium reacts with;

i. Oxygen.

- ✓ Sodium burns in excess oxygen with a bright yellow flame forming a yellow solid of sodium peroxide.

  $2Na(s) \ + \ O_2(g) \longrightarrow \ Na_2O_2(s)$
- ✓ Sodium also burns in limited oxygen with a bright yellow flame forming a white solid of sodium oxide.

  $4Na(s) \ + \ O_2(g) \longrightarrow \ 2Na_2O(s)$

ii. Water.

- ✓ Sodium melts into a silvery ball that moves rapidly on the water surface producing a hissing sound, effervescence of a colourless gas and a colourless solution is formed. The colourless gas is hydrogen gas and the colourless solution is sodium hydroxide.

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

iii. Chlorine.

- ✓ Sodium burns in chlorine with a bright yellow flame forming white fumes which solidify into a white solid.

  $2Na(s) \ + \ Cl_2(g) \ \ \longrightarrow 2NaCl(s)$

e) During extraction of iron, the ores are first roasted in air before being transferred into the blast furnace;

i. State the purpose of roasting the iron ore in air.

- ✓ To remove water and to convert the carbonate to iron(III) oxide.

ii. Name the major impurity in the iron ore.

- ✓ Sand or silicon(IV) oxide.

iii. Name two substances that are also fed into the furnace together with the roasted iron ore.

✓ Coke and limestone (calcium carbonate)

iv. Name any one substance that is also fed into the furnace, and describe where from the substance is let into the furnace.

✓ Hot air through holes at the bottomed of the furnace.

f) Using equations, outline the reactions which take place in the blast furnace up to;

i. Reduction of the ore.

✓ $C(s) + O_2(g) \longrightarrow CO_2(g)$

✓ $CO_2(g) + C(s) \longrightarrow 2CO(g)$

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

ii. Removal of the major impurity in the ore.

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

✓ $CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(l)$

g) State the importance of slag during the extraction of iron in the furnace.

✓ To prevent oxidation of iron by hot air.

h) When excess iron filings was added to 250cm^3 of a solution containing 0.5 moles of copper(II) sulphate per dm^3 and the experiment was allowed to stand until there was no further change, a brown solid formed on the iron filings. Determine the maximum mass of the brown solid that was formed. ($S = 32; Fe = 56; Cu = 64; O = 16$)

$$Moles\ of\ CuSO_4 = \frac{0.5 \times 250}{1000}$$
$$= 0.125\ moles$$
$$Fe(s) + CuSO_4(aq) \longrightarrow FeSO_4(aq) + Cu(s)$$
$$1\ mole\ of\ CuSO_4\ produced\ 1\ mole\ of\ copper$$
$$Moles\ of\ copper\ formed = 0.125\ moles$$
$$Mass\ of\ copper\ formed = (64 \times 0.125)$$
$$= 8\ g$$

QUESTIONS ON CALCULATIONS

1. (a) Define the term heat of combustion.

(b) When 3000cm^3 of methane gas measured at room temperature and pressure was burnt, 195KJ of heat were evolved.

i. Write equation for the complete combustion of methane.

ii. Calculate the heat of combustion.

2. A hydrocarbon Z contains 82.7% carbon. The formula mass of Z is 58g.

(a) Calculate the;

(i) Simplest formula of Z.

(ii) Molecular formula of Z.

(b) Write the;

(i) Structural formula of Z

(ii) Equation for the incomplete (partial) combustion of Z.

3. 6.3g of a hydrated dibasic acid, $H_2X.nH_2O$ were dissolve in water to form one litre of solution. 25cm^3 of this solution was found to require 12.5cm^3 of 0.2M sodium hydroxide solution for complete reaction.

(a) Calculate the molar concentration of the acid.

(b) Determine the;

(i) Relative formula mass of the acid.

(ii) Value of n in the formula, $H_2X.nH_2O$ $(H = 1; O = 16; X = 88)$

4. Sodium stearate, $C_{17}H_{35}CO_2Na$, an example of soap can be prepared by heating a fat with sodium hydroxide solution. Calculate the mass of soap formed when 100cm^3 of 2M sodium hydroxide solution is heated with excess fat. ($Mole\ ratio\ of\ NaOH: C_{17}H_{35}CO_2Na = 1:1$)

5. When 18g of a mixture of sodium carbonate and sodium hydrogen carbonate was strongly heated, 2.4 litres of carbon dioxide were evolved at room temperature. Calculate the mass of sodium carbonate in the mixture.

6. A metal Q is below hydrogen in the reactivity series. When 2.4g of Q was burnt in excess oxygen, 4.0g of the residue was formed. $(Q = 24; O = 16)$

(a) Determine the formula of Q.

(b) Write the equation for the reaction between hydrogen and the residue.

7. Bio gas burns in excess air according to the equation;

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)\ ;\ \Delta H = -474KJmol^{-1}$

(i) Why is it dangerous to cook using bio gas in a poorly ventilated room?

(ii) Calculate the mass of bio gas required to produce 8600KJ of heat.

8. (a) Barium chloride and potassium carbonate can react to form barium carbonate according to the following equation;

$Ba^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow BaCO_3(s)$

State ;

i. What would be observed if barium chloride solution was added to a solution containing carbonate ions?

ii. One practical application of the reaction shown by the ionic equation above.

(b) 25cm^3 of a 1M potassium carbonate solution was all added to 40cm^3 of a 0.5M barium chloride solution and the mixture stirred.

i. Determine the respective numbers of moles carbonate and barium ions that reacted.
ii. Calculate the maximum mass of barium carbonate that was formed. $(Ba = 137; C = 12; O = 16)$

9. (a) Write the equation to show how ethene can be;
i. Obtained from ethanol.
ii. Converted into Polyethene.

(b) With reference to the equation you have written in (a)(ii), state
i. What name ethene is known as.
ii. The general name given to the group of compounds to which Polyethene belongs.

(c) Calculate the number of moles of ethene in a Polyethene molecule of molecular mass 16856. $(C = 12; H = 1)$

10. When excess hydrogen was passed over 3.600g of a strongly heated oxide of copper, 3.200g of the residue remained.

(a) (i) Calculate the empirical formula of the oxide.
$(Cu = 64; O = 16; RFM\ of\ the\ oxide = 144)$
(ii) Determine the true formula of the oxide.

(b) Write the name of the oxide, the formula of which you have determined in (a)(i)

11. (a) (i) Name one reagent that can react with sulphuric acid to produce hydrogen chloride gas in the laboratory.
(ii) State the conditions for the reaction between sulphuric acid and the substance you have named in (a)(i) above.
(iii) Write the equation for the reaction between sulphuric acid and the substance named in (a)(i)

(b) A solution of hydrogen chloride reacts with lead(II) nitrate solution to form lead(II) chloride according to the following equation below;
$Pb^{2+}(aq) + 2Cl^{-}(aq) \longrightarrow PbCl_2(s)$
Calculate the maximum mass of lead(II) chloride that would be formed if excess solution of hydrogen chloride was added to 20.0cm^3 of 0.5M lead(II) nitrate solution. $(\boldsymbol{Ans = 2.78g})$

12. (a) State what is observed when zinc powder is added to copper(II) sulphate solution.
(b) Explain your observation.
(c) When 6.5g of zinc powder was added to 100cm^3 of 1M copper(II) sulphate solution in a plastic beaker, 5.5KJ of heat was produced.
i. Calculate the number of moles of copper(II) nitrate that reacted.

ii. Calculate the enthalpy change in $kjmol^{-1}$

13. 37.6g of copper(II) nitrate crystals were completely decomposed by heat.

(a) State what was observed.

(b) Calculate the mass of the residue. $(Cu = 64; O = 16; N = 14)$

(c) Write an equation for the reaction between the residue in (a) and dilute sulphuric acid.

14. 2.0g of ammonium nitrate was dissolved in $100cm^3$ of water; and the temperature of the water dropped from 25.0℃ to 21.0℃.

(a) Give a reason why there was a drop in temperature of the water.

(b) Calculate the molar enthalpy of solution of ammonium nitrate.

$(H = 1; N = 14; O = 16; density\ of\ water = 1gcm^{-3}\ and\ SHC = 4.2Jg^{-1}k^{-1})$

15. A compound Q consists of 26.7% carbon and 2.2% hydrogen by mass; the rest being oxygen.

(a) Calculate the empirical formula of Q$(C = 12; O = 16; H = 1)$

(b) An aqueous solution of Q turns blue litmus paper red.

i. Suggest how the PH value of a 2M aqueous solution of Q would compare with the PH of a 2M hydrochloric acid. Give a reason for your suggestion.

- ✓ 2M aqueous solution of Q would have a higher PH value than 2M hydrochloric acid. Q must be a weak acid which partially ionizes producing fewer hydrogen ions ; since its solution turns blue litmus paper red.

ii. Predict how Q would react with magnesium powder.

- ✓ Aqueous Q would react with magnesium power with effervescence, liberating hydrogen gas and magnesium salt of Q remains.

iii. Write an ionic equation for the reaction that you have predicted in (b)(ii)

(c) $100cm^3$ of a solution containing 4.5g of Q per dm^3 of solution required exactly 0.12g of magnesium powder for complete reaction.
$(Mg = 24; 1\ mole\ of\ Q\ reacts\ with\ 1\ mole\ of\ magnesium)$
Calculate;

(i) The concentration of Q in moles per dm^3

(ii) The formula mass of Q.

(d) Determine the molecular formula of Q.

16. Calculate the value of $\boldsymbol{x}$ in hydrated aluminium sulphate, $Al_2(SO_4)_3.\boldsymbol{x}H_2O$ if the percentage of aluminium is 14.3%. ($Al = 27; S = 32; O = 16; H = 1$)

$Let\ the\ molar\ mass\ of\ Al_2(SO_4)_3.\boldsymbol{x}H_2O\ be\ y$

$Percentage\ of\ aluminium\ in\ Al_2(SO_4)_3.\boldsymbol{x}H_2O$

$$= \left(\frac{mass\ of\ aluminium}{molar\ mass\ of\ Al_2(SO_4)_3.\boldsymbol{x}H_2O} \times 100\right)$$

$$14.3 = \frac{(27 \times 2)}{y} \times 100$$

$$14.3 = \frac{54}{y} \times 100$$

$$14.3y = 5400$$

$$y = 377.6\ g$$

$\therefore$ $\boldsymbol{The\ Molar\ mass\ of\ Al_2(SO_4)_3.xH_2O = 377.6\ g}$

$$Al_2(SO_4)_3.xH_2O = 377.6$$

$$(27 \times 2) + (32 \times 3) + (16 \times 4 \times 3) + x[(1 \times 2) + (16 \times 1)] = 377.6$$

$$54 + 96 + 193 + 2x + 16x = 377.6$$

$$342 + 18x = 377.6$$

$$18x = 377.6 - 342$$

$$18x = 35.6$$

$$x = 1.9778$$

$$x \approx 2$$

$\boldsymbol{Therefore, the\ value\ of\ x\ is\ 2}$

17. Hydrated sodium carbonate, $Na_2CO_3.\boldsymbol{n}H_2O$ contains 16.1% sodium. Calculate the value of $\boldsymbol{n}$ hence write the formula of the compound.
($Na = 23; C = 12; O = 16; H = 1$)

18. Hydrated iron(II) sulphate, $FeSO_4.\boldsymbol{y}H_2O$ contains 20.1% of iron. Determine the value of **y** ($Fe = 56; S = 32; O = 16; H = 1$)

19. A metal sulphate, $X_2(SO_4)_3$, contains 28% by mass of metal X. determine the relative atomic mass of X and the relative molecular mass of $X_2(SO_4)_3$
($S = 32; O = 16$)

20. (a)What is meant by the term 'water of crystallization?'
(b) 0.465g of hydrated form of sodium carbonate exactly reacted with 75cm^3 of 0.1M hydrochloric acid. Calculate the number of moles of water of crystallization present in one mole of hydrated salt.

(c) A metal M formed a carbonate,MCO_3. 1.0g of this carbonate was dissolved in 50.0cm^3 of 1M hydrochloric acid. The resultant solution required 30.0cm^3 of 1M sodium hydroxide solution for complete neutralization.

i. Determine the relative atomic mass of M. ($5\frac{1}{2}marks$)

ii. State the chemical name of M. ($\frac{1}{2}mark$)

21.(a) Zinc can react with sulphuric acid according to the following ionic equation.

$Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$

100cm^3 of 0.5M of sulphuric acid was carefully added to 2.0g of zinc powder and the volume of hydrogen evolved was measured at room temperature.

Calculate the number of moles of;

i. Zinc that was used. (Zn=65)

$65g\ of\ Zinc\ contain\ 1\ mole$

$2.0g\ of\ Zinc\ contain\ \left(\frac{1}{65} \times 2.0\right)\ moles$

$= 0.03\ moles\ of\ Zinc$

ii. Hydrogen ions that were added.

$Number\ of\ moles\ of\ hydrogen\ ios = 2 \times moles\ of\ acid\ used.$

$= \left(2 \times \frac{0.5}{1000} \times 100\right)$

$= 0.1\ moles.$

(b) Deduce the number of moles of hydrogen ions that reacted.

$Moles\ of\ H^+\ ions\ that\ reacted = 2 \times moles\ of\ Zinc\ used.$

$= 2 \times 0.03$

$= 0.06\ moles.$

(c) Determine the volume of hydrogen that was evolved.(1mole of a gas occupies 24dm^3 at room temperature).($1\frac{1}{2}marks$)

$Moles\ of hydrogen\ evolved\ = \frac{1}{2}\ moles\ of\ H^+\ ions$

$= \frac{1}{2} \times 0.06$

$= 0.03\ Moles.$

$Volume\ of\ hydrogen\ evolved = 0.03 \times 24$

$= 0.72dm^3$

(e) The solution that remained after evolution of hydrogen had stopped was tested with litmus paper. State what was observed, and explain your observation fully. $(1\frac{1}{2}marks)$

- Blue litmus paper turned red.
- Not all the hydrogen ions added reacted with zinc. The excess hydrogen ions turned blue litmus red.

(b) When Xg of ammonium chloride were used in the preparation of ammonia gas as shown by the equation in (a), 3.40g of pure and dry calcium chloride were obtained.

i. Determine the value of X

$(2\frac{1}{2}marks)$

$$Mass\ of\ 1\ mole\ of\ CaCl_2 = 40 + 2 \times 35.5$$
$$= 111g$$
$$Moles\ of\ CaCl_2\ obtained = \frac{3.40}{111}$$
$$= 0.03$$
$$So\ moles\ of\ NH_4Cl\ \ used\ = 2 \times 0.03$$
$$= 0.06$$
$$But\ mass\ of\ 1\ mole\ of\ NH_4Cl\ = 14 + 4 + 35.5$$
$$= 53.5g$$
$$\therefore Mass\ of\ 0.06\ moles\ of\ NH_4Cl = 0.06 \times 53.5$$
$$= 3.21g$$
$$So\ \ X = 3.21g$$

ii. Calculate the volume of dry ammonia, measured, at room temperature that was collected. (1mole of a gas occupies 24.0dm^3 at room temperature). $(2marks)$

$$Moles\ of\ ammonia\ collected = 0.06$$
$$\therefore Volume\ of\ ammonia\ collected = 0.06 \times 24$$
$$= 1.44dm^3$$

(c) State the conditions under which dry ammonia can react with oxygen and write equation(s) for the reaction(s) that take(s) place. $(5marks)$

- In the presence of a hot platinum catalyst.

  $4NH_3(g)\ + 5O_2(g) \quad \longrightarrow 4NO(g)\ \ + 6H_2O(l)$
- When ammonia is burnt in oxygen rich in air.

  $4NH_3(g)\ + 3O_2(g) \quad \longrightarrow 2N_2(g)\ \ + 6H_2O(l)$

(d) Write equation to show how ammonia reacts with chlorine. $(1\frac{1}{2}marks)$

- $8NH_3(g) + 3Cl_2(g) \longrightarrow N_2(g) + 6NH_4Cl(s)$

22. (a) Chlorine can be prepared by the reaction of hydrochloric acid with potassium manganate(VII) according to the following equation.

$$2KMnO_4(s) + 16HCl(aq) \longrightarrow 2MnCl_2(aq) + 2KCl(aq) + 8H_2O(l) + 5Cl_2(g)$$

Calculate the mass of potassium manganate(VII) that would be required to react with hydrochloric acid to produce 1120.0cm^3 of dry chlorine, measured at s.t.p. (1mole of potassium manganate(VII) weighs 158.0g and 1mole of a gas occupies 22.4dm^3 at s.t.p)

$(2marks)$

$$Moles\ of\ chlorine\ produced = \frac{1120}{22400}$$

$$\therefore Moles\ of\ KMnO_4\ that\ reacted = \left(\frac{2}{5} \times \frac{1120}{22400}\right)$$

$$Mass\ of\ KMnO_4\ that\ reacted = \left(\frac{2}{5} \times \frac{1120}{22400} \times 158\right)g$$

$$= 3.16g$$

23. (a) 45.0cm^3 of solution containing 0.2moldm^{-3} of sodium hydroxide required exactly 20.0cm^3 of a solution containing 0.15moldm^{-3} of an acid D

i. Calculate the basicity of acid D.

- $Moles\ of\ NaOH\ that\ reacted = \frac{45.0 \times 0.2}{1000}$

  $= 0.009$
- $Moles\ of\ D\ that\ reacted = \frac{20.0 \times 0.15}{1000}$

  $= 0.003$
- $Mole\ ratio\ f\ D : NaOH = 1:3$
- $But\ 1\ mole\ of\ NaOH \equiv 1\ mole\ of\ H^+$
- $\therefore Basicity\ of\ D = 3$

ii. Determine the concentration of D in moldm^{-3} with respect to the hydrogen ions

- $Since\ 1\ mole\ of\ D\ releases\ 3\ moles\ of\ H^+\ ions$
- $0.15\ moles\ will\ release\ 3 \times 0.15\ moles\ of\ H^+\ ions$
- $\therefore concentration\ of\ D = 0.45\ Moldm^{-3}$

24. (a) Distilled water was added to 25.0cm^3 of a 0.5M nitric acid to make 250.0cm^3 of a dilute acid solution. Calculate

i. The concentration of the dilute solution in moldm^{-3} (02 $marks$)

$$Moles\ of\ HNO_3\ in\ 25.0cm^3\ of\ 0.5M\ solution = \left(\frac{25.0}{1000} \times 0.5\right)$$

$$Since\ \ 250cm^3\ of\ dilute\ solution\ contains\ \left(\frac{25.0}{1000} \times 0.5\right) moles.$$

$$1000cm^3\ of\ dilute\ solution\ contains \left(\frac{25.0}{1000} \times \frac{0.5}{250} \times 1000\right)\ moles$$

$$\therefore Concentration\ of\ the\ dilute\ acid\ solution = 0.05\ moldm^{-3}$$

ii. The volume of the dilute nitric acid solution that would be required to react completely with 20.0cm^3 of a solution containing 0.2mole of potassium carbonate per dm^3. (02$marks$)

$$Moles\ of\ HNO_3\ that\ reacted = 2 \times moles\ K_2CO_3\ in\ 20.0cm^3$$

$$= \left(\frac{2 \times 20.0 \times 0.2}{1000}\right) moles$$

$$Since\ 0.5\ moles\ are\ contained\ \ in\ 1000cm^3$$

$$\left(\frac{2 \times 20.0 \times 0.2}{1000}\right) moles\ are\ contained\ in\ \left(\frac{1000}{0.5} \times \frac{2 \times 20.0 \times 0.2}{1000}\right)\ cm^3$$

$$Hence\ volume\ of\ dilute\ HNO_3\ require = 16.0cm^3$$

25. When 7.2g of sodium carbonate, $Na_2CO_3.\boldsymbol{n}H_2O$ was strongly heated, the mass of the residue was 2.7g. calculate;

(a) Number of moles of water of crystallization.

(b) The percentage of water of crystallization.

26. Concentrated sulphuric acid reacts with graphite according to the following equation;

$$C(s)\ + 2H_2SO_4(l) \quad\longrightarrow\ CO_2(g)\ + 2SO_2(g)\ + 2H_2O(l)$$

Calculate the mass of graphite that can completely react with a solution containing 19.6g of sulphuric acid.

27. Calcium nitrate reacts with aqueous sodium hydroxide according to the following equation.

$$Ca(NO_3)_2(aq)\ + 2NaOH(aq) \quad\longrightarrow\ Ca(OH)_2(s)\ + 2NaNO_3(aq)$$

When excess aqueous sodium hydroxide was added to 50cm^3 of calcium nitrate solution, 1.85g of calcium hydroxide was formed.

(a) State what is observed when excess sodium hydroxide is added to calcium nitrate solution in a test tube.

(b) Calculate the concentration of calcium nitrate solution in moles per litre. $(Ca = 40; H = 1; O = 16)$

28. Barium nitrate solution reacts with aqueous sodium hydroxide solution according to the equation below.

$Ba(NO_3)_2(aq) \; + 2NaOH(aq) \quad \longrightarrow \; Ba(OH)_2(s) \; + 2NaNO_3(aq)$

Excess Barium nitrate solution was added to 20cm^3 of 2M sodium hydroxide solution in a beaker, the mixture stirred, filtered and the residue dried.

(a) Calculate the maximum mass of the dried residue.

$(Ba = 40; H = 1; O = 16)$

(b) The dried residue was strongly heated in a test tube, write the equation for the reaction.

29. When 0.6g of zinc powder was added to 40cm^3 of 0.15M copper(II) nitrate solution in a plastic beaker, the temperature of the solution rose from 24℃ to 33℃.

(a) (i) Other than increase in temperature, state what else was observed.

(ii) Write the ionic equation for the reaction that took place.

(b) Calculate:

(i) The heat change that occurred during the reaction. $(density\ of\ solution = 1gcm^{-3}, S.H.C = 4.2Jg^{-1}℃^{-1})$

(ii) Molar heat of reaction.

(iii) The excess moles of zinc powder.$(Zn = 65)$

30. (a) (i) Define the term water of crystallization.

(ii) State two physical properties of salts that can be affected by the presence of water of crystallization.

- ✓ Colour of crystals.
- ✓ Texture of shape and size.

(b) A hydrated salt contains 16.10% sodium, 4.20% carbon, 16.80% oxygen and 62.90% water of crystallization.

(i) Determine the formula of the salt.

(ii) State what would be observed when the crystals of the salt in (b)(i) are allowed to stand in air for a long time. Give a reason.

- ✓ The white crystals turns to a white powder because it has lost water of crystallization(efflorescent)

31. 5g of a mixture of zinc carbonate and zinc chloride was added to 400cm^3 of water in a beaker, stirred and filtered.

(a) Identify the compound in the;

(i) Residue.

(ii) Filtrate.

(b) The residue was washed with distilled water, dissolved in dilute hydrochloric acid and 501.76cm^3 of a gas was collected at s.t.p. calculate the percentage of zinc chloride in the mixture.

32. Ethanol burns in oxygen according to the equation.

$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)\ \Delta H = -1120KJmol^{-1}$.

Calculate the mass of ethanol required to raise the temperature of 200g of water by 30℃. $(S.H.C\ of\ water = 4.2)$

33. When 6.5g of zinc powder was added to 100cm^3 of IM copper(II) sulphate solution in a plastic beaker, 5.50kj of heat was produced. Calculate the enthalpy change in $kjmol^{-1}$.

34. 37.6g copper(II) nitrate crystals was completely decomposed by heat.

(a) State what was observed.

(b) Calculate the mass of the residue.$(Cu = 64; O = 16; N = 14)$

35. (a) A hydrocarbon Y contains 85.7% carbon. Calculate its simplest formula. $(C = 12; H = 1)$

(b) 0.224g of Y occupied 96cm^3 at room temperature. $(molar\ gas\ volume\ at\ room\ temperature = 24dm^3)$

(i) Calculate its molecular mass.

(ii) Hence its molecular formula.

36. Calcium nitrate decomposes when strongly according to the following equation;

$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + NO_2(g)$

(a) Name the gas that can be dried using the solid residue formed.

(b) Calculate the total volume of the gaseous products formed at room temperature when 4.5g of calcium nitrate is strongly heated. $(Ca = 40; O = 16; N = 14; 1\ mole\ of\ ga\ occupies\ 24\ litres\ at\ rt)$

37. When 40cm^3 of a 2M nitric acid was mixed with 40cm^3 of a 2M sodium hydroxide solution at initial temperature of 25.0℃, the temperature of the solution rose to T℃. Determine the temperature T.
$(S.H.C\ of\ water = 4.2jg^{-1}℃^{-1};\ density\ of\ water = 1gcm^{-3}; enthalpy\ of\ neutralisation\ of\ nitric\ by\ NaOH = -56.6KJmol^{-1})$

38. 12g of a mixture of sodium carbonate and sodium sulphate were mixed with distilled water in a flask and topped up to 1 litre. 25cm^3 of this solution

required 12.5cm^3 of 0.2M sulphuric acid for complete reaction. Calculate the percentage of sodium sulphate in the mixture.
$(Na = 23; S = 32; O = 16; C = 12)$

39. When 7.17g of an oxide,W of lead was completely reduced by heating in a stream of carbon monoxide, 6.21g of lead was produced.

(a) Determine the percentage composition of W.

(b) Calculate the molecular formula of W. $(O = 16; Pb = 207; W = 239)$

(c) Write the name of W.

40. Potassium chlorate decomposes on heating to produce oxygen according to the equation.

$2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$

Calculate the volume of oxygen produced at s.t.p when 12.25g of potassium chlorate are strongly heated.
$(K = 39; Cl = 35.5; O = 16; 1\ mole\ of\ a\ gas\ occupies\ 22.4dm^3\ at\ s.t.p)$

41. (a) A compound M containing water of crystallization has 20.1% iron, 11.5% sulphur, 23.0% oxygen and 45.3% water. Calculate the empirical formula of M

(b) M was gently heated in a boiling tube

(i) State what was observed.

(ii) Write the equation for the reaction.

42. 50.0cm^3 of a 2M sodium hydroxide solution was accurately measured into a volumetric flask and water added to make one litre of dilute solution. Calculate the volume of the dilute solution that would be required to react completely with 25.0cm^3 of 0.04M copper(II) nitrate solution.

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

43. A compound **J** consists of 26.7% carbon and 2.2% hydrogen by mass, the rest being oxygen.

(a) Calculate the simplest formula of **J**. $(C = 12; H = 1; O = 16)$

(b) 20.0cm^3 of a solution containing 1.125g of J in 250cm^3 of a solution required exactly 25.0cm^3 of 0.08M sodium hydrogen carbonate solution for complete reactions.

$(1\ mole\ of\ solution\ of\ \boldsymbol{J}\ reacts\ with\ 2\ moles\ of\ NaHCO_3\ solution)$

Calculate the;

(i) Concentration of the solution of **J** in moles per litre.

(ii) Molar mass of **J**

(c) Determine the molecular formula of **J**.

44. When 4.62g of ammonium sulphate was heated with excess aqueous sodium hydroxide solution, a colourless gas with a pungent smell was evolved. Calculate the volume of the gas evolved at s.t.p

45. Magnesium hydrogen carbonate can be converted to magnesium carbonate according to the following equation.

$Mg(HCO_3)_2(aq) \longrightarrow MgCO_3(s) + H_2O(l) + CO_2(g)$

(a) State;

(i) The conditions for the reaction.

(ii) One practical application of the reaction.

(b) Calculate the maximum mass of magnesium carbonate that can be obtained from 100.0cm^3 of a 0.5M magnesium hydrogen carbonate solution.

46. (a) A sugar Q of molecular mass 180g contains 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass.

Calculate the;

(i) Empirical formula of Q.

(ii) Molecular formula of Q

(b) Q undergoes fermentation in the presence of yeast to form ethanol, CH_3CH_2OH

(i) Write the equation for the fermentation of Q.

(ii) State one use of ethanol.

47. Methanol burns in oxygen according to the equation

$$CH_3OH(l) + \frac{3}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) \ \Delta H = -120KJmol^{-1}$$

When a certain mass of methanol was burnt, the heat evolved raised the temperature of 100g of water from 25.3℃ to 45.3℃. Calculate the mass of methanol burnt.

$(S.H.C\ of\ water = 4.2jg^{-1}℃^{-1}; density\ of\ water = 1gcm^{-3}; C = 12; H = 1; O = 16)$

48. (a) Define the term Hard water (01$mark$)

(b) 25cm^3 of a solution of hard water containing calcium ions reacted with 10cm^3 of 0.05M soap solution. Calculate the molar concentration of calcium ions in the hard water.

(1 mole of calcium ions reacts with 2 moles of soap solution.)

49. 25.0cm^3 of a 0.02M potassium hydroxide solution reacted with **v**cm^3 of an aqueous solution containing $0.025Moldm^{-3}$ of **Y**. Calculate the value of **v** (2 moles of potassium hydroxide react with 1 mole of **Y**)

(04$marks$)

50. Hydro carbon Z contains 85.7% by mass of carbon and the rest being hydrogen. Formula mass of **Z** is 84 grams.

a) Calculate the empirical formula of **Z**.

b) Determine the molecular formula of **Z**. ***(1 ½ marks)***

c) (i) Write the structural formula of **Z**. ***(01 mark)***

(ii) State what is observed when **Z** is bubbled through Bromine water.

51. 5.6g of impure sodium carbonate was dissolved in water to make one litre of solution. 25cm^3 of this solution required exactly 24cm^3 of 0.1M hydrochloric acid for complete reaction. Calculate the percentage purity of the original sample of sodium carbonate.

$Na = 23; O = 16; H = 1; C = 12$

52.

DETERMINATION OF FORMULA MASS OR MOLAR MASS OR MOLECULAR MASS

53. 3.548g of a solid alkali, MOH were dissolved in water to make one litre of solution. 25.0cm^3 of the alkali solution required 8.00cm^3 of 0.1M sulphuric acid for complete neutralization.

- **a)** Write the equation for the reaction between sulphuric acid and the metal alkali.
- **b)** Calculate the;
  - **(i)** Number of moles of sulphuric acid that reacted.
  - **(ii)** Number of moles of the metal alkali that reacted.
- **c)** Determine the;
  - **(i)** The molar concentration of the metal alkali ($\boldsymbol{ans = 0.064M}$)
  - **(ii)** The molar mass of the metal alkali.($\boldsymbol{Ans = 55.4375g}$)
  - **(iii)** The relative atomic mass of M ($H = 1; O = 16$) ($\boldsymbol{Ans \approx 38}$)

54. 2.76g of a metal carbonate, M_2CO_3 was dissolved in distilled water to make 1.0dm^3 of solution. When 15cm^3 of a carbonate solution was titrated with 0.03M sulphuric acid, the volume of the acid required to reach end point was 10cm^3.

- **a)** Calculate the molarity of the carbonate.($\boldsymbol{Ans = 0.02M}$)
- **b)** Calculate the relative atomic mass of the carbonate.($\boldsymbol{Ans = 138}$)
- **c)** Determine the value of M ($C = 12; O = 16$) $\boldsymbol{Ans\ M = 39}$

55. 6.3g of a hydrated dibasic acid, $H_2X.nH_2O$ were dissolved in water to form one litre of solution. 25cm^3 of this solution was found to require 12.5cm^3 of 0.2M sodium hydroxide solution for complete reaction.
The acid reacts with sodium hydroxide according to the equation.
$H_2X(aq) + 2NaOH(aq) \longrightarrow Na_2X(aq) + 2H_2O(l)$

a) Calculate the molar concentration of the acid.($\boldsymbol{Ans = 0.05M}$)
b) Determine the;
   (i) Relative formula mass of the acid.($\boldsymbol{Ans = 126}$)
   (ii) Value of n in the formula, $H_2X.nH_2O$. $(X = 88; H = 1; O = 16)$ ($\boldsymbol{Ans; n = 2}$)

56. 3.584g of a solid alkali, XOH were dissolved in water to make a solution of the alkali. 25.00cm^3 of the alkali solution required solution required 8.00cm^3 of 0.1M nitric acid solution for complete neutralization. Determine the relative atomic mass of M $(H = 1; O = 16)$ ($\boldsymbol{Ans\ M = 95}$)

57. A solution of a carbonate M_2CO_3 was made by dissolving 2.65g to make 250cm^3 of solution. 25cm^3 of this solution reacted exactly with 10cm^3 of 0.25M hydrochloric acid. Determine the value of M $(C = 12; O = 16)$
($\boldsymbol{Ans; M = 76}$)

58. 25cm^3 of an acid HX was neutralized by 24cm^3 of a 0.125M sodium hydroxide solution. The acid solution contains $2.4gl^{-1}$. Determine the relative atomic mass X. $(H = 1)$ ($\boldsymbol{Ans; X = 19}$)

59. 12.5cm^3 of a dibasic acid,H_2X reacted completely with 15.63cm^3 of 0.08M sodium hydroxide solution. The acid solution was made by dissolving $4.5gl^{-1}$.

a) Write the equation for the reaction that took place.
b) Determine the relative molecular mass of the acid.($\boldsymbol{ANS; R.M.M = 90}$)

60. 0.2moles of a hydroxide, $X(OH)_2$, weighed 11.6g. Determine the relative atomic mass of X. $(H = 1; O = 16;)$

61. 0.4g of a metal hydroxide, MOH, reacted completely with 20cm^3 of a 0.5M hydrochloric acid. Determine the relative formula mass of MOH.

62. 100cm^3 of a solution containing 4.5cm^3 of Q per dm^3 of solution required exactly 0.12g of magnesium powder for complete reaction.$(Mg = 24; 1\ mole\ of\ Q\ reacts\ with\ 1\ mole\ of\ magnesium.)$

a) Calculate;
   (i) the concentration of Q in moles per dm^3.
   (ii) The formula mass of Q.

63. A monobasic acid has the molecular formula, $X - CH_2COOH$. An aqueous solution of the solution contains 9.8g of the acid per litre of solution. 25cm^3 of the acid solution required 25.9cm^3 of 0.1M sodium hydroxide solution.
Calculate**;**

a) the molar mass of the acid.

b) The atomic mass of X. ($C = 12; O = 16; H = 1$)

64. A 0.2M solution of X was made by dissolving 4.5625g in 250cm^3 of solution. Determine the relative formula mass of X.

CALCULATING WATER OF CRYSTALLISATION IN A HYDRATED COMPOUND

65. 8.58g of sodium carbonate, $Na_2CO_3.XH_2O$ were dissolved to make 250cm^3 of solution. 25.0cm^3 of the carbonate solution required 15.00cm^3 of 0.4M hydrochloric acid solution for complete reaction.

a) Write the equation for the reaction that took place.

b) Calculate the;

(i) Number of moles of hydrochloric acid that reacted.

(ii) Number of moles of carbonate that reacted.

c) Determine the number moles of water of crystallization ($Value\ of\ X$)

66. 6.24g of hydrated sodium carbonate, $Na_2CO_3.XH_2O$ were dissolved in water to make 100cm^3 of solution. 25cm^3 of this solution reacted completely with 20cm^3 of 0.8M nitric acid.

a) Write the equation for the reaction that took place.

b) Calculate the;

(i) Number of moles of nitric acid that reacted.

(ii) Number of moles of the carbonate that reacted.

c) Calculate the;

(i) molar concentration the carbonate.

(ii) The relative formula mass of $Na_2CO_3.XH_2O$

(iii) The value of X in the formula $Na_2CO_3.XH_2O$
($Na = 23; C = 12; H = 1; O = 16$)

67. 20cm^3 of a solution containing 25.8g/l of a dibasic hydrated acid $H_2X.nH_2O$ neutralised 10cm^3 of 0.8M sodium hydroxide solution. If the relative formula mass of $H_2X = 90$. Determine the value of n. ($\boldsymbol{Ans}; \boldsymbol{n = 2}$)

68. 20cm^3 of solution containing 12.0g/l of an acid, $H_2A.nH_2O$ neutralised 19.90cm^3 of 0.2M sodium hydroxide. Determine the value of n. ($A = 88; H = 1; O = 16$)

69. An anhydrous salt R has a relative formula mass of 158 and forms a hydrated salt $R.nH_2O$. 79g OF R combines with 45g of water. Determine the value of n

70. 40g of zinc sulphide combined with 30g of water of crystallization to form hydrated zinc sulphide, $Zns.xH_2O$. find the value of x.($Zn = 65; S = 32; O = 16$)

Determination of Basicity of acid.

71. 25cm^3 of 0.2M potassium hydroxide solution reacted completely with 25cm^3 of 0.1M solution of acid, H_nX. Calculate the basicity of the acid.

72. 25cm^3 of 0.5M sodium hydroxide solution required 16.4cm^3 of 0.25M solution of the acid with formula, H_nY. Determine the reaction mole ratio of sodium hydroxide to acid.

73. 20.0cm^3 of 0.1M sodium hydroxide reacted with 0.1M solution of Y. Determine the volume of solution of Y that reacted completely with sodium hydroxide.($mole\ ratio\ of\ NaOH: Y = 2:1$)

74. 25cm^3 of 0.25M acid required 25cm^3 of 0.5M sodium hydroxide solution for complete neutralization. Determine the basicity of the acid.

75. 10cm^3 of a dibasic acid was neutralized by 20cm^3 of a 0.2M sodium hydroxide solution. Determine the molar concentration of the acid.

76. Determine the volume of 0.01M sodium hydroxide required to react completely with 25cm^3 of a 0.02M hydrochloric acid.

77. Calculate the volume of a 0.25M hydrochloric acid required to exactly react with 20.0cm^3 of 0.1M sodium carbonate solution.

78. Calculate the maximum volume of 0.1M sulphuric acid required to completely react with 10cm^3 of 0.5M sodium hydroxide.

79. Determine the volume of a 0.2M sodium hydroxide solution that would be required to completely precipitate iron(III) hydroxide from 2cm^3 of 0.1M solution of iron(III) chloride.

80.

Set 1

$\boldsymbol{SECTION\ A}$ $(\mathbf{50}\ \boldsymbol{MARKS})$

*Answer **all** questions in this section*

1. (a) A strip of zinc metal was dipped in a solution of copper(II) sulphate.

(i) State what was observed. $(1\frac{1}{2}\ marks)$

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(ii) Write the ionic equation for the reaction. $(1\frac{1}{2}\ marks)$

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(b) (i) What would be observed if a strip of silver metal was dipped into copper(II) sulphate solution? $(01\ mark)$

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(ii) Explain your answer in (b)(i) $(01\ mark)$

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2. Large scale preparation of nitrogen is done by passing air through solution A and then over heated metal Z.

(a) Identify;

(i) Solution A $(\frac{1}{2}\ mark)$

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(ii) Metal Z $(\frac{1}{2}\ mark)$

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(b) State the role of solution A and metal Z in the above process.

(i) Solution A. $(\frac{1}{2}\ mark)$

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(ii) Metal Z. $(\frac{1}{2}\ mark)$

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(c) Write the equation of reaction that took place when air was passed

(i) Through solution A. $(1\frac{1}{2}\ marks)$

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(ii) Over heated metal Z. $(1\frac{1}{2}\ marks)$

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3. (a) An element **W** has mass number 27 and 14 neutrons.

(i) Write down the electronic configuration of **W**. $(01\ mark)$

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(ii) **W** combines with oxygen to form compound **R**. write down the formula of **R** and state the type of bond in **R**.

Formula. $(01\ mark)$

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Type of bond. $(\frac{1}{2}\ mark)$

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(b) **R** was dissolved in dilute hydrochloric acid and to the resultant solution was added ammonia solution drop wise until in excess.

(i) State what was observed. $(01\ mark)$

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(ii) Write the ionic equation to explain the observation in (b) above. $(1\frac{1}{2}\ marks)$

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4. 1.5g of a hydrocarbon M consists of 1.2g of carbon.

(a) Calculate the empirical formula of M. $(02\ marks)$

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(b) 0.125g of hydrocarbon M occupies a volume of 100cm^3 at room temperature.

(i) Calculate the relative molecular mass of M. $(1\frac{1}{2}\ marks)$

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(ii) Determine the molecular mass of M. $(1\frac{1}{2}\ marks)$

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5. Classify the following oxides as acidic, basic, neutral, amphoteric or mixed oxides. $(05\ marks)$

Name of oxide	Type of oxide
Sulphur dioxide.	
Carbon monoxide.	
Copper(II) oxide.	
Aluminium oxide.	
Tri lead tetra oxide.	

6. (a) Define the term heat of combustion. $(01\ mark)$

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(b) Ethanol burns in oxygen according to the following equation.

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)\ \Delta H = -154kJmol^{-1}$$

Calculate the;

(i) Heat evolved when 11.5g of ethanol is reacted with oxygen at s.t.p

$(1\frac{1}{2}\ marks)$

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(ii) Volume of carbon dioxide produced at s.t.p. $(02\ marks)$

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7. Electrolysis of 1M sulphuric acid was carried out using zinc cathode and copper anode.

(a) State what was observed at the anode. $(\frac{1}{2}\ mark)$

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(b) Write equations for the reaction that took place at the;

(i) Cathode. $(1\frac{1}{2}\ marks)$

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(ii) Anode. $(1\frac{1}{2}\ marks)$

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(c) Write equation for the overall cell reaction. $(1\frac{1}{2}\ marks)$

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8. Hydrogen is produced in the laboratory according to the equation.

$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$

(a) State three ways in which the rate of reaction of hydrogen can be increased. $(03\ marks)$

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(b) Sketch a graph to show how the rate of production of hydrogen varies with time. $(2\frac{1}{2}\ marks)$

9. (a)(i) Name one reagent that can be used to identify iodide ions in the laboratory. $(\frac{1}{2}\ mark)$

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(ii) State what would be observed when the solution containing iodide ions is treated with the reagent named in (a)(i) above. $(\frac{1}{2}\ mark)$

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(b) Write the equation of reaction that took place in (a)(ii) above. $(1\frac{1}{2}\ marks)$

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(c) Chlorine gas was bubbled through a solution of sodium iodide.

(i) State what was observed. $(\frac{1}{2}\ mark)$

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(ii) Write equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

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10. Polyethene is a plastic made of numerous monomers known as ethene.

(a) Write down the structural formula of ethene. $(01\ mark)$

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(b) Name the homologous series to which ethene belongs. $(01\ mark)$

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(c) (i) State how ethene can be tested in the laboratory. $(01\ mark)$

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(ii) State the conditions under which ethanol can be converted to ethene.

$(1\frac{1}{2}\ marks)$

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(iii) Suggest one other use of ethene apart from making Polyethene.

$(01\ mark)$

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$\boldsymbol{SECTION\ B}$ $(\mathbf{30}\ \boldsymbol{marks})$

$Attempt\ any\ \boldsymbol{two}\ questions\ from\ this\ section.$

11. (a)(i) Briefly explain how a pure and dry sample of carbon dioxide can be prepared in the laboratory (diagram not required) $(5\frac{1}{2}\ marks)$

(ii) Write the equation for the reaction. $(1\frac{1}{2}\ marks)$

(b) State what is observed and write equations where possible when;

(i) Burning magnesium is lowered in a gas jar containing carbon dioxide. $(3\frac{1}{2}\ marks)$

(ii) Carbon dioxide is bubbled through a solution of calcium hydroxide until excess. $(4\frac{1}{2}\ marks)$

12. Glucose can be converted to ethanol by a catalytic reaction caused by the enzymes produced by yeast.

(a) Name;

(i) The reaction in which yeast converts glucose into ethanol. $(01\ mark)$

(ii) The enzyme produced by yeast during the above reaction. $(01\ mark)$

(b) Write the equation for the reaction leading to the formation of ethanol by the process named in (a)(i) $(1\frac{1}{2}\ marks)$

(c) When ethanol was strongly heated together with concentrated sulphuric acid, gas W was formed.

(i) Identify gas W. $(01\ mark)$

(ii) Write the equation for the reaction leading to the formation of gas W. $(01\ mark)$

(d) (i) Name one reagent that can be used to identify W in the laboratory. $(01\ mark)$

(ii) State what is observed when the reagent is treated with gas W.

$(01\ mark)$

(iii) Write equation for the reaction that takes place in (d)(ii) above.

$(01\ mark)$

(e) When treated at high pressure and heat, in the presence of a catalyst, W reacts to form a plastic P of high molecular mass.

(i) Identify P. $(\frac{1}{2}\ mark)$

(ii) Write the equation leading to formation of P from W. $(01\ mark)$

(iii) State any three uses of P. $(03\ marks)$

(f) Differentiate between thermosetting and the thermo softening plastics

$(02\ marks)$

13. (a) Define the following terms and give one example in each case.

(i) Normal salt. $(02\ marks)$

(ii) Acid salt. $(02\ marks)$

(b) Mention any three methods of preparing salts. $(1\frac{1}{2}\ marks)$

(c) Describe how a pure sample of lead(II) chloride can be prepared from lead(II) nitrate. $(6\frac{1}{2}\ marks)$

(d) (i) Copper(II) nitrate and zinc nitrate were heated in separate test tubes.

(ii) Write the equation of reaction for the decomposition of zinc nitrate solid.

$(1\frac{1}{2}\ marks)$

14. (a) Define the term rate of chemical reaction. $(01\ mark)$

(b) State how the following factors affect the rate of the chemical reaction.

(i) Temperature. $(1\frac{1}{2}\ marks)$

(ii) Concentration. $(1\frac{1}{2}\ marks)$

(c) The table below shows how the variation in volume of hydrogen evolved with time when dilute sulphuric acid was reacted with excess magnesium.

Volume of hydrogen (cm^3)	0	20	35	46	56	72	78	78
Time(s)	0	10	20	30	40	60	80	90

Plot a graph of volume of hydrogen evolved against time. $(06\ marks)$

(d)Use your graph to determine the time taken to collect $65cm^3$ of hydrogen gas

$(01\ mark)$

(e) (i) Draw tangents on your graph at points when time is 20 and 60 seconds and determine the gradients. $(03\ marks)$

(ii) Comment on your results in (e)(i) above. $(01\ mark)$

END

SET 2

$\boldsymbol{SECTION\ A}$ **(50** $\boldsymbol{MARKS}$**)**

Answer ***all*** *questions in this section*

1. (a) Name the method you would use to separate the following mixtures.

(i) Sodium carbonate and ammonium chloride. $(01\ mark)$

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(ii) Oil and water. $(01\ mark)$

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(iii) Kerosene and crude oil. $(01\ mark)$

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(iv) Components of food colour. $(01\ mark)$

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(b) Give a reason for the method used in (a)(iii) $(01\ mark)$

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2. Chlorine is prepared in the laboratory by reacting manganese(IV) oxide with substance **Q** and when chlorine is passed over heated iron wool, substance **R** is formed.

(a) Identify substance

(i) **Q**……………………………………………………………($\frac{1}{2}$ $mark$)

(ii) **R**…………………………………………………………..($\frac{1}{2}$ $mark$)

(b) (i) State the conditions for the preparation of chlorine using manganese(IV) oxide and with substance **Q**. (01 $mark$)

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(ii) Write an equation for the formation of substance **R**. ($1\frac{1}{2}$ $marks$)

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(c) Explain what is observed when chlorine is bubbled through a solution of potassium bromide. ($1\frac{1}{2}$ $marks$)

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3. (a) When concentrated sulphuric acid is added to ethanol and the mixture heated, ethene is formed.

(i) Write an equation for the reaction which took place. ($1\frac{1}{2}$ $marks$)

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(ii) What type of reaction took place? ($\frac{1}{2}$ $mark$)

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(b) Ethene undergoes a reaction to form a compound **Z** of high molecular mass. State;

(i) The name of the reaction leading to the formation of **Z**. $(\frac{1}{2}\, mark)$

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(ii) Name of **Z**. $(\frac{1}{2}\, mark)$

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(iii) one use of **Z**. $(\frac{1}{2}\, mark)$

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(iv) one disadvantage of **Z**. $(\frac{1}{2}\, mark)$

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(c) Name one reagent that can be used to identify ethene. $(01\, mark)$

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4. A hydrated salt **Q** has the following composition by mass; iron 20.2%, oxygen 23.0%, sulphur 11.5% and water of crystallization 45.3%. Its relative molecular mass is 278.

(a) Determine the molecular formula of the hydrated salt. $(03\, marks)$

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(b) 6.95g of the hydrated salt **Q** were dissolved in distilled water to make $250cm^3$ of solution. Calculate the concentration of the solution in moles per litre. $(02\ marks)$

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5. Two dilute mineral acids **X** and **Y** were each added separately to solid calcium carbonate and gas **Z** was produced in each case.

Acid **X** produced little bubbles of gas **Z** and the reaction stopped.

Acid **Y** produced much more bubbles of gas **Z** and the reaction proceeded to completion.

(a) State the possible name of acid;

(i) **X**…………………………………………………………..……….$(\frac{1}{2}\ mark)$

(ii) **Y**…………………………………………………………………$(\frac{1}{2}\ mark)$

(b) Give a reason why the reaction between the carbonate and acid **X** stopped. $(01\ mark)$

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(c) Write an ionic equation for the reaction between acid **Y** and the carbonate.

$(1\frac{1}{2}\,marks)$

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(d) Explain how gas **Z** can be identified. $(1\frac{1}{2}\,marks)$

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6. On large scale, nitrogen was obtained from air according to the following scheme.

O_2 N_2 CO_2 H_2O	$\xrightarrow{step\ I}$	O_2 N_2 CO_2	$\xrightarrow{step\ II}$	O_2 N_2	$\xrightarrow{step\ III}$	N_2

(a) Name one substance that could be used in

(i) Step I…………………………………………………………$(01\,mark)$

(ii) Step II…………………………………………………………$(01\,mark)$

(b) Write the equation for the reaction at step II $(1\frac{1}{2}\,marks)$

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(c) What process is represented by step III? $(\frac{1}{2}\,mark)$

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(d) State one large scale use of nitrogen. $(01\ mark)$

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7. A student added soap solution to water but it did not form lather and when the same water was boiled and soap solution added, it formed lather.

(a) (i) Identify the type of hard water that the student used. $(\frac{1}{2}\ mark)$

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(ii) Name the cations and anion present in the above type of hard water

Cations……………………………………………………………$(01\ mark)$

Anion…………………………………………………………...…..$(\frac{1}{2}\ mark)$

(b) (i) Name one other physical and one chemical method that can be used to improve the effectiveness of the above type of water

Physical method $(\frac{1}{2}\ mark)$

……………………………………………………………………………………

Chemical method $(\frac{1}{2}\ mark)$

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(ii) State two advantage of using the above type of water. $(02\ marks)$

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8. A dilute solution of copper(II) chloride was first electrolysed using graphite electrodes and then copper electrodes.

(a) State the observations made at the anode while using

(i) Graphite electrodes. $(01\ mark)$

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(ii) Copper electrodes. $(01\ mark)$

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(b) Write the equation for the reaction at anode while using;

(i) Graphite electrodes. $(01\ mark)$

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(ii) Copper electrodes. $(01\ mark)$

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(c) State one application of electrolysis of copper(II) chloride. $(01\ mark)$

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9. 12g of a mixture of sodium carbonate and sodium sulphate were mixed with distilled water in a flask and topped up to 1 litre. 25cm^3 of this solution required 12.5cm^3 of 0.2M sulphuric acid for complete reaction.

(a) Which substance in the mixture reacted with dilute sulphuric acid? $\frac{1}{2}\ mark)$

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(b) Write the equation for the reaction that took place between sulphuric acid and the substance named in (a) above. $(1\frac{1}{2}\ marks)$

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(c) Calculate the percentage of sodium sulphate in the mixture.

$(Na = 23; S = 32; O = 16; C = 12)$

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10. The equation below shows a redox reaction between copper(II) oxide and zinc metal.

$CuO(s) + Zn(s) \longrightarrow ZnO(s) + Cu(s)$

(a) State with a reason which is;

(i) The oxidising agent. $(01\ mark)$

…………………………………………………………………………………

(ii) The reducing agent. $(01\ mark)$

…………………………………………………………………………………

(b) (i)State what is observed when iron filings is added to a solution of copper(II) sulphate. $(1\frac{1}{2}\ marks)$

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(ii) Write an ionic equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

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***SECTION B* (30 *MARKS*)**

Answer any two questions from this section.

11. Haematite is one of the ores from which iron can be extracted

(a) (i) Write the chemical formula of haematite. $(\frac{1}{2}\ mark)$

(ii) Give the name and formula of any other ore from which iron can be extracted $(1\frac{1}{2}\ marks)$

(b) During the extraction of iron, roasted haematite is mixed with coke and limestone. The mixture is fed into the blast furnace from the top and hot air is blown into the furnace.

(i) Write equation for the reaction(s) in the blast furnace that leads to the formation of iron. $(4\frac{1}{2}\,marks)$

(ii) Explain the role of limestone. $(3\frac{1}{2}\,marks)$

(c) Write equation for the reaction between iron and

(i) Water. $(1\frac{1}{2}\,marks)$

(ii) Hydrochloric acid. $(1\frac{1}{2}\,marks)$

(d) To the resultant mixture in the reaction (c)(ii) was added sodium hydroxide solution drop wise until in excess. State what was observed and write equation for the reaction which took place. $(3\frac{1}{2}\,marks)$

12. (a) Nitrogen can react with gas **P** in the presence of a catalyst which is finely divided to form ammonia in the Haber process.

(i) State the source of nitrogen. $(\frac{1}{2}\,mark)$

(ii) Identify gas **P**. $(\frac{1}{2}\,mark)$

(iii). Explain why the catalyst is finely divided. $(1\frac{1}{2}\,marks)$

(iv) Write equation for the reaction leading to the formation of ammonia. $(1\frac{1}{2}\,marks)$

(b) Ammonia was passed over heated copper(II) oxide.

(i) State what was observed. $(01\,mark)$

(ii) Write equation for the reaction that took place. $(1\frac{1}{2}\,marks)$

(iii). State the property exhibited by ammonia in the above reaction. $(\frac{1}{2}\,mark)$

(c) Ammonia obtained by the Haber process can be converted to nitrogen(II) oxide.

(i) Write an equation for the reaction leading to conversion of ammonia to nitrogen(II) oxide. $(1\frac{1}{2}\, marks)$

(ii) State the conditions for the reaction leading to conversion of ammonia to nitrogen(II) oxide. $(1\frac{1}{2}\, marks)$

(d) Write equation(s) to show how nitrogen(II) oxide can be converted to nitric acid. $(03\, marks)$

(e) When aqueous ammonia was added drop wise until in excess to a solution zinc sulphate, a white precipitate **M** which dissolves in excess ammonia to give a colourless solution was formed.

(i) Identify **M**. $(01\, mark)$

(ii) Write the formula and name of the cation in the colourless solution.

$(01\, mark)$

13. (a)(i) Write equation for the reaction that can take place between copper(II) oxide and dilute nitric acid. $(1\frac{1}{2}\, marks)$

(ii) Briefly describe how dry crystals of the product of the reaction in (a)(i) can be obtained in the laboratory. $(3\frac{1}{2}\, marks)$

(b) State what would be observed and write equation for the reaction that would take place if

(i) The crystals in (a)(ii) were heated. $(3\frac{1}{2}\, marks)$

(ii) The solution of the crystals in (a)(ii) was added few drops of aqueous sodium hydroxide solution. $(02\, marks)$

(c) 100cm^3 of 2M barium chloride solution was added to a solution containing silver nitrate solution.

(i) State what was observed. $(\frac{1}{2} mark)$

(ii) Write equation for the reaction that took place. $(1\frac{1}{2}\, marks)$

(iii) Calculate the mass of silver ions that was used in the reaction.

$(Ag = 108)$ $(03\, marks)$

14. (a)(i) Write an equation for the reaction between dilute hydrochloric acid and zinc granules. $(1\frac{1}{2}\, marks)$

(ii) State how a large surface of powdered zinc can affect the rate of the reaction in (a)(i) above. $(02\, marks)$

(iii) State any other factor that can affect the rate of reaction in (a) above. $(02\, marks)$

(b) The table below shows the variation in volume of hydrogen evolved with time when dilute hydrochloric acid was added to excess zinc powder.

Volume of hydrogen (cm^3)	0	20	35	47	56	73	77	79	79
Time(s)	0	10	20	30	40	60	80	90	100

Plot a graph of volume of hydrogen gas evolved against time. $(05\, marks)$

(c) Using the graph, determine the volume of the gas formed after 15 seconds. $(01\, mark)$

(d) (i) Draw tangents on your graph at points when time is 20 seconds and 60 seconds. Determine the gradient of each. $(02\, marks)$

(ii) Compare the rate of reaction at 20 seconds and 60 seconds. Explain your answer. $(02\, marks)$

END

SET 3

SECTIOIN A: 50 MARKS

1. (a) Write the name and formula of one salt that causes permanent hardness of water (1 mark)

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…………………………………………………………………………………………………..

(b) State one physical and one chemical method of removing permanent hardness of water.

Physical method. (½ mark)

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Chemical method (1 mark)

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(c) Write equation for the reaction that takes place during removal of permanent hardness of water by chemical method. (1 ½ marks)

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(d) State one advantage and one disadvantage of hard water.

Advantage (½ mark)

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Disadvantage (½ marks)

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2. (a) During the laboratory preparation of hydrogen at room temperature, zinc metal is reacted with sulphuric acid or hydrochloric acid but not nitric or ethanoic acid

(i) Write an ionic equation for the reaction leading to the formation of hydrogen (1 ½ marks)

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(ii) State the condition for the reaction in (a) (i) (½ mark)

…………………………………………………………………………………………………..

(iii) State the method of collecting hydrogen (½ mark)

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(iv) Give a reason why laboratory preparation of hydrogen from zinc cannot be done using;

nitric acid (½ mark)

…………………………………………………………………………………………

Ethanoic acid (½ mark)

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(b) Write equation for the reaction that would take place if dry hydrogen is passed overheated copper (II) oxide. (1 ½ marks)

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……………………………………………………………………………………………..

3. (a) When hydrogen chloride was passed through a solution containing a cation X, a white shiny and crystalline precipitate was formed. The precipitate dissolved when the mixture was heated, but recrystallised on cooling the solution.

(i) State the identity of X. (1 mark)

……………………………………………………………………………………………..

(ii) Write an ionic equation for the reaction that took place between hydrogen chloride and X. (1 ½ mark)

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……………………………………………………………………………………………..

(b) Silver nitrate can react with sodium chloride to form silver chloride according to the following equation:

$$Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \longrightarrow AgCl_{(s)}$$

Calculate the maximum mass of silver chloride that would be formed if excess sodium chloride solution was added to 20.0cm^3 of a 0.5M silver nitrate solution (Ag = 108, Cl = 35.5) (2 ½ marks)

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4. (a) Sulphuric acid can react with ethanol to produce ethene

(i) Write equation for the reaction leading to the formation of ethene (1 mark)

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(ii) State the conditions for the reaction in a (i) (1 ½ marks)

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(iii) Write equation for the reaction of ethene leading to formation of 1, 2 – dibromoethane. (1 mark)

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(b) When butane is burnt in oxygen, the reaction is accompanied by heat change according to the following equation:

$2C_4H_{10(g)} + 13O_{2(g)} \longrightarrow 10H_2O_{(l)} + 8CO_{2(g)}$ $\Delta H = -288\ Kjmol^{-1}$

(i) Suggest one use of butane. (½ mark)

……………………………………………………………………………………………..

(ii) Calculate the heat energy change obtained when $5.6dm^3$ of butane is burnt in oxygen at s.t.p (1 mole of a gas occupies $22.4dm^3$ at s.t.p) (2 marks)

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5. Warm dilute nitric acid was added to a mixture of lead (II) oxide and copper (II) oxide and the solution formed divided into two portions.

(a) To the first portion was added dilute sodium hydroxide drop wise until in excess and filtered.

Identify the cation in the

(i) Filtrate (1 mark)

…………………………………………………………………………………………………..

(ii) Residue (1 mark)

…………………………………………………………………………………………………..

(iii) Write equation for the reaction that led to the formation of the residue (1 ½ marks)

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…………………………………………………………………………………………………..

(b) To the second portion was added aqueous ammonia drop wise until in excess. State the colour of the;

(i) Residue (½ mark)

…………………………………………………………………………………………………..

(ii) Filtrate (½ mark)

…………………………………………………………………………………………………..

(c) Write the formula of the cation that was in the filtrate. (1 mark)

…………………………………………………………………………………………………..

6. During laboratory preparation of carbon dioxide, calcium carbonate reacts with dilute hydrochloric acid according to the following equation.

$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

(a) Calculate the maximum volume of carbon dioxide in cm^3 that would be produced at room temperature if dilute hydrochloric acid reacted completely with 4.5g of calcium carbonate. (3 marks)

(C = 12, O = 16, Ca = 40, 1 mole of a gas occupies 24.0 cm^3 at room temperature)

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(b) A quantity of dilute sulphuric acid having the same hydrogen ion concentration as that of the hydrochloric acid in (a) was reacted with 4.5g of the calcium carbonate at room temperature.

(i) State how the maximum volume of carbon dioxide produced would compare with your answer in (a) (1 mark)

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(ii) Give a reason for your answer in (b) (i) (1 mark)

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7. The atomic numbers of elements Q, R and W are 15, 17 and 19 respectively.

(a) Write the electronic configuration of

(i) Q (½ mark)

……………………………………………………………………………………………..

(ii) R (½ mark)

……………………………………………………………………………………………..

(iii) W (½ mark)

……………………………………………………………………………………………..

(b) R can combine with Q and W to form compounds Y and Z respectively. State the type of bond in

(i) Y (½ mark)

……………………………………………………………………………………………..

(ii) Z (½ mark)

……………………………………………………………………………………………..

(c) State one property in which

(i) Y resemble Z (1 mark)

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(ii) Y differs from Z (1 mark)

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8. (a) Name one allotrope of carbon that is used;

(i) in extraction of iron (½ mark)

…………………………………………………………………………………………………..

(ii) as an electrode (½ mark)

…………………………………………………………………………………………………..

(b) State one property of the allotrope of carbon that you have named in (a) which is the reason for its use;

(i) In extraction of iron (1 mark)

…………………………………………………………………………………………………..

(ii) As an electrode (1 mark)

………………………………………………………………………………………………….

…………………………………………………………………………………………………..

(c) Carbon – 12 and carbon – 14 are the two common atoms of carbon and carbon – 14 is used extensively in determining ages of old objects,

State

(i) One word, which means the relationship between atoms like carbon – 12 and carbon – 14 (1 mark)

…………………………………………………………………………………………………..

(ii) The property of carbon – 14 that is applied when it is used in determining the ages of old objects. (1 mark)

…………………………………………………………………………………………………..

9. Both carbon and sulphur can burn in air to form oxides

(a) Name the product of complete combustion of

(i) Sulphur (½ mark)

…………………………………………………………………………………………………..

(ii) Carbon

……………………………………………………………………………………………..

(b) The products of combustion in (a) were carefully collected into separate boiling tubes and burning magnesium introduced in each. State what was observed in the boiling tube containing the product of combustion of

(i) Sulphur (1 mark)

……………………………………………………………………………………………..

(ii) Carbon (1 mark)

……………………………………………………………………………………………..

(c) Write equation to illustrate your observation in

(i) (b) (i) (1 ½ marks)

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(ii) (b) (ii) (1 ½ marks)

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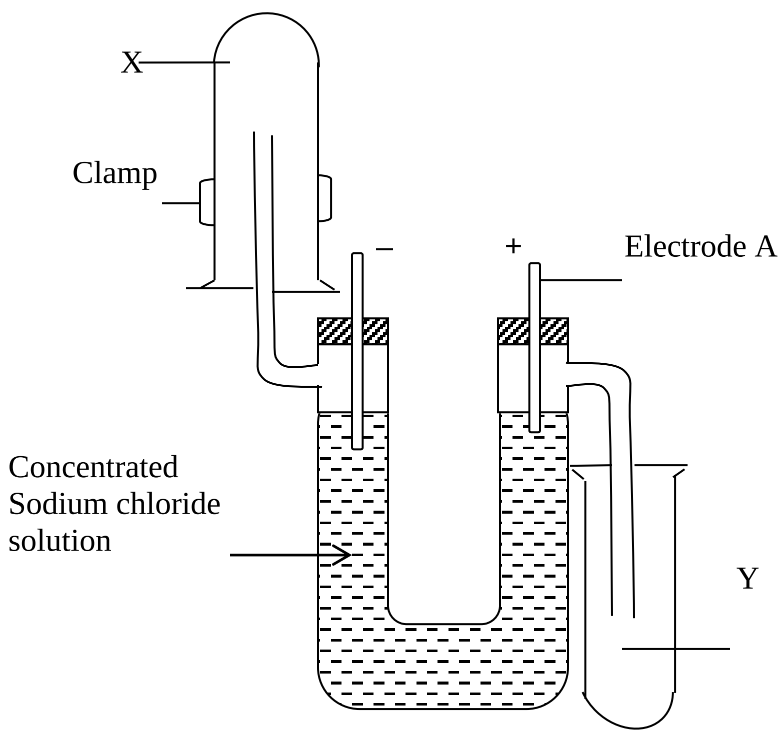
10.



The diagram above is U-tube voltammeter for the electrolysis of concentrated sodium chloride solution

(a) Identity

(i) Gas X (½ mark)

…………………………………………………………………………………………….

(ii) Gas Y (½ mark

……………………………………………………………………………………………..

(iii) The material electrode A is made of (1 mark)

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(b) Give a reason why electrode A should be made of the material you have identified in (a) (iii) (1 mark)

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(c) State why each of the gases X and Y is collected as shown in the diagram (1 mark)

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(d) Litmus paper was dropped into the solution near the cathode.

(i) State what was observed. (½ mark)

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(ii) Give a reason for your observation in (d) (i) (½ mark)

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SECTION B:

Answer any two questions only in this section. Extra questions answered will not be marked.

11. (a) Burning sulphur was lowered into a jar of oxygen.

(i) State what was observed. ***(01 mark)***

(ii) Write equation for the reaction that took place. ***(01 mark)***

(b) The major product of combustion of sulphur is sulphur dioxide

(i) Name one reagent, which can be used to test for sulphur dioxide. ***(01 mark)***

(ii) State what would be observed if the reagent which you have named in (b) (i) was tested with sulphur dioxide and give a reason for your observation ***(1 ½ marks)***

(c) Under certain temperature and pressure conditions in the presence of a suitable catalyst, sulphur dioxide can be converted into sulphuric acid on a large scale through an industrial process known as the Contact process.

(i) Using equations to illustrate your answer, outline the reactions that lead to conversion of sulphur dioxide to sulphuric acid by the Contact process. ***(5 ½ marks)***

(ii) Describe the temperature and pressure conditions used during the contact process; and briefly explain their effects on the reaction(s) where they are applied. ***(04 marks)***

(iii) Name the suitable catalyst in modern day contact process and give a reason for its suitability.

12. (a) (i) Write equation for reaction that takes place when excess carbon dioxide is bubbled through concentrated sodium hydroxide solution ***(1 ½ marks)***

(ii) Briefly describe how a pure dry sample of the product of the reaction in (a) (i) can be obtained in the laboratory. ***(2 ½ marks)***

(b) State what would be observed and write equation for the reaction that would take place if

(i) to the solution of the dry sample in (a) (ii) was added aqueous lead (II) nitrate solution. ***(02 marks)***

(ii) to some of the dry sample in (a) (ii) was added dilute sulphuric acid ***(02 marks)***

(d) The Table below shows the variation in volume of carbon dioxide evolved when dilute hydrochloric acid solution was added to several weighed samples of a carbonate with formula, MCO_3 at s.t.p

Mass of MCO_3(g)	0.025	0.050	0.100	0.150	0.200	0.300	0.40
Volume of CO_2 at s.t.p (cm^3)	4.0	11.0	21.0	33.0	44.5	56.0	56.0

(i) Plot a graph of volume of carbon dioxide evolved (vertical axis) against mass of the carbonate, MCO_3 used (horizontal axis. ***(03 marks)***

(ii) Determine the number of moles of the carbonate, MCO_3 that gave maximum volume of carbon dioxide evolved. ***(02 marks)***

(iii) Calculate the atomic mass of M in the carbonate, MCO_3 (C=12,O=16) ***(02 marks)***

13. Spathic iron is one of the major ores of iron

(a) Write the chemical name and formula of spathic iron ***(01 mark)***

(b) During the extraction of iron, spathic iron is first roasted in air before being transferred into the Blast furnace. State the purpose of roasting the ore in air ***(01 mark)***

(c) Name;

(i) the major impurity in iron ore ***(01 mark)***

(ii) two substances, which are fed into the Blast furnace together with roasted iron ore ***(01 mark)***

(iii) any other substance that is also fed into the furnace, and describe where from the substance is let into the furnace ***(01 mark)***

(d) Using equations only, outline reactions which take place inside the Blast furnace up to

(i) Formation of iron ***(3 ½ marks)***

(ii) Removal of the major impurity in the ore ***(02 marks)***

(e) State the importance of slag during extraction of iron in the furnace. ***(01 mark)***

(f) Describe how iron reacts with

(i) Water ***(02 marks)***

(ii) Chlorine ***(02 marks)***

14. (a) Draw a labeled diagram for the set up of apparatus that can be used to prepare a dry sample of ammonia in the laboratory ***(04 marks)***

(b) Explain each of the following and write equation to illustrate your explanation

(i) Ammonia gives dense white fumes with hydrogen chloride ***(3 ½ marks)***

(ii) Fused calcium chloride is not a suitable drying agent for ammonia ***(02 marks)***

(c) Describe the reactions of ammonia with oxygen. ***(5 ½ marks)***

END

SET 4

SECTION A:

2. (a) The full symbol of phosphorus atom is ${}^{31}_{15}P$

Write;

(i) the electronic configuration of phosphorus. (1 mark)

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(ii) the formulae of two compounds that can be formed when phosphorus reacts with chlorine.
(1 mark)

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(b) An oxide of phosphorus, Q, consists of 43.7% phosphorus by mass.

(i) Calculate the formula of Q (O = 16, P = 31) (3 marks)

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(ii) Write the name of Q (1 mark)

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3. In the industrial production of sulphuric acid by the contact process, sulphur dioxide is oxidized to sulphur trioxide in the presence of a catalyst according to the following equation

$$2SO_{2(g)} + O_{2(g)} \xrightleftharpoons{500^oC} 2SO_{3(g)} \quad \Delta H = -96\ Kjmol^{-1}$$

(i) Name the catalyst used in the process (1 mark)

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(ii) Give a reason why the reaction is carried out at 500^oC (2 marks)

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(iii) Sulphuric acid is used in the manufacture of super phosphate fertilizer. Write equation for the reaction (1½ marks)

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(iv) Give one other large scale use of sulphuric acid. (½ mark)

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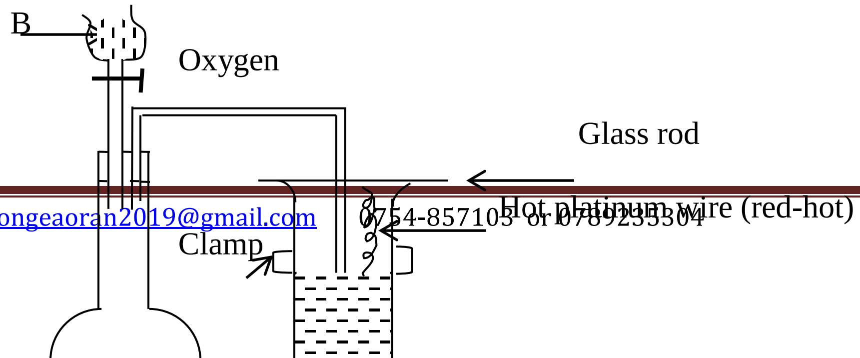
4. The following apparatus was set up to show the catalytic oxidation of ammonia in the laboratory.



(d) Name the chemicals A and B used to prepare oxygen:

A ………………………………………………………………………… (½ mark)

B. ………………………………………………………………………… (½ mark)

(e) State two observations that were made in the boiling tube. (2 marks)

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(f) (i) Write equation for the reaction of ammonia and oxygen in the presence of platinum. (1 ½ marks)

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(ii) State one industrial application of the reaction in (c) (i) (½ mark)

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5. 5cm^3 of 1M hydrochloric acid and 5cm^3 of 1M sodium hydroxide solution were mixed.

(a) Write equation for the reaction that took place. (1 ½ marks)

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(b) The resulting solution was electrolysed between carbon electrodes. Name the product at the:

(i) Anode

……………………………………………………………………………………………(½ mark)

(ii) Cathode

……………………………………………………………………………………………. (½ mark)

(c) The product at the anode was carefully collected in a test tube and then shaken with aqueous potassium iodide solution.

(i) State what was observed. (1 mark)

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(ii) Write an ionic equation to illustrate your answer in (c) (i) (1 ½ marks)

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6. (a) Magnetite, Fe_3O_4 is one of the principal ores of iron.

(i) Write the chemical name of magnetite. (1 mark)

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(ii) Name one other principal ore of iron. (½ mark)

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(iii) Write the formula of the iron compound found in the ore which you have named in (a) (ii)

(1 mark)

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(b) $600.0cm^3$ of hydrogen gas measured at s.t.p was given off when 2.5g of a sample of an iron ore was boiled with excess dilute sulphuric acid. Calculate the percentage purity of the iron ore.

(Fe = 56, 1 mole of a gas occupies 22.4dm^3 at s.t.p) (2 ½ marks)

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7. (a) Iron (II) sulphide can be prepared by direct synthesis.

(i) State what is meant by the term "direct synthesis" (1 mark)

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(ii) Write equation for the reaction leading to the direct synthesis of iron (II) sulphide. (1 ½ marks)

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(b) Name one other salt that can be prepared by direct synthesis. (½ mark)

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(c) State the method that can be used to prepare lead (II) sulphate in the laboratory. (1 mark)

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8. (a) When chlorine was bubbled into a test-tube containing a saturated solution of a potassium salt W, and the resultant mixture shaken with tetra chloro methane, the saturated solution first turned red, followed by formation of a dark-red liquid which sunk to the bottom of the test tube

(i) Identify W (1 mark)

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(ii) Write an ionic equation for the reaction that took place. (1 ½ marks)

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(iii) State any conclusion that can be drawn from the equation you have written in (ii) (1 mark)

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(b) Write equation for the reaction between chlorine and ammonia (1 ½ marks)……………………………………………………………………………………

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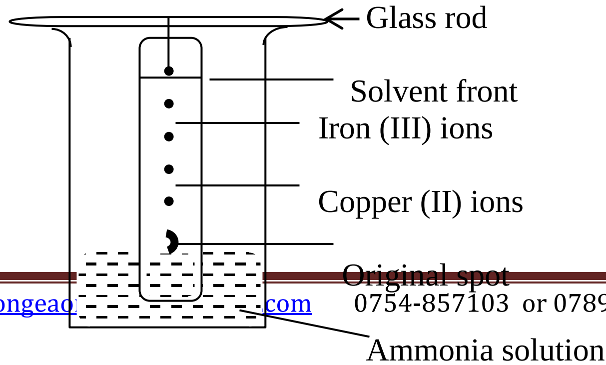
9. Below is shown a chromatogram of a solution containing a mixture of copper (II) ions, iron (III) ions and zinc ions



(a)
(b)
(c)
(d)
(e) Name the method used to separate the mixture. (1 mark)

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(f) (i) State the colour of copper (II) ions and of iron (III) ions in this experiment.

Copper (II) ions ………………………………………………………………….(½ mark)

Iron (III) ions …………………………………………………………………(½ mark)

(ii) Give a reason why zinc ions are not observed in the experiment (1 mark)

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(iii) Write an ionic equation for the reaction between iron (III) ions with the solvent (ammonia solution) (1 ½ marks)

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(g) Give one other mixture that can be separated by the method you have named in (a) (½ mark)

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10. Oxygen can be prepared in the laboratory from sodium peroxide.

(a) (i) State the condition(s) under which sodium peroxide can react to produce oxygen. (1 mark)

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(ii) Write equation for the reaction leading to the formation of oxygen. (1 ½ marks)

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(b) The aqueous product in the reaction in (a) (ii) was added drop wise until in excess to iron (II) sulphate solution.

(i) State what was observed (1 mark)

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(ii) Write equation for the reaction that took place. (1 ½ marks)

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11. (a) State what would be produced if burning magnesium was lowered into a gas jar containing;

(i) Oxygen (½ mark_

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(ii) Nitrogen (½ mark)

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(b) (i) Name one substance that can be used to distinguish between the reaction products that you have stated in (a) (i) and a) (ii) (1 mark)

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(ii) State what would be observed if cold samples of the products that you have stated in (a) (i) and (a) (ii) were treated separately with the substance you have named in (b) (i) (1 ½ marks)

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(iii) Write equation for the reaction that would take place between the product you have stated in (a) (i) and the substance you have named in (b) (i) (1 ½ marks)

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SECTION B:

Answer two questions only in this section. Extra questions answered will not be marked.

12. (a) State what is meant by the term hydrocarbon and name two classes of hydrocarbons. (2 marks)

(b) A hydrocarbon T, molecular formula C_4H_{10} is a gas that undergoes complete combustion in air and is commonly used for domestic purposes.

Write;

(i) The name and structural formula of T (2 marks)

(ii) The equation for complete combustion of T (1 ½ marks)

(c) If the enthalpy of combustion of the hydrocarbon T in (b) were 2877.0 $Kjmol^{-1}$

(i) Calculate the amount of heat that would be evolved at room temperature when $840cm^3$ of T was completely burnt in air. (2 ½ marks)

(C = 12 , H = 1, 1 mole of a gas occupies $24.0dm^3$ at room temperature)

(ii) Suggest one domestic use of T. (1 mark)

(d) Crude oil is a source of many hydrocarbons.

(i) Name the industrial process used to separate hydrocarbons in crude oil. (1 mark)

(ii) State two physical properties of hydrocarbons in crude oil on which the separation by the process you have named in (d) (i) depends. (2 marks)

(iii) Petrol is a hydrocarbon in crude oil. Explain briefly the effect on the environment of the burning of petrol in car engines. (3 marks)

13. Magnesium reacts with dilute sulphuric acid according to the following equation

$$Mg_{(s)} + H_2SO_{4(aq)} \longrightarrow MgSO_{4(aq)} + H_{2(g)}$$

(a) State;

(i) Two factors other than concentration of acid that can affect the rate of the reaction (2 marks)

(ii) The effect of each of the factors you have stated in (a) (i) on the rate of the reaction

(2 marks)

(b) Describe an experiment you would carry out in the laboratory to find the relationship between the rate of the magnesium/sulphuric acid reaction and the concentration of the acid. (6 marks)

Your answer should include;

- Measurements you would make
- How you would vary the concentration of the acid
- What results you would expect.
- How you would use your results to find the relationship.

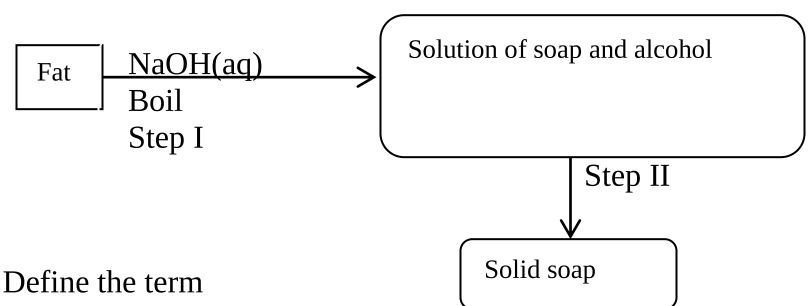
(c) The table below shows the volumes of hydrogen that were produced per minute when a standard solution of sulphuric acid reacted with certain lengths of magnesium ribbon.

Length of ribbon (cm)	1.0	2.0	3.0	5.0	6.0
Volume of hydrogen/cm^3 min^{-1}	3.8	7.2	10.6	18.2	21.6

(i) Plot a graph of volume of hydrogen against length of magnesium ribbon. (3 marks)

(ii) Explain the shape of your graph (2 marks)

14. The scheme below was used to prepare soap



(a) Define the term

(i) Soap (1 marks)

(ii) Saponification (1 mark)

(b) Name one chemical substance added in step II and state the purpose of adding this chemical substance. (2 marks)

(c) State one source of fat from which soap is prepared. (1 mark)

(d) Briefly explain how soap can remove dirt from linen when linen is washed. (3 marks)

(e) When soap is used for washing in hard water, lathering does not occur immediately, when a soapless detergent is used for washing in the same water, there is immediate lathering. Explain the observation.

(3 ½ marks)

(f) (i) Name two raw materials from which a sample of soapless detergent can be prepared in the laboratory. (2 marks)

(ii) State two disadvantages of soapless detergent over soap. (2 marks)

15. (a) (i) Draw a labeled diagram to show how a dry sample of hydrogen gas can be prepared in the laboratory. (2 ½ marks)

(ii) Write an ionic equation for the reaction leading to the formation of hydrogen (1 ½ marks)

(b) Calcium, lead, potassium, and zinc form part of the reactivity series.

(i) Arrange the elements in order of reactivity starting with the most reactive element. (1 mark)

(ii) Describe how potassium, zinc and lead react with water. (Illustrate your description with equation where necessary.) (7 marks)

(c) Iron reacts with steam according to the following equation;

$Fe_{(s)} + 4H_2O_{(g)} \longrightarrow Fe_3O_{4(s)} + 4H_{2(g)}$

Calculate the mass of iron required to produce 6.72 dm^3 of hydrogen gas at s.t.p
(H = 1, Fe = 56, 1 mole of a gas occupies 22.4dm^3 at s.t.p) (3 marks)

END

SET 5

SECTION A (50 *MARKS*)

*Answer **all** questions in this section*

1.(a) Name two types of flames that a Bunsen burner can produce. (01 *mark*)

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(b) State;

(i) The condition(s) under which each of the Bunsen burner flames that you have named in (a) is produced. $(01\ mark)$

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(ii) Which one of the flames that you have named in (a) is more suitable for use. $(\frac{1}{2}\ mark)$

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(c) Give a reason for your answer in (b) (ii) $(\frac{1}{2}\ mark)$

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(d) The gas, which is used as a fuel in a Bunsen burner, is hydrocarbon of molecular formula C_4H_{10}

(i) Name the gas. $(01\ mark)$

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(ii) State the homologous series to which the hydrocarbon belongs. $(01\ mark)$

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2. (a) Water was added to sodium peroxide.

(i) State what was observed. $(02\ marks)$

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(ii) Write the equation for the reaction which took place. $(1\frac{1}{2} marks)$

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(b) State;

(i) How the gaseous product from the reaction between sodium peroxide and water can be tested. $(\frac{1}{2}mark)$

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(ii) Two uses of the other product of the reaction between sodium peroxide and water. $(01\ mark)$

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4. (a) Name one substance in each case, which is

(i) A carbonate that shows no change in mass when heated. $(\frac{1}{2}\ mark)$

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(ii) A compound that when heated turns directly into gas(es) without first melting. $(01\ mark)$

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(iii) a nitrate, which when heated produces oxygen as the only gaseous product. $(\frac{1}{2}\ mark)$

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(b) Write the equation for the reaction that would take place if each of the following mixtures was heated.

(i) Iron and sulphur. $(1\frac{1}{2}marks)$

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(ii) Zinc and dilute sulphuric acid. $(1\frac{1}{2}marks)$

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5. (a) Magnesium powder was added to copper(II) oxide and the mixture heated.

(i) State what was observed. $(02\ marks)$

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(ii) Write the equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

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(b) (i) If the procedure in (a) was repeated using calcium oxide instead of copper(II) oxide, state how calcium oxide would be affected. $(\frac{1}{2}\ mark)$

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(ii) Give a reason for your answer in (b)(i). $(01\ mark)$

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6. (a) (i) Define the term 'alloy' $(01\ mark)$

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(ii) Name one common alloy of iron. $(\frac{1}{2}\ mark)$

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(iii) Give two reasons why the alloy you have named in (a)(ii) is more often used than iron itself. $(01\ mark)$

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(b) Name the major components of the following alloys.

(i) Solder. $(01\ mark)$

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(ii) Duralumin. $(01\ mark)$

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(c) State one use of duralumin. $(\frac{1}{2}\ mark)$

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7. The atomic numbers of elements X, Y and Z are 11, 15 and 17 respectively.

(a) Write the electronic configuration of

a. X……………………………………………………..(01$mark$)

b. Y……………………………………………..………(01 $mark$)

c. Z……………………………………………...………(01 $mark$)

(b) State the period in the periodic table to which each of the three elements belongs. $(01\ mark)$

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(c) Element Z can react with both X and Y to form solid products Q and R respectively.

(i) Identify which one of the products would have a lower melting point. $(01\ mark)$

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(ii) Give a reason for your answer in (c)(i) $(01\ mark)$

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8. In an experiment to study the reaction of lead(II) and copper(II) ions, excess dilute ammonia solution was added to an aqueous solution containing a mixture of copper(II) and lead(II) ions, and the resultant solution filtered.

(a) State the colour of the;

a. Residue. $(01\ mark)$

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b. Filtrate. $(01\ mark)$

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(b) Write the;

(i) The formula of the cation that was in the filtrate. $(\frac{1}{2}\ mark)$

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(ii) Equation for the reaction that resulted into formation of the residue. $(1\frac{1}{2}\ marks)$

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(c) If the experiment above was repeated using, excess dilute sodium hydroxide solution, identify the cation that would appear in the.

(i) Residue. $(\frac{1}{2}\ mark)$

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(ii) Filtrate. $(\frac{1}{2}\ mark)$

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9. (a) Potassium hydroxide can react with a solution of ammonium sulphate to produce ammonia according to the following equation;

$$2KOH(aq) + (NH_4)_2SO_4(aq) \longrightarrow K_2SO_4(aq) + 2H_2O(l) + 2NH_3(g)$$

Calculate the volume of ammonia that would be produced at room temperature if excess potassium hydroxide reacted with $150cm^3$ of a 2M ammonium sulphate solution. (1 mole of a gas occupies $24.0dm^3$ at room temperature) $(3\frac{1}{2}\ marks)$

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(b)(i) Name a laboratory reagent that is used to detect ammonia. $(\frac{1}{2}\ mark)$

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(ii) State what would be observed if ammonia was treated with the reagent you have named in (b)(i). $(01\ mark)$

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10. The mass numbers of some particles Q to Z, and their numbers of electrons and neutrons are shown in the table below;

Particle	Mass number	Number of electrons	Number of neutrons
Q	14	7	7
R	24	10	12
T	31	15	16
W	36	18	19
X	39	19	20
Y	40	18	22

Z	41	19	22

Identify which of the particles is/are (01 $mark\ each$)

(a) Isotopes

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(b) An anion.

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(c) A cation.

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(d) Atoms of elements in the same group of the periodic table.

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(e) The atom of an inert gas.

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11. (a) Name one allotrope of carbon which is;

(i) Amorphous. ($\frac{1}{2}\ mark$)

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(ii) Crystalline. ($\frac{1}{2}\ mark$)

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(b) State one use of each of the carbon allotropes that you have named in (a)

(02 $marks$)

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(c) Name one element other than carbon, which shows allotropy. (01 $mark$)

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$SECTION\ B\ (30\ MARKS)$

$Answer\ any\ \boldsymbol{two}\ questions\ only\ in\ this\ section. Extra\ questions(s) answered\ will\ \boldsymbol{not}\ be\ marked$

12. (a) Define the term "enthalpy of combustion" $(01\ mark)$

(b)(i) Draw a labelled diagram of the set up of apparatus that can be used to determine the enthalpy of combustion of ethanol in the laboratory. $(04\ marks)$

(ii) State why the enthalpy of combustion of ethanol obtained experimentally using the kind of apparatus that you have drawn is normally found to be less than the literature values and suggest two ways by which the experimental value can be improved. $(02\ marks)$

(c) State two practical applications of enthalpies of combustion. $(02\ marks)$

(d) When 4.0g of ammonium nitrate. NH_4NO_3 was dissolved in 96.0cm^3 of water, the temperature of the water dropped from 27.0℃ to 24.1℃

(i) Give a reason why there was a drop in the temperature of the water. $(01\ mark)$

(ii) Calculate the enthalpy of solution of ammonium nitrate.

$(H = 1; N = 14; O = 16, density\ of\ water = 1.0gcm^{-3}\ and$
$heat\ capacity\ of\ ammonium\ nitrate\ solution = 4.2jg^{-1}℃^{-1})$ $(05\ mark)$

13. (a)(i) State the conditions under which hydrochloric acid reacts with potassium manganate(VII) during the laboratory preparation of chlorine; and write equation for the reaction leading to the formation of chlorine. $(2\frac{1}{2}\ marks)$

(ii) Explain how a pure dry sample of chlorine can be obtained during its preparation as stated in (i). (No diagram is required) $(03\ marks)$

(b) State and explain how chlorine is prepared on a large scale using sodium chloride. (No diagram is required.) $(05\ marks)$

(c) Dilute hydrogen chloride solution was added drop wise to lead(II) oxide until in small excess and the mixture allowed to stand.

(i) State what was observed and write the equation for the reaction that took place. $(03\ marks)$

(ii) From the reaction in (c)(i), deduce any conclusion, that can be made concerning the composition of hydrogen chloride. $(1\frac{1}{2}\ marks)$

14. (a) Outline how a sample of concentrated solution of ethanol can be prepared by fermentation of glucose. $C_6H_{12}O_6$ (No diagram is required but your answer should include equation of reaction) $(05\ marks)$

(b) Briefly describe and explain how a sample of ethene can be prepared from ethanol using sulphuric acid. (Your answer should include conditions and equation; but no diagram is required.) $(4\frac{1}{2}\ marks)$

(c) Write equation to show the reaction of ethene, leading to formation of

(i) 1,2-dibromoethane. $(1\frac{1}{2}\ marks)$

(ii) Polyethene. $(01\ mark)$

(iii) Water and carbon dioxide. $(1\frac{1}{2}\ marks)$

(d) State one

(i) Use of ethanol other than preparation of Polyethene. $(01\ mark)$

(ii) Disadvantage of Polyethene. $(01\ mark)$

END

SET 6

SECTION A

*Attempt **all** questions in this section.*

1. Potassium manganate(VII) was reacted with compound **X** in a test tube and yellow-green gas evolved.

a) (i) Identify compound **X**? ***(½ mark)***

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(ii) Name gas that was evolved. ***(½ mark)***

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b) (i) Write equation of reaction that lead to formation of gas you have named in a(ii) above. ***(1 ½ marks)***

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(ii) State the possible conditions for the above reaction. ***(1 mark)***

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c) Write equation for the reaction of hot iron wire with the gas you have named in a(ii) above. ***(1 ½ marks)***

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2. Oxidation and reduction are two chemical processes which always occur together.
   a) Give differences between oxidation and reduction in terms of electrons. ***(02 marks)***

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b) Write the equations of the following half reactions and in each case state whether the reaction is oxidation or reduction.

(i) Conversion of chlorine molecule to chloride ions. ***(1 ½ marks)***

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(ii) Conversion of iron (II) ions to iron (III) ions. ***(1 ½ marks)***

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3. A stream of dry ammonia gas was passed over strongly heated lead (II) oxide in a combustion tube.

a) (i) State what was observed. ***(1 ½ marks)***

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(ii) Write the equation of reaction that took place. ***(1 ½ marks)***

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b) Aqueous ammonia solution was added to a mixture of iron (II) sulphate and copper (II)
sulphate until in excess. After thorough shaking the mixture was filtered.

(i) Identify the metal ion in the residue. ***(01 mark)***

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(ii) Identify the metal ion in the filtrate. ***(01 mark)***

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4. Sulphur (IV) oxide reacts with oxygen in the contact process according to the following equation.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)\ \Delta H = -192KJmol^{-1}$

a) State the conditions needed to increase the yield of sulphur (VI) oxide. ***(1 ½ marks)***

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b) Write equations of reactions leading to the production of sulphuric acid from sulphur (VI) oxide. ***(03 marks)***

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c) State one use of sulphuric acid. ***(01 mark)***

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5. A piece of sodium metal was burnt in a limited oxygen supply.

   a) State what was observed. ***(01 mark)***

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   b) Write equation for the reaction that took place. ***(1 ½ marks)***

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   c) Water was added to the product (b) above.

   (i) Write equation for the reaction that occurred. ***(1 ½ marks)***

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   (ii) State what was observed in (c) above. ***(01 mark)***

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6. Hydro carbon Z contains 85.7% by mass of carbon and the rest being hydrogen. Formula mass of Z is 84 grams.

a) Calculate the empirical formula of Z. ***(02 marks)***

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b) Determine the molecular formula of Z. ***(1 ½ marks)***

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c) (i) Write the structural formula of Z. ***(01 mark)***

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(ii) State what is observed when Z is bubbled through Bromine water. ***(01 mark)***

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7. a) 100cm^3 of molar sulphuric acid was added to 18.6g of copper (II) carbonate for complete reaction according to the following equation.

$$H_2SO_4(aq) + CuCO_3(s) \longrightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$$

Note:

(Cu = 64, C = 12, H = 1, O = 16, S = 32, 1 mole of gas at s.t.p occupies 22.4 litres)

Calculate the volume of the gaseous product at s.t.p. ***(02 marks)***

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b) Briefly explain why dilute sulphuric acid hardly reacts with limestone effectively to form carbon dioxide. ***(02 marks)***

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8. Element **T** belongs to group II of the periodic table.

a) (i) State the type of bond that can exist in the chloride of **T**? ***(01 mark)***

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(ii) Write the formula of the ion formed by **T**? ***(01 mark)***

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b) The nitrate of element **T** was strongly heated until no further change.

(i) State what was observed. ***(1 ½ marks)***

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(ii) Write the equation for the reaction that took place. ***(1 ½ marks)***

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9. a) Write equation for the reaction between aqueous hydrochloric acid and marble stones? ***(1 ½ marks)***

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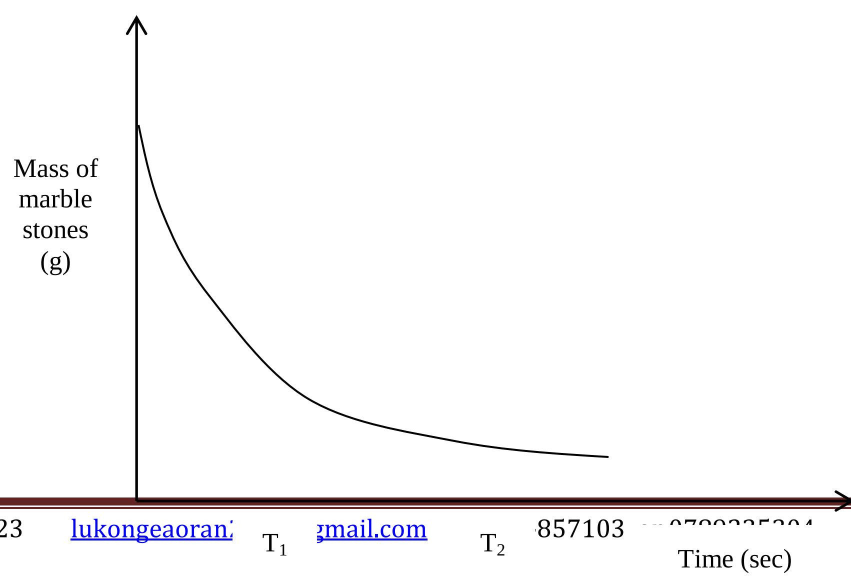
b) Sketch graph below shows variation in the mass of marble stones with time when excess dilute hydrochloric acid was added to some marble stones.



| |

(i) Show how the rate of reaction at time t_1 seconds can be determined (your answer should include units.) ***(1 ½ marks)***

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(ii) The rate of reaction at time T_2 seconds was found to be slower than that at T_1. Give a reason.

(01 mark)

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c) Other than changes in mass of marble stones, suggest one property which can be used to determine the rate of the same reaction. ***(01 mark)***

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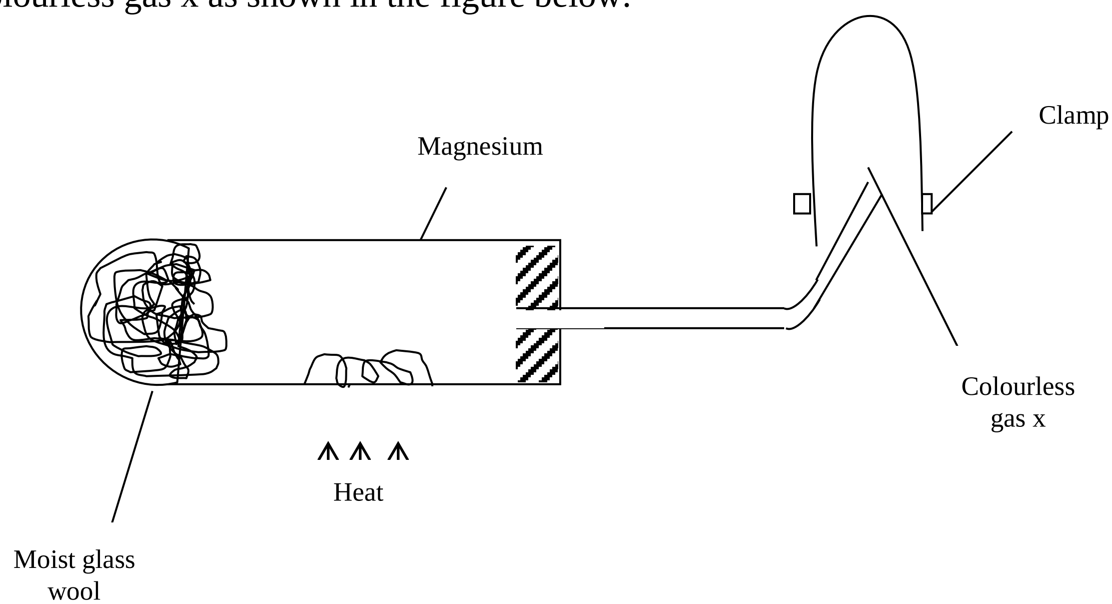
10. Heating of clean magnesium ribbon in steam produced a white solid and a colourless gas x as shown in the figure below.



a) Write the equation for the reaction that took place ***(1 ½ marks)***

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b) Identify gas x and the white solid formed. ***(01 mark)***

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c) State why gas x is collected as shown in the diagram above. ***(01 mark)***

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d) White powder/ solid formed in the reaction was reacted with water.

(i) Write equation of reaction for the reaction that occurred. ***(1 ½ marks)***

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SECTION B

Answer any 2 questions

11. a) (i) State two properties which show that air is a mixture. ***(02 marks)***

(ii) Name two other gases other than oxygen that are constituents of air and give their

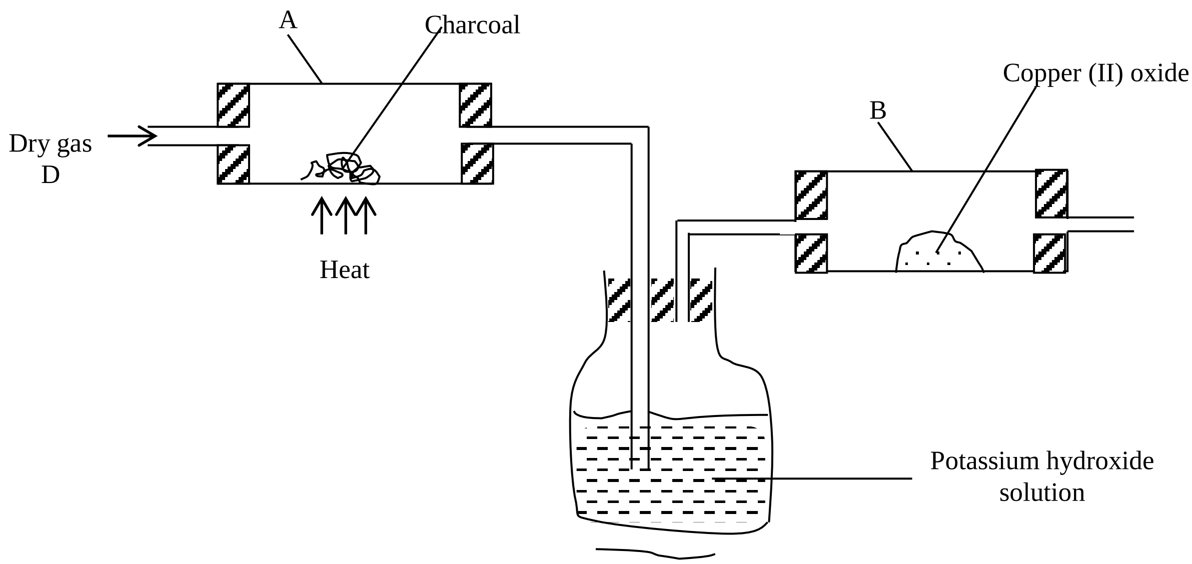
approximate percentages in air. ***(02 marks)***

b) Describe an experiment to determine the percentage of oxygen in air. Show how the
percentage can be calculated from the results. ***(8 ½ marks)***

c) (i) State what is observed when burning iron is lowered into a gas jar full of oxygen. ***(1 ½ marks)***

(ii) Write the name and formula of the product of the reaction between iron and oxygen. ***(01 mark)***

12. An experiment was carried out to prepare and investigate effects of one gas of carbon on copper (II) oxide as indicated in the diagram below.



a) (i) Name gas D. ***(½ mark)***

(ii) Write an equation for the reaction that occurred in tube A ***(01 mark)***

b) (i) Explain using an equation the role of potassium hydroxide solution in this experiment. ***(02 marks)***

(ii) State what was observed in tube B. ***(01 mark)***

(iii) Write an equation and name the type of reaction that took place. ***(1 ½ marks)***

c) (i) What precautions should be carried out in this experiment? ***(½ mark)***

(ii) Give one industrial application of carbon monoxide gas. ***(½ mark)***

d) Using equations, briefly describe what happens when;

(i) Burning magnesium is lowered into a gas jar full of carbon dioxide gas.

(5 ½ marks)

(ii) Excess carbon dioxide is bubbled into a solution of calcium hydroxide and then heated. ***(2 ½ marks)***

13. Two gases **L** and **M** have the following descriptions;

- **L** does not burn
- **L** fumes in moist air
- **M** can burn in air enriched with oxygen.
- **M** can turn moist red litmus paper to blue.

a) (i) Identify gas **L** and **M**.

(ii) Name the drying agent used during the laboratory preparation of gas **L** and gas **M**.

b) Write an equation for the laboratory preparation of gas **L** and gas **M**.

c) Write an equation for the combustion of **M** in the presence of platinum catalyst.

d) **L** was bubbled through silver nitrate solution.

(i) State what was observed.

(ii) Write equations for the reactions that took place.

e) **M** was dissolved in water to form an aqueous solution. A portion of the resultant solution

was added to zinc sulphate solution drop wise until in excess.

(i) State what was observed.

(ii) Write equations for the reactions that took place.

14. Copper is extracted from an ore, but in the final stage it is obtained by roasting copper (II) sulphide in a stream of limited air supply.

a) (i) Write an equation for the reaction that takes place.

(ii) Name and write the formula of the commonest ore from which copper is extracted.

b) Write the equation for the initial roasting process of the ore you have named in a(ii) above.

c) (i) What is the name of the chemical process by which copper (I) sulphide is converted to copper?

(ii) Write the equation for the reaction occurring during the chemical process you have

named in c(i) above.

d) (i) Name the process by which impure copper is purified.

(ii) Draw a labeled diagram for the purification process.

(iii) State three uses of copper.

End -

SET 7

$\boldsymbol{SECTION\ A}$ $(\mathbf{50}\ \boldsymbol{MARKS})$

Answer ***all*** *questions in this section*

1. An atom of element **M** has 12 protons and 13 neutrons

(a) (i) To which group of the periodic table does **M** belong? $(0\frac{1}{2}\,mark)$

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(ii) What is the atomic mass of **M**? $(0\frac{1}{2}\,mark)$

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(iii) What is the relationship between element **M** and **N**? $(0\frac{1}{2}\,mark)$

(**N** has 12 neutrons and 12 protons.)

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(b) Write;

(i) The formula of the ion **M** forms most. $(0\frac{1}{2}\,mark)$

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(ii) The formula of the compound formed when **M** reacts with nitrogen gas. $(0\frac{1}{2}\, mark)$

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(iii) The equation for the reaction between M and chlorine gas$(1\frac{1}{2}\, marks)$

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(c) State;

(i) The type of bond formed when **M** combines with chlorine. $(\frac{1}{2}\, mark)$

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(ii) Two properties of the product formed when **M** combines with chlorine. $(02 marks)$

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2. (a) A magnet was rubbed through a mixture of sulphur and iron fillings. State;

(i) What was observed? $(0\frac{1}{2}\, mark)$

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(ii) What would be observed if the mixture was heated? $(01\, mark)$

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(b) Write an equation for the reaction which takes place when the mixture in (a) is heated. $(1\frac{1}{2}\, marks)$

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(c) Apart from using a magnet, briefly explain how sulphur can be obtained from the mixture. $(1\frac{1}{2}\, marks)$

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3. Dilute hydrochloric acid was added to zinc granules contained in a round bottomed flask connected to a U-tube containing anhydrous calcium chloride.

(a) (i) State the role of anhydrous calcium chloride in this experiment. $(01 mark)$

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(ii) What would be observed if an opening was made on the U-tube and a flame applied? $(01\, mark)$

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(iii) Write an equation for the reaction which takes place in (a)(ii) above $(1\frac{1}{2}\, marks)$

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(b) How can you test for the product formed in (a)(ii)? $(01\, mark)$

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4. A mixture of copper turnings and concentrated sulphuric acid was heated in a round bottomed flask.

(a) (i) State what was observed? $(1\frac{1}{2}\, marks)$

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(ii) Write an equation for the reaction. $(1\frac{1}{2}\,marks)$

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(b) The residue in (a) above was dissolved in water to make a solution. State what would be observed if ammonia solution was added to the resultant solution drop wise until in excess. $(1\frac{1}{2}\,marks)$

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5. A current of 2.68A was passed through dilute sodium chloride solution for one hour using carbon electrodes.

(a) (i) Name the cation(s) in sodium chloride solution. $(01\,mark)$

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(ii) Write an equation for the reaction that took place at the anode. $(1\frac{1}{2}\,marks)$

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(b) Concentrated sodium chloride solution was used instead of dilute sodium chloride solution

(i) State what was observed at the anode. $(01\,mark)$

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(ii) Explain the observation in (b)(i) above. $(01\,mark)$

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(iii) Write the equation for the reaction. $(1\frac{1}{2}\, marks)$

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6. A colourless gas **W** which forms dense white fumes with ammonia is formed when an acid **X** reacts with sodium chloride.

(a) (i) Name acid **X**. $(0\frac{1}{2}\, mark)$

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(ii) State the condition(s) for the reaction. $(01\, mark)$

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(iii) Write an equation for the reaction. $(1\frac{1}{2}\, marks)$

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(b) **W** was dissolved in water to form an aqueous solution.

(i) Name the anion in the solution. $(0\frac{1}{2}\, mark)$

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(ii) Write an ionic equation for the reaction between the anion in (i) above and silver nitrate solution. $(1\frac{1}{2}\, marks)$

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7. A nitrate of metal **Y** when heated decomposed to form a yellow residue **Z** when hot which turned white on cooling.

(a) (i) Identify the nitrate and the residue. $(01\ mark)$

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(ii) Write an equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

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(b) (i) Determine the mass of **Z** if 1.89g of the nitrate was decomposed. $(1\frac{1}{2}\ marks)$

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(ii) State what would be observed if sodium hydroxide solution was added to an aqueous solution of the nitrate drop wise until in excess. $(01\ mark)$

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8. (a)(i) What are allotropes? $(01\ mark)$

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(ii) Name the crystalline allotropes of carbon. $(01\ mark)$

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(b) Describe a simple experiment that you would carryout to show that the allotropes in (a)(ii) are allotropes of carbon. $(02\ marks)$

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9. (a) An oxide of sulphur contains 50% by mass of sulphur. Determine the molecular formula of the oxide. $(S = 32; O = 16)$ $(2\frac{1}{2}\ marks)$

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(b) The oxide was bubbled through iron(III) sulphate solution.

(i) State what was observed. $(01\ mark)$

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(ii) Write an ionic equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

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10. (a) State;

(i) The main components of air. $(01\ mark)$

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(ii) The component(s) of air that affects iron fillings. $(01\ mark)$

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(b) Describe an experiment you can carryout to show that one of the components in (a)(i) affects iron fillings. (No diagram required) $(3\frac{1}{2}\ marks)$

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$\boldsymbol{SECTION\ B}$ $(\mathbf{30}\ \boldsymbol{MARKS})$

$Answer\ any\ \boldsymbol{TWO}\ questions\ from\ this\ section$

11. (a) Sodium thiosulphate reacts with dilute hydrochloric acid to form a yellow precipitate of sulphur. Describe an experiment you would carry out in the laboratory to show that the rate of the reaction depends on the concentration of hydrochloric acid. $(08\ marks)$

(b) Explain how the rate of the reaction can be obtained from your results in (a) $(03\ marks)$

(c) (i) Apart from concentration, state two other factors that affect reaction rates. $(01\ mark)$

(ii) What volume of 2M hydrochloric acid will precipitate 3.2g of sulphur in (a) above.

$$Na_2S_2O_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$$

$(03\ marks)$

12. (a)(i) Apart from spathic iron ore, write the name and formula of two ores from which cast iron can be obtained. $(03\ marks)$

(ii) Name the main impurity in iron ore. $(01\ mark)$

(b) Before being introduced into the blast furnace, spathic iron ore is first roasted in air then mixed with other substances before being introduced into the blast furnace.

(i) Name two substances which are mixed with spathic iron ore. $(02\ marks)$

(ii) Name the other substance needed in the extraction of iron. $(01\ mark)$

(iii) Explain the purpose of adding each of the substances in (b)(i) above. $(08\ marks)$

13. Air was passed through two wash bottles one containing calcium hydroxide the other containing concentrated sulphuric acid, then into a combustion tube containing heated copper.

(a) (i) State what was observed in the bottle that was containing calcium hydroxide. $(01\ mark)$

(ii) Write equation(s) for the reaction(s) that took place. $(03\ marks)$

(iii) State what was observed in the wash bottle containing concentrated sulphuric acid. $(01\ mark)$

(iv) State the purpose of passing the air through a wash bottle containing concentrated sulphuric acid. $(01\ mark)$

(v) State the property of sulphuric acid being investigated. $(0\frac{1}{2}\ mark)$

(b) (i) State what was observed in the combustion tube. $(01\ mark)$

(ii) Write an equation for the reaction that took place in the combustion tube. $(1\frac{1}{2}\,marks)$

(iii) Name the gas that comes out of the combustion tube. $(01\,mark)$

(c) Burning magnesium was lowered into a gas jar of the gas in (b)(iii)

(i) State what was observed. $(01\,mark)$

(ii) Write an equation for the reaction that took place. $(1\frac{1}{2}\,marks)$

(iii) State what would be observed and write equation for the reaction when the product in (c) above is shaken with water and the resultant solution tested with litmus. $(2\frac{1}{2}\,marks)$

14. Ammonium sulphate was dissolved in water to form an aqueous solution. The resultant solution was divided into 3 portions.

(a) To the first portion was added sodium hydroxide solution and the mixture warmed.

(i) State what was observed. $(01\,mark)$

(ii) Write an ionic equation for the reaction that took place. $(1\frac{1}{2}\,marks)$

(b) To the second portion was added lead(II) nitrate solution.

(i) State what was observed. $(01\,mark)$

(ii) Write an ionic equation for the reaction that took place. $(1\frac{1}{2}\,marks)$

(c) State what would be observed if litmus was added to the third portion. $(01\,mark)$

(d) Explain the following observations;

(i) When lead(II) nitrate is heated a reddish brown gas is given off which relights a glowing splint, the colourless crystal turn yellow$(3marks)$

(ii) When a mixture of sodium carbonate and sodium hydrogen carbonate is heated, there is no colour change but the mass of the mixture decreases. $(03\ marks)$

(iii) When a mixture of calcium hydroxide and ammonium sulphate is ground then heated, the mass of the mixture decreases, when red litmus paper is held over the mixture. $(03\ marks)$

END

Set 8

SECTION A **(50 *MARKS*)**

*Answer **all** questions in this section*

1. (a) State the conditions under which sulphuric acid can react with;

(i) Copper $(01\ mark)$

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(ii) Zinc hydroxide. $(0\frac{1}{2}\ mark)$

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(b) Write the equation for the reaction between sulphuric acid and

(i) Copper $(1\frac{1}{2}\ marks)$

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(ii) Zinc hydroxide. $(1\frac{1}{2}\ marks)$

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(c) State the property of sulphuric acid shown by the reaction in (b)(i)

$(0\frac{1}{2}\ mark)$

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2. (a) Brass is an alloy of copper and zinc.

Define the term alloy. $(01\ mark)$

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(b) State ;

(i) Two physical properties in which brass differs from copper. $(01 mark)$

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(ii) One use of brass. $(0\frac{1}{2}\ mark)$

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(c) Give a reason why brass is not considered a compound of copper.

$(01\ mark)$

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(d) (i) Name one other alloy of copper that is used for making aircrafts.

$(0\frac{1}{2}\ mark)$

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(ii) Give one reason why the alloy you have named in (d)(i) is suitable in making aircrafts. $(01\ mark)$

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3. (a) State the condition(s) under which ammonia can be produced from;

(i) Magnesium nitride. $(01\ mark)$

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(ii) Ammonium chloride. $(01 mark)$

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(b) Write the equation for the reaction leading to the formation of ammonia from magnesium nitride under the condition(s) you have stated in (a)(i)

$(1\frac{1}{2}\ marks)$

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(c) Aqueous ammonia is used in laundry work.

(i) State the role of aqueous ammonia in laundry work. $(01\ mark)$

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(ii) Write the equation of reaction to illustrate your answer in (c) (i)

$(1\frac{1}{2}\ marks)$

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4. Ethene is an unsaturated hydrocarbon

(a) State what is meant by the term "unsaturated hydrocarbon" $(01\ mark)$

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(b) (i) Name one reagent that can be used to test for unsaturation in ethene.

$(01\ mark)$

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(ii) State what would be observed if ethene was treated with the reagent you have named in (b)(ii). $(01 mark)$

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(iii) Write equation to illustrate your answer in (b)(ii). $(01\ mark)$

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(c) Give one industrial use of ethene. $(01\ mark)$

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5. (a) Calcium oxide is a hygroscopic white powder.

(i) State what is meant by the term "hygroscopic substance" $(01mark)$

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(ii) Write equation to illustrate the hygroscopic nature of calcium oxide.

$(1\frac{1}{2}\ marks)$

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(b) Write equation for the reaction that can take place when a mixture of calcium oxide and silicon(IV) oxide is heated. $(1\frac{1}{2}\ marks)$

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6. (a) When hydrochloric acid was added to a solid **Q**, at room temperature, chlorine was evolved.

(i) Identify **Q**. $(01 mark)$

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(ii) State the condition(s) for the reaction. $(0\frac{1}{2}\ mark)$

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(iii) Write equation for the reaction that led to the formation of chlorine.

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(b) When a glass tube with chlorine water was inverted in a beaker of water, and left exposed to bright sun light for some time, oxygen was produced.

(i) State the role of sun light. $(0\frac{1}{2}\ mark)$

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(ii) Write the equation to illustrate your answer in (b)(i) $(1\frac{1}{2}\ marks)$

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7. (a) Butane C_4H_{10} is a gas that can undergo complete combustion in air and is commonly used for domestic purposes. Write the equation for the complete combustion of butane in air. $(1\frac{1}{2}\ marks)$

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(b) If the enthalpy of combustion of butane were $3062.5 Kjmol^{-1}$

(i) Calculate the amount of heat that would be evolved at room temperature when 840cm^3 of butane was completely burnt in air.

$(H = 1; C = 12; 1\ mole\ of\ a\ gas\ at\ room\ temperature\ occupies\ 24.0dm^3)$

$(2\frac{1}{2}\ marks)$

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(ii) Suggest one domestic use of butane. $(01\ mark)$

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8. (a) Define the term "allotropy" $(01 mark)$

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(b) Name;

(i) One crystalline allotrope of carbon. $(0\tfrac{1}{2}\ mark)$

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(ii) One amorphous allotrope of carbon. $(0\tfrac{1}{2}\ mark)$

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(c) State one use of the crystalline allotrope of carbon that you have named in (b)(i). $(01\ mark)$

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(d) State;

(i) One word which means the relationship between carbon-12, ${}^{12}_{6}C$ and carbon-14, ${}^{14}_{6}C$. $(01 mark)$

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(ii) One use of carbon-14. $(01 mark)$

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9. When excess hydrogen was passed over 2.50g of a strongly heated oxide, Z of iron, 1.82g of solid residue remained. Calculate the formula of Z.

$(Fe = 56; O = 16; Z = 232)$ $(04 marks)$

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10. Substance **W** is a green powder which shows the following properties;

- It reacts with dilute hydrochloric acid to produce a gas which turns lime water milky.
- It decomposes on heating to form a black solid **X** and the same gas that turns lime water milky. **X** dissolves in dilute nitric acid to give a blue solution **Y** which reacts with aqueous ammonia to form a blue precipitate. The precipitate dissolves in excess ammonia to produce a deep blue solution **Z**.

(a) Identify;

(i) **W** $(0\frac{1}{2}\,mark)$

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(ii) **X** $(0\frac{1}{2}\,mark)$

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(b) Write equation to show what happens when **W** is heated. $(1\frac{1}{2}\,marks)$

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(c) (i) Name the blue solution **Y**. $(01 mark)$

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(ii) Write the formula of the ion that is responsible for the deep blue colour of solution **Z**. $(01 mark)$

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(d) State how you would obtain a sample of a metal from the solution **Y**.

$(01 mark)$

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$SECTION\ B\ (30\ MARKS)$

Answer only two questions from this section. Extra question(s) answered will not be marked

11. (a)(i) Name the raw material from which sulphuric acid can be manufactured by the contact process. $(01 mark)$

(ii) With the help of equations, outline the reactions which take place during the contact process. $(05 marks)$

(b) Explain why fuming sulphuric acid has no effect on litmus paper whereas dilute sulphuric acid readily turns blue litmus paper red. $(3\frac{1}{2}\,marks)$

(c) State what would be observed and write the equation for the reaction that would take place when concentrated sulphuric acid was added to;

(i) Sugar. $(2\frac{1}{2}\ marks)$

(ii) Heated sodium chloride crystals. $(2\frac{1}{2}\ marks)$

12. (a) During the laboratory preparation of nitric acid, a mixture of concentrated sulphuric acid and a white crystalline solid R was heated. Effervescence occurred giving out brown fumes which condense in the cooled flask and nitric acid collects as a yellow liquid.

(i) Identify R. $(01\ mark)$

(ii) Name the piece of apparatus in which the preparation of nitric acid was carried out and give a reason for the suitability of the apparatus. $(02 marks)$

(iii) Briefly explain why the nitric acid collects as a yellow liquid. $(03 marks)$

(iv) State how the yellow colour in the acid can be removed. $(1 mark)$

(v) Write equation for the reaction that led to the formation of nitric acid from the reaction mixture. $(1\frac{1}{2}\ marks)$

(vi) State one large scale use of nitric. $(0\frac{1}{2}\ mark)$

(b) Concentrated nitric acid was added to iron(II) sulphate solution that contained dilute sulphuric acid.

(i) State what was observed. $(1\frac{1}{2}\ marks)$

(ii) Explain briefly your observation in (b) (i). $(2\frac{1}{2}\ marks)$

(c) The following equations show the effect of heat on the nitrates of metals J and G.

$$2GNO_3(s) \longrightarrow 2G(s) + 2NO_2(g) + O_2(g)$$

$$2J(NO_3)_2(s) \longrightarrow 2JO(s) + 4NO_2(g) + O_2(g)$$

Suggest one possible identity of;

(i) G. $(01 mark)$

(ii) J $(01 mark)$

13. (a) Distinguish between the terms covalent bond and electrovalent bond. $(02 marks)$

(b) The numbers of protons, neutrons and electrons in atoms, **A**, **D** and **E** are given below

Atom	*Protons*	*Neutrons*	*Electrons*
A	8	8	8
D	8	10	8
E	19	20	19

(i) Write the full symbol of each of atoms, **A, D** and **E** $(03 marks)$

(ii) State the relationship between **A** and **D**. $(01 mark)$

(iii) Describe with the aid of a labelled diagram how atoms **A** and **D** combine to form a molecule. $(03 marks)$

(c) Explain;

(i) How atoms **D** and **E** can combine to form a compound. $(3\frac{1}{2} marks)$

(ii) Why the solid form of compound formed in (c)(i) does not conduct electricity whereas its aqueous form does. $(2\frac{1}{2} marks)$

14. (a)(i) Define the term electrolysis. $(01 mark)$

(ii) Give a reason why pure water does not conduct electricity whereas water containing a little dilute sulphuric acid does. $(1\frac{1}{2} marks)$

(b) Draw a labelled diagram of the set up of apparatus that can be used to show that during electrolysis anions move to the anode whereas cations move to the cathode. $(2\frac{1}{2} marks)$

(c) Explain with the aid of one suitable example in each case, how the selection of the ion to be discharged at the electrodes depends on the following factors;

(i) Position of metal or group in the electrochemical series. $(03 marks)$

(ii) Concentration of the solution. $(04 marks)$

(iii) Nature of the electrodes. $(03 marks)$

END

Set 9

SECTION A (50 MARKS)

*Answer **all** questions in this section*

1. (a)A pure sample of ammonium chloride can be separated from its mixture with sodium chloride by heating.

   (i) State what is observed during the heating $(01\ mark)$

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   (ii) What property of ammonium chloride makes its separation from the mixture possible? $(01\ mark)$

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   (b) Name **three** substances other than ammonium chloride which can be separated from its impurity using the method in (a) $(1\frac{1}{2}\ marks)$

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(c) Ammonium chloride was dissolved in water.

(i) State the effect of the solution formed on litmus paper. $(01\ mark)$

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(ii) State the method by which ammonium chloride crystals can be obtained from the solution. $(01 mark)$

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2. When dilute hydrochloric acid is added to zinc granules, oxidation and reduction simultaneously occur leading to the formation of hydrogen gas.

(a) State the type of reaction undergone by

(i) Zinc atoms;………………………………………..……… $(0\frac{1}{2}\ mark)$

(ii) Hydrogen ions from the acid;……………………………… $(0\frac{1}{2}\ mark)$

(b) Write equation for the reaction undergone by

(i) Zinc atoms. $(01\ mark)$

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(ii) Hydrogen ions; $(01 mark)$

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(c) Write the ionic equation for the overall reaction leading to the formation of hydrogen gas. $(1\frac{1}{2}\ marks)$

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3. (a) Oxygen gas can be prepared by heating nitrates. Complete the following equations;

   (i) $NaNO_3(s) \xrightarrow{heat}$ ……………………..……..……..…….$(1\frac{1}{2}\ marks)$

   (ii) $Pb(NO_3)_2(s) \xrightarrow{heat}$ ……………………….……………...$(1\frac{1}{2}\ marks)$

   (b) Potassium chlorate decomposes on heating to produce oxygen according the equation.

   $2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$

   Calculate the volume of oxygen produced at s.t.p when 12.25g of potassium chlorate are strongly heated.

   $(K = 39; Cl = 35.5; O = 16; 1\ mole\ of\ a\ gas\ occupies\ 22.4dm^3\ at\ s.t.p)$

   $(2\frac{1}{2}\ marks)$

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4. (a) Nitrogen under ordinary conditions does not under chemical reactions. State the reason for the chemical inactivity of nitrogen. $(1\frac{1}{2} marks)$

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(b) Red hot magnesium burns in a stream of nitrogen to form compound **Z**.

(i) Identify **Z**. $(01 mark)$

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(ii) Write equation for the reaction leading to the formation of **Z**.

$(01 mark)$

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(c) **Z** was dissolved in water. Write the equation for the reaction. $(1\frac{1}{2} marks)$

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5. (a) A compound **M** containing water of crystallisation has 20.1% iron, 11.5% sulphur, 23.0% oxygen and 45.3% water. Calculate the empirical formula of **M** $(Fe = 56; S = 32; O = 16; H = 1)$ $(2\frac{1}{2} marks)$

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(b) **M** was gently heated in a boiling tube.

(i) State what was observed. $(1\frac{1}{2}\, marks)$

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(ii) Write equation for the reaction that took place. $(1\frac{1}{2}\, marks)$

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6. Four atoms of elements are given as ${}^{35}_{17}M, {}^{39}_{19}N, {}^{19}_{9}X \text{ and } {}^{40}_{20}Y$

(the letters are not the actual symbols of the elements)

(a) Write down the electronic structure of;

(i) M……………………………………………………………... $(01 mark)$

(ii) N.......…………………………………………………………… $(01\ mark)$

(iii) Ion of Y ………………………………………...……. $(01\ mark)$

(b) State how the ion of X can be formed. $(01 mark)$

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(c) Which of the above atoms belong o the same group in the periodic table

$(01 mark)$

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7. A mixture of lead(II) oxide and anhydrous sodium carbonate was strongly heated with charcoal.

(a) (i) State what was observed. $(01 mark)$

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(ii) Write the equation for the reaction that took place when the mixture was strongly heated. $(1\frac{1}{2} marks)$

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(b) What was the role of anhydrous sodium carbonate in the experiment? $(01\ mark)$

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(c) Name one other substance that can be used instead of lead(II) oxide in the experiment. $(0\frac{1}{2} mark)$

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8. During a practical experiment, lead(II) nitrate solution was added to a solution **Y** of unknown composition. A white precipitate was observed.

(a) Identify the anions that were probably present in solution **Y**. $(02\ marks)$

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(b) Name **one** reagent that can be used to distinguish between the anions identified in (a) above. $(01\ mark)$

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(c) State what would be observed when solution **Y** is separately treated with the reagent named in (b) $(01 mark)$

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9. Chlorine gas can be prepared in the laboratory by oxidation of hydrochloric acid using manganese(IV) oxide.

   (a) (i) State the conditions for the reaction leading to the formation of chlorine gas. $(01 mark)$

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   (ii) Write the equation for the oxidation of hydrochloric acid. $(1\frac{1}{2} marks)$

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   (b) Name **one** other compound that can be used instead of manganese(IV) oxide to oxidise hydrochloric acid. $(01\ mark)$

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   (c) State how a pure dry sample of chlorine can be obtained in the laboratory when hydrochloric acid is oxidised by the compound named in (b) above. $(02 marks)$

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10. An organic compound **G** of formula C_2H_6O when heated with concentrated sulphuric acid gave gas **H** of formula C_2H_4.

(a) Name the classes of the compounds to which **G** and **H** belong;

(i) **G**.. $(0\frac{1}{2}\ mark)$

(ii) **H**.. $(0\frac{1}{2}\ mark)$

(b) Gas **H** was bubbled through liquid bromine in a test tube.

(i) State what was observed. $(01 mark)$

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(ii) Write the equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

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(c) Compound C_2H_6O can be prepared from glucose $C_6H_{12}O_6$

(i) Name the process by which glucose is converted to compound C_2H_6O

$(0\frac{1}{2}\ mark)$

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(ii) Write equation for the reaction leading to the formation of C_2H_6O from glucose. $(1\frac{1}{2}\ marks)$

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$\boldsymbol{SECTION\ B}$ $(\mathbf{30}\ \boldsymbol{MARKS})$

$Answer\ any\ \boldsymbol{two}\ questions\ from\ this\ section.$

11.(a) State the main differences between covalent and electrovalent compounds. $(01 mark)$

(b) Carbon forms hydrocarbons when it's covalently bonded to hydrogen atoms.

(i) What is meant by the term hydrocarbon? $(01 mark)$

(ii) Write the equation for the reaction between carbon and hydrogen $(1\frac{1}{2}\ marks)$

(iii) State whether the product formed in (ii) above is a saturated or un saturated hydrocarbon and give a reason for your answer. $(2\ marks)$

(c) When 8.20g of methane were burnt, 446.3kJ of heat were evolved. Calculate the heat of combustion of methane. $(C = 12; H = 1)$ $(2\frac{1}{2}\ marks)$

(d) Electrovalent compounds are soluble in water and usually exist as solids at room temperature. Explain why electrovalent compounds are;

(i) Solids at room temperature while covalent compounds are usually liquids or gases. $(02\ marks)$

(ii) Soluble in water and not in organic solvents. $(1\frac{1}{2}\ marks)$

(e) Using well labelled diagrams show how sodium chloride crystal is formed from sodium and chlorine atom by bonding. $(3\frac{1}{2}\ marks)$

12.(a) Describe how a dry sample of hydrogen chloride gas can be prepared in the laboratory. (Diagram not required). $(04 marks)$

(b) Explain the following observation;

A solution made by dissolving dry hydrogen chloride gas in methylbenzene did not evolve carbon dioxide from sodium carbonate while a solution of hydrogen chloride in water did evolve carbon dioxide. $(03 marks)$

(c) Draw a setup of apparatus that can be used to prepare iron(II) chloride in the laboratory. $(03\ marks)$

(d) Electrolysis of very dilute hydrochloric acid was carried out using carbon electrodes.

(i) State what was observed at the anode. $(01\ mark)$

(ii) Write the equation for the reaction that took place at the anode. $(1\frac{1}{2}\ marks)$

(e) The process of electrolysis of hydrochloric acid was repeated but this time using concentrated hydrochloric acid and carbon electrodes.

(i) Write the equation for the reaction at the anode. $(1\frac{1}{2}\ marks)$

(ii) Give a reason for your answer in (e)(i) above. $(01\ mark)$

13. (a) What is meant by the term rate of reaction? $(01\ mark)$

(b) The rate of decomposition of calcium carbonate chips by dilute hydrochloric acid can be followed by recording the loss in mass against time. Briefly explain the changes in the rate of decomposition that can be caused by;

(i) Grinding the calcium carbonate chips into powder. $(2\frac{1}{2}\ marks)$

(ii) Using the acid of higher concentration. $(2\frac{1}{2}\ marks)$

(c) Draw a diagram of the setup of apparatus that can be used to measure the rate of decomposition of calcium carbonate by dilute hydrochloric acid in the laboratory. $(03 marks)$

(d) An excess of dilute hydrochloric acid was added to 10.2g of calcium carbonate and left to react to completion until the reaction stopped.

(i) Write ionic equation for the reaction that took place. $(1\frac{1}{2}\,marks)$

(ii) Calculate the maximum volume of carbon dioxide that can be formed at s.t.p. $(1\frac{1}{2}\,marks)$

$(1\ mole\ of\ gas\ at\ s.t.p\ occupies\ 22.4dm^3; Ca = 40; C = 12; O = 16)$

(e) (i) Sketch a graph of volume of carbon dioxide in cm^3 against time in seconds that would be expected after complete decomposition of the calcium carbonate chips. $(02marks)$

(ii) Using the same axis, sketch another curve that would be expected if the experiment was repeated using powdered calcium carbonate. $(01\ mark)$

14. (a) Name and write the formula of two principal ores from which iron can be extracted. $(03marks)$

(b) Using equations outline the process of extraction of iron from one of the ores named in (a) above. $(08marks)$

(c) (i) Write equation to show how iron reacts with steam. $\left(1\frac{1}{2}\,marks\right)$

(ii) State how the gaseous product in (c)(i) above can be identified in the laboratory. $(01mark)$

(d) One of the uses of iron is to make alloys. Name one alloy of iron and state the other element with which iron is mixed. $(1\frac{1}{2}\,marks)$

END

Set 10

$\textbf{SECTION A (50 MARKS)}$

*Answer **all** questions in this section*

1. Air is a mixture consisting mainly of two gases **X** and **Y** in the ratio of 1:4 by volume respectively.

   (a) Name gas;

   a. **X**………………………………………………………….. $(01\ mark)$

   b. **Y**………………………………………………………….. $(01mark)$

   (b) (i) State a suitable method by which the mixture **X** and **Y** can be separately industrially. $(01\ mark)$

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   (ii). Give a reason for the choice of the method you have stated in (b) (i) $(01mark)$

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   (c) Name **one** process during which the concentration of **X** in the atmosphere can be increased. $(\frac{1}{2}\ mark)$

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   (d) State **one** industrial use of **Y**. $(\frac{1}{2}\ mark)$

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2. (a) State the difference between **hard water** and **soft water**. $(01\ mark)$

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(b) Name one substance that causes

(i) Temporary hardness of water. $(01\ mark)$

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(ii) Permanent hardness of water. $(01\ mark)$

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(c) State one method that can be used to remove.

(i) Temporary hardness in water. $(01 mark)$

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(ii) Permanent hardness in water. $(01\ mark)$

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3. The number of electrons, protons and neutrons in the atoms of elements **A, B**, **C, D** and **E** are shown in the table below.

Atoms	*Electrons*	*Protons*	*Neutrons*
A	8	8	8
B	13	13	14
C	16	16	16
D	**Y**	11	11
E	8	**Z**	10

(a) Determine the values of;

(i) **Y**……………………………………………………… $(\frac{1}{2}\ mark)$

(ii) **Z**……………………………………………………….. $(\frac{1}{2}\ mark)$

(b) State the mass number of atom **C**. $(\frac{1}{2}\, mark)$

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(c) Indicate which of the atoms

(i) Are isotopes. $(\frac{1}{2}\, mark)$

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(ii) Belong to the same group in the periodic Table. $(1\frac{1}{2}\, marks)$

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(d) Write the electronic configuration of

(i) Atom C. …………………………………………………… $(\frac{1}{2}\, mark)$

(ii) Ion A^{2-}…………………………………………………… $(\frac{1}{2}\, mark)$

(iii) Ion B^{3+}……………………………………………………$(\frac{1}{2}\, mark)$

4. An oxide **W** of formula mass 160 consists of 70.0% iron.

(a) (i) Calculate the empirical formula of **W**. $(2\frac{1}{2}\, marks)$

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(ii) Deduce the formula of **W**. $(1\frac{1}{2}\, marks)$

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(b) Write the chemical name of **W**. $(01 mark)$

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5. In the preparation of ammonia in the laboratory, a mixture of ammonium chloride and calcium hydroxide is heated. The gas evolved is passed into a tower packed with calcium oxide before it is collected using up ward delivery method.

(a) (i) Write an equation for the reaction that leads to the formation of ammonia. $(1\frac{1}{2}\ marks)$

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(ii) State why ammonia is passed into a tower packed with calcium oxide. $(0\frac{1}{2}\ mark)$

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(iii) Give a reason why ammonia is collected using upward delivery method. $(0\frac{1}{2}\ mark)$

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(b) (i) Name one reagent that can be used to identify ammonia. $(01\ mark)$

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(ii) State what would be observed if ammonia was treated with the reagent you have named in (b) (i) $(01 mark)$

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(c) Name the catalyst that is used in the oxidation of ammonia during the manufacture of nitric acid. $(\frac{1}{2}\ mark)$

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6. (a) Hydrogen chloride can be produced from potassium chloride.

   (i) Name another reagent that is used with potassium chloride to produce hydrogen chloride. $(\frac{1}{2}\ mark)$

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   (ii) Write an equation for the reaction leading to the formation of hydrogen chloride. $(1\frac{1}{2}\ marks)$

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   (b) Write an equation for the reaction between hydrogen chloride and

   (i) Silver nitrate solution. $(1\frac{1}{2}\ marks)$

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   (ii) Iron in the presence of water. $(1\frac{1}{2}\ marks)$

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7. Ethene is classified as an alkene and can be prepared in the laboratory by dehydration of ethanol.

   (a) (i) State what is meant by the term alkene. $(01\ mark)$

   (ii) Write the structural formula of ethene. $(01\ mark)$

(iii) Name the reagent which is used as a dehydrating agent in the preparation of ethene. $(01\ mark)$

(b) Bromine was added to ethene. Write equation for the reaction that took place. $(01\ mark)$

(c) Under high temperature and pressure, ethene molecules can react with one another to form a big molecule **Z**.

(i) Name **Z**.. $(\frac{1}{2}\ mark)$

(ii) State one use of **Z**... $(\frac{1}{2}\ mark)$

8. In the extraction of sodium from sodium chloride, calcium chloride is added to sodium chloride and the mixture is melted. The molten mixture is the electrolysed using graphite electrodes.

(a) State the purpose of adding calcium chloride. $(\frac{1}{2}\ mark)$

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

(i) Anode. $(1\frac{1}{2}\ marks)$

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(ii) Cathode. $(1\frac{1}{2}\ marks)$

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(c) Bromine vapour was passed over heated sodium. Write an equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

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9. (a) Hydrogen peroxide decomposes quite easily at room temperature.

(i) Write the equation for the decomposition of hydrogen peroxide.

$(01\ mark)$

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(ii) State two ways by which the decomposition can be made faster.

$(02\ marks)$

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(b) Using the space below, on the same axes, sketch graphs of concentration of hydrogen peroxide versus time for the decomposition of the peroxide at;

(i) Room temperature. $(01\ mark)$

(ii) **One** of the conditions you have stated in (a)(i). $(01\ mark)$

10. (a) State the conditions under which sulphuric acid can react with

(i) Sucrose, $C_{12}H_{22}O_{11}$ $(\frac{1}{2}\ mark)$

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(ii) Zinc oxide. $(\frac{1}{2}\ mark)$

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(b) Write the equation for the reaction of sulphuric acid with;

(i) Sucrose. $(1\frac{1}{2}\ marks)$

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(ii) Zinc oxide. $(1\frac{1}{2}\ marks)$

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(c) State the property of sulphuric acid which is shown by its reaction with;

(i) Sucrose. $(\frac{1}{2}\ mark)$

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(ii) Zinc oxide. $(\frac{1}{2}\ mark)$

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$\boldsymbol{SECTION\ B}: (\mathbf{30}\ \boldsymbol{MARKS})$

*Answer **two** questions from this section.*

*Additional question(s) answered will **not** be marked.*

11. (a) Describe how a pure sample of carbon dioxide can be prepared in the laboratory from the calcium carbonate and write the equation for the reaction that takes place. (*Diagram is not required*) $(07 marks)$

(b) Explain with the aid of equations the changes that take place when excess carbon dioxide is bubbled into sodium hydroxide solution. $(5\frac{1}{2}\ marks)$

(c) Potassium hydrogen carbonate decomposes when heated according to the following equation

$2KHCO_3(s) \longrightarrow K_2CO_3(s) + H_2O(l) + CO_2(g)$

Calculate the mass of carbon dioxide evolved when 8g of potassium hydrogen carbonate is heated strongly. $(H = 1; C = 12; O = 16; K = 39)$ $(2\frac{1}{2}\ marks)$

12. (a) One of the ores from which iron is extracted is spathic iron ore.

(i) Write the formula of the iron compound that is in the ore. $(01\ mark)$

(ii) Describe how impure iron is extracted from spathic iron ore

$(Your\ answer\ should\ include\ equations)$ $(07\ marks)$

(b) Write equation(s) where possible and state the condition(s) for the reaction of the iron with

(i) Water. $(04\ marks)$

(ii) Chlorine. $(2\frac{1}{2}\ marks)$

(c) State one use of iron. $(\frac{1}{2}\ mark)$

13. (a) The elements copper, zinc, and sulphur react with oxygen to form their oxides. Write the formula of the oxide of each of the elements and state the type of oxide whose formula you have written. $(03\ marks)$

(b) Hydrogen gas was passed separately over the heated oxides of copper and zinc.

(i) State what was observed in each case and explain your observation. $(04\ marks)$

(ii) Write equation for any reaction that took place. $(1\frac{1}{2}\ marks)$

(c) Excess dilute sodium hydroxide solution was added to a mixture of the oxides of zinc and copper. State what was observed and give a reason for your observation. $(2\frac{1}{2}\ marks)$

(d) A mixture of the oxides of zinc and copper was added to excess dilute sulphuric acid and warmed. State what was observed and write the equation(s) for the reaction(s) that took place. $(1\frac{1}{2}\ marks)$

14. (a) (i) Write the equation for the complete combustion of ethanol. $(01\ mark)$

(ii) Outline an experiment that can be carried out in the laboratory to determine the enthalpy of combustion of ethanol. $(6\frac{1}{2}\ marks)$

$(A\ diagram\ is\ not\ required, but\ your\ answer\ should\ include\ how\ the\ enthalpy\ of\ combustion\ of\ ethanol\ can\ be\ calculated\ from\ the\ experimental\ values)$

(b) When 0.15g of a compound **W**, molecular mass 60g was burnt, it caused the temperature of $150cm^3$ of water to rise by 8°C. Calculate the enthalpy of combustion of **W**. ($Density\ of\ water = 1.0gcm^{-3}, S.H.C\ of\ water = 4.2Jg^{-1}K^{-1}$). $(02\ marks)$

(c) The enthalpies of combustion $\Delta \boldsymbol{H_C}$ of some hydrocarbons are shown in the table below.

$Hydrogen$	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_6H_{14}
$\Delta \boldsymbol{H_C}$	890	1560	2220	2880	4160

(i) Plot a graph of enthalpy of combustion (vertical axis) against number of carbon atoms in the hydrocarbon (horizontal axis) $(03\ marks)$

(ii) State from the graph you have plotted in (c)(i), the enthalpy of combustion of C_5H_{12} . $(\frac{1}{2}\ mark)$

(iii) Determine the slope of the graph you have drawn. $(01 mark)$

(iv) Using your slope and intercept, calculate the enthalpy of combustion of hydrocarbon C_7H_{16} $(01\ mark)$

END

Set 11

$\boldsymbol{SECTION\ A}$ (**50** $\boldsymbol{MARKS}$)

*Answer **all** questions in this section*

1. When calcium turnings were added into water in a beaker, bubbles of a colourless gas, **X** and a cloudy solution formed.

(a) State the identity of;

(i) Gas **X**. $(0\frac{1}{2}\ mark)$

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(ii) The cloudy solution. $(0\frac{1}{2}\,marks)$

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(b) Write the equation for the reaction leading to the formation of gas **X**. $(1\frac{1}{2}\,marks)$

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(c) State ;

(i) How gas **X** could be identified in the laboratory. $(1\frac{1}{2}\,marks)$

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(ii) One laboratory use of the resultant solution in the beaker. $(01\,mark)$

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2. (a) State the principle on which each of the following methods of separating mixtures works.

   c. Chromatography. $(01\,mark)$

   d. Fractional crystallisation. $(01\,mark)$

(b) State what would be observed and give a reason for your observation, if a mixture of water and the following substances was shaken, then allowed to stand for some time.

(i) Ethanol.

- Observation. $(0\frac{1}{2}\,mark)$

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……………………………………………………………………………………………

- Reason. $(0\frac{1}{2}\,mark)$

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(ii) Edible oil.

- Observation. $(0\frac{1}{2}\,marks)$

………………………………………………………………………………………

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- Reason. $(0\frac{1}{2}\,marks)$

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(c) Name a piece of apparatus that can be used to separate components of the mixture in (b) (ii). $(01\,mark)$

………………………………………………………………………………………

3. Ethanol obtained from glucose can be converted to ethene as shown below.

$$C_6H_{12}O_6 \xrightarrow{STEP\ I} C_2H_5OH \xrightarrow{STEP\ II} C_2H_4$$

(a) Name the process that takes place in;

(i) Step I $(0\frac{1}{2}\,mark)$

………………………………………………………………………………………

(ii) Step II $(0\frac{1}{2}\,mark)$

………………………………………………………………………………………

(b) State ;

(i) One other product formed together with ethanol in step I. $(0\frac{1}{2}\,mark)$

………………………………………………………………………………………

(ii) The conditions for the conversion in step II. $(1\frac{1}{2}\,marks)$

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(c) Ethene can be converted to a polymer **J** of relative molecular mass 16,800.

(i) Write the structural formula of **J**. $(01\ mark)$

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(ii) Calculate the number of moles of ethene that make up **J**. $(01\ mark)$

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(iii) Give one disadvantages of continued use of **J**. $(0\frac{1}{2}\ mark)$

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4. (a) Name one crystalline and one amorphous allotrope of carbon and in each case state one use of the allotrope that you have named.

(i) Crystalline carbon allotrope. $(0\frac{1}{2}\ mark)$

……………………………………………………………………………………

Use:

……………………………………………………………………………………

(ii) Amorphous carbon allotrope. $(0\frac{1}{2}\ mark)$

……………………………………………………………………………………

Use:

……………………………………………………………………………………

(b) Write equation for the reaction to show

(i) Combustion of carbon monoxide. $(01\ mark)$

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(ii) Reduction of iron(II, III) oxide by carbon monoxide. $(1\frac{1}{2}\ marks)$

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(c) State one practical application of the reaction in (b) (ii) $\left(0\frac{1}{2}\ mark\right)$

…………………………………………………………………………………………

5. (a) 2.0g of ammonium nitrate was dissolved in $100cm^3$ of water; and the temperature of the water dropped from 25.0℃ to 21.0℃.

   Give a reason why there was a drop in the temperature of the water. $(01\ mark)$

   (b) Calculate the molar enthalpy of solution of ammonium nitrate. $(04\ marks)$

$(H = 1; N = 14; O = 16, density\ of\ water = 1gcm^{-3}\ S.H.C = 4.2Jg^{-1}K^{-1})$

6. (a)(i) Define the term electrolyte. $(01\ mark)$

   …………………………………………………………………………………………

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   (ii) Water in which a small amount of acid has been added is an electrolyte whereas pure water is a non-electrolyte. Give a reason for this observation. $(01\ mark)$

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   (b) Molten lead(II) bromide conducts electricity whereas solid lead(II) bromide does not. Explain briefly. $(02 marks)$

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(c) Name the particles by means of which electric current is conducted in;

(i) Carbon electrodes. $(0\frac{1}{2}\,mark)$

……………………………………………………………………………………

(ii) Molten lead(II) bromide. $(0\frac{1}{2}\,mark)$

……………………………………………………………………………………

7. Under suitable conditions, hydrogen peroxide solution, $H_2O_2(aq)$ can decompose rapidly to produce oxygen.

(a) (i) Write equation for the decomposition of hydrogen peroxide. $(1\frac{1}{2}\,marks)$

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(ii) State two ways in which the decomposition of hydrogen peroxide can be made to occur rapidly. $(01mark)$

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(b) Burning magnesium ribbon was lowered into a gas jar of oxygen.

(i) State what was observed. $(01\,mark)$

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(ii) Write an equation for the reaction that took place. $(1\frac{1}{2}\,marks)$

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8. The atomic numbers of elements **W**, chlorine and **Y** are 15, 17 and 20 respectively.

   (a) Write the electronic configuration of an atom of element

   a. **W**. $(0\frac{1}{2}\,mark)$

   ……………………………………………………………………………………

   b. **Y**. $(0\frac{1}{2}\,mark)$

   ……………………………………………………………………………………

   (b) State which one of the elements **W** or **Y** would form a chloride which is

   (i) A solid with high melting point. $(0\frac{1}{2}\,mark)$

   ……………………………………………………………………………………

   (ii) A volatile liquid at room temperature. $(0\frac{1}{2}\,mark)$

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   (c) Give reasons for your answer in (b) $(01mark)$

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   (e) State how a chloride ion in aqueous solution can be identified. $(1\frac{1}{2}\,marks)$

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9. (a) Anhydrous sodium carbonate was dissolved in water to form carbonic acid and sodium hydroxide as shown in the equation below;

   $Na_2CO_3(s) + H_2O(l) \quad 2NaOH(aq) + H_2CO_3(aq)$

   The solution turned red litmus blue. Give a reason. $(1\frac{1}{2}\,marks)$

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(b) Dilute sulphuric acid was added to sodium hydrogen carbonate solution.

(i) State what was observed. $(0\frac{1}{2}\,mark)$

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(ii) Write an ionic equation for the reaction that took place. $(1\frac{1}{2}\,marks)$

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(c)(i) Name one reagent that can be used to differentiate between aqueous sodium carbonate and aqueous sodium hydrogen carbonate. $(01mark)$

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(ii) State what would be observed if the reagent you have named in (c) (i) was treated separately with aqueous sodium carbonate and aqueous sodium hydrogen carbonate. $(01mark)$

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10. (a) Sulphur dioxide can be prepared by burning iron pyrites, FeS_2, in air according to the following equation.

$4FeS_2(s)\ +110_2(g) \qquad \longrightarrow 22Fe_2O_3(s) +\ 8SO_2(g)$

Calculate the volume of sulphur dioxide evolved at room temperature when 9.60g of iron pyrites is reacted with excess oxygen. $(2\frac{1}{2}\,marks)$

$(Fe = 56; S = 32; 1\ mole\ of\ a\ gas\ occupies\ 24dm^3\ at\ room\ temperature)$

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(b) During the manufacture of sulphuric acid by the contact process, sulphur dioxide is heated with oxygen in the presence of a catalyst.

i. Name the catalyst. $(01\ mark)$

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ii. Write the equation for the reaction between sulphur dioxide and oxygen.

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……………………………………………………………………………………

SECTION B (30 MARKS)

Answer any two questions from this section. Extra questions answered will not be marked.

11. (a) A pure dry sample of chlorine was prepared in a fume cupboard in the laboratory by adding concentrated hydrochloric acid from a tap funnel onto a solid **R**, in a flask and then heating the mixture. The gas evolved was passed through water, then through a liquid, **T**, before it was collected.

i. Identify **R**. $(01\ mark)$

ii. State why the preparation of chlorine was carried out in the fume cupboard. $(01\ mark)$

iii. Name **T** and state its role. $(01\ mark)$

iv. Give a reason why **T** was preferred for its role, which you have stated in (iii) $(01\ mark)$

v. Why was chlorine passed through water? $(\frac{1}{2}\ mark)$

vi. State, giving a reason, a method by which chlorine was collected.(1mk)

vii. Write the equation for the reaction, which led to the formation of chlorine. $(1\frac{1}{2}\ marks)$

(b) Chlorine was bubbled through saturated potassium iodide solution, which was containing tetrachloromethane and the mixture shaken, and left to stand for some time.

i. State what was observed. $(02\ marks)$

ii. Write the equation for the reaction that took place. $(1\frac{1}{2}\ marks)$

(c) When exposed to bright sunlight, chlorine water produces a colourless gas,

i. Name the gas. $(\frac{1}{2}\ mark)$

ii. Explain briefly how the gas was formed. $(2\frac{1}{2}\ marks)$

(d) (i) Write equation for the reaction that can take place between iron and chlorine. $(1\frac{1}{2}\ marks)$

(ii) Give a reason why the reaction in (d)(i) is regarded as oxidation.(1 mark)

12. A compound Q consists of 26.7% carbon, 2.2% hydrogen by mass and the rest being oxygen.

(a) Calculate the empirical formula of Q. $(3\frac{1}{2}\ marks)$

$(C = 12; H = 1; O = 16)$

(b) An aqueous solution of Q turns blue litmus paper red.

a. Suggest how the pH of a 2M aqueous solution of Q would compare with the pH value of a 2M hydrochloric acid. Give a reason for your suggestion. $(2\ marks)$

b. Predict how Q would react with magnesium powder. $(1\frac{1}{2}\ marks)$

c. Write an ionic equation for the reaction that you have predicted in (b)(ii) $(1\frac{1}{2}\ marks)$

(c) 100cm^3 of a solution containing 4.5g of Q per dm^3 of solution required exactly 0.12g of magnesium powder for complete reaction.

$(Mg = 24; 1\ mole\ of\ Q\ reacts\ with\ 1\ mole\ of\ magnesium.)$

Calculate the;

(i) Concentration of Q in moles per dm^3 $(03\ marks)$

(ii) The formula mass of Q. $(02\ marks)$

(d) Determine the molecular formula of Q. $(02\ marks)$

13. Under suitable conditions, iron can rust.

(a) State;

(i) What is meant by the term rusting? $(01\ mark)$

(ii) The condition(s) necessary for iron to rust. $(02\ marks)$

(b) (i) Draw labelled diagram(s) for the set up of an experiment which can be used to show that the condition(s) you have stated in (a)(ii), is/are necessary for iron to rust. $(05\ marks)$

(ii) State and explain observations that would be made if the experimental set up in the diagrams that you have drawn in (b)(i) was allowed to stand for some days. $(04\ marks)$

(c) (i) State two methods by which rusting can be prevented. $(02\ marks)$

(ii) Give one reason why rusting must be prevented. $(02\ marks)$

14. (a) Describe the effect of heat on the nitrates of copper, potassium and silver, illustrate your answers with equations. $(07\ marks)$

(b) Potassium nitrate can be used in the preparation of nitric acid.

(i) State the conditions and write equation for the reaction that leads to the formation of nitric acid. $(03\ marks)$

(ii) Draw a labelled diagram of the set up of apparatus used in the laboratory preparation of nitric acid. $(03\ marks)$

(c) Write equation for the reaction of nitric acid with sulphur. $(1\frac{1}{2}\ marks)$

(d) State one use of nitric acid. $(\frac{1}{2}\ mark)$

END

set 12

SECTION A

Attempt ALL questions in this section.

1. Some methods of separation of mixtures are given in the table below. Complete the table by naming a pair of substance which can be separated by the method given and the principle behind the methods. (5 marks)

	Method	Mixture	Principle
Eg	Separating tunnel	Water and paraffin	Immiscible liquids
(a)	Fractional distillation		
(b)	A magnet		
(c)	Filtration		
(d)	Sublimation		
(e)	Fractional crystallization		

2. (a) Graphite and lead(II) bromide are conductors of electricity.

Name the particles which are responsible for conducting electricity in. (1 mark)

(i) Graphite:___________________________

(ii) Lead(II) bromide:________________________________

(b)(i) Draw a labeled diagram of the set up of apparatus that can be used to electrolyze molten Lead(II) bromide. (2 marks)

(ii) State what is observed at the anode. (½ mark)

____

(iii) Write the equation for the observation in(II) above. (1 ½ marks)

____

3. (a) Excess Sodium hydroxide solution is added to a solution of a mixture of Copper(II) nitrate and Zinc Sulphate and the mixture filtrated.

State the colour of the (1 mark)

(i) Filtrate ____

(ii) Residue ____

(b) Write the ionic equation leading to the formation of the residue.

____(1 ½ marks)

(c) The residue was dried, transferred to a test tube and heated strongly

(i) State what is observed (1 mark)

____

(ii) Write the equation for the reaction when the residue was heated.

(1 ½ marks)

4. Ethene can be prepared in the laboratory using the set of apparatus shown in figure 1

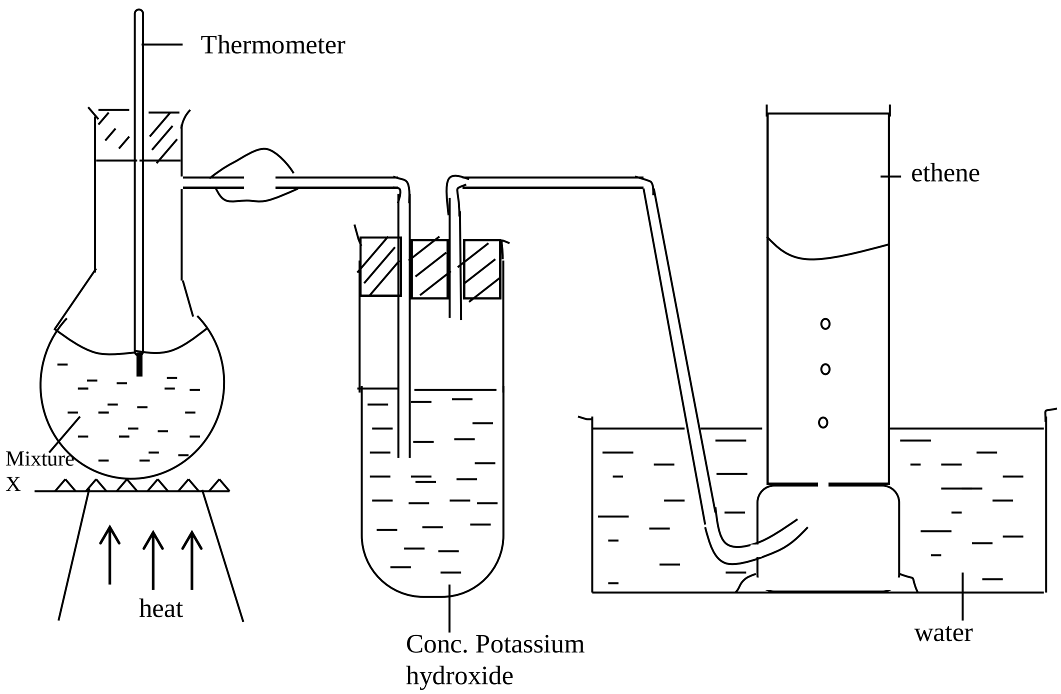

Fig. 1

(a) Name the mixture being heated (1 mark)

____

(b) Write the equation of reaction (1 mark)

____

(c) What is the function of the

(i) Concentrated Potassium hydroxide solution?

____(½ mark)

(ii) Thermometer

____(½ mark)

(d) Ethene was bubbled through a solution of acidified potassium permanganate

(i) State what is observed. (1 mark)

(ii) Name one other gas which shows similar behavior like ethane with potassium permanganate. (½ mark)

5. $20cm^3$ of dilute hydrochloric acid reacted completely with Zinc metal and $480cm^3$ of Hydrogen gas evolved at room temperature.

(a) Write the equation of reaction (1 ½ marks)

(b) Calculate:

(i) The mass of zinc the reacted (2 marks)

(ii) The concentration of the acid in moles per litre. (1 ½ marks)

____

6. The atomic members of elements P,Q and R are 2,9 and 20 respectively.

(a) State the

(i) Group number of P and Q (1 mark)

P = ________________

Q = ________________

(ii) The period of element R (½ mark)

____

(b) Element P is generally Nureactive

(i) Give a reason

____ (½ mark)

(ii) Name one other element in the periodic table which shows similar behavior like P (½ mark)

____

(c) The compound formed when Q combines with R conducts electricity.

(i) State the condition under which the compound conducts electricity. (½ mark)

____

(ii) Explain your answer in C(i) (2 marks)

____

____

____

____

7. (a) Define the term rusting (1 mark)

____

____

(b) Draw a well labeled diagram t show that rusting cannot take place in the absence of oxygen (1 mark)

(c) Two Iron rods X and Y were connected with a wire to magnesium and Lead metal respectively as shown in figure 2.

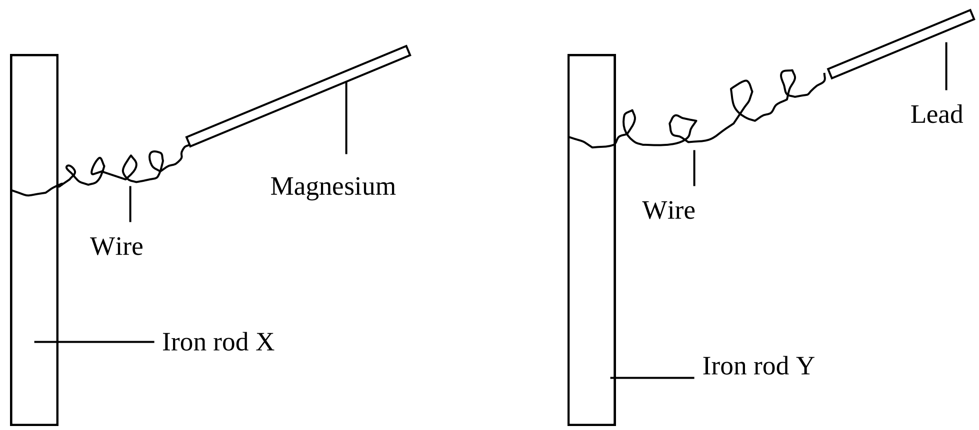

Figure 2

The Iron were left in the open for several months

State what would be observed on

(i) Iron rod X (1 ½ marks)

____

Explain your answer

____

____

(ii) Iron rod Y (1 ½ marks)

Explain your answer

8. To aqueous magnesium hydrogen carbonate was added the following:-

(a) Sodium carbonate solution

(i) State what was observed (½ mark)

(ii) Write the equation for the reaction that took place (1 ½ marks)

(b) Soap solution.

State what was observed (½ mark)

(c) Aqueous magnesium hydrogen carbonate was heated.

(i) Write the equation for the reaction that took place (1 ½ marks)

(ii) Soap solution was added to resultant mixture in (c)

State what was observed (½ mark)

9. (a) What is a hydrocarbon? (1 mark)

(b) A gaseous hydrocarbon, W contains 82.8% carbon. Calculate the empirical formular of the hydrocarbon W (2 marks)

(c) If 1.16gm of the hydrocarbon W occupied $0.448dm^3$ at s.t.p

(i) Calculate the molecular mass of hydrocarbon W. (1 ½ marks)

(ii) Determine the molecular formular of W (1 mark)

10. (a)(i) Define the term "alloy" (1 mark)

(ii) Give a reason why alloys are more useful than pure substances. (1 marks)

(b) State the composition of the following alloys

(i) Bronze (1 mark)

(ii) Solder (1 mark)

(c) State one use of

(i) Bronze (½ mark)

(ii) Solder (½ mark)

SECTION B(30 MARKS)

Attempt only two questions

11. (a) When Sulphur is extracted from the Sulphur beds, Super heated water is pumped down a shaft into the beds containing sulphur

(i) Name the process by which Sulphur is extracted. (½ mark)

(ii) What is meant by Sulphur heated water? (1 mark)

(iii) Why does the water have to be super heated? (1 mark)

(b) When the moltar Sulphur is pumped to the Sulphur, it Solidifies

(i) Name the allotrope of Sulphur which forms first (½ mark)

(ii) Give a reason for your answer in b(i) (1 mark)

(c) Write equations only to show how Sulphuric acid is obtained from Sulphur. (6 marks)

(d) Name the gas produced when each of the following substances is heated with concentrated sulphuric acid

(i) Sodium Chloride (½ mark)

(ii) Sodium Chloride and Managanese(IV) oxide (½ mark)

(iii) Copper (½ mark)

(e) Explain what is observed when burning magnesium is lowered into a gas jar Sulphur dioxide. (3 ½ marks)

12. Explain the following observations

(a) When Zinc powder is added to a solution of Copper(II) Sulphate, the colour of the solution terms from blue to colourless and the temperature of the solution rises.

(b) The pH of a solution of sodium carbonate is greater than 7 where as the pH of a solution of ammonium chloride is less than 7

(c) Moltar sodium chloride conduct electricity but sodium chloride crystals does not.

(d) Aqueous hydrogen chloride reacts with magnesium producing hydrogen gas where as a solution of hydrogen chloride is methyl benzene has no effect on magnesium.

(e) A mixture of Zinc oxide and Aluminium reacts when heated but there is no reaction when a mixture of Aluminium oxide and Zinc is heated.

13. (a) Explain how nitric acid can be prepared in the laboratory. (No diagram needed) (7 marks)

(b) Concentrated nitric acid is added to copper in a test tube.

(i) State what is observed (1 mark)

(ii) Write the equation for the reaction (1 ½ marks)

(c) Write equation to show the effect of heat on

(i) Potassium nitrate (1 ½ marks)

(ii) Silver nitrate (1 ½ marks)

(d) Lead(II) nitrate dedecompases when heated according to the equation.

$2Pb(No_3)_{2(s)} \longrightarrow 2PbO_{(s)} + 4NO_{2(g)} + O_{2(g)}$

Calculate the mass of Lead(II) nitrate to be heating to form 1.5 dm3 of nitrogen dioxide gas at s.t.p (mm of $Pb(NO_3)_2$ = 331gm) (2 ½ marks)

14. (a) (i) What is meant by the term sewage? (1 mark)

(ii)	Explain the role of bacteria is sewage treatment.	(2 marks)
(iii)	State two uses of sewage sludge	(2 marks)
(b)(i)	What is water treatment	(1 mark)
(ii)	Name four water pollutants	(4 marks)
(iii)	Mention three characteristics of a polluted water	(3 marks)
(c)	Describe a test for purity of water	(2 marks)