CALTEC ACADEMY MAKERERE

S 3 CHEMISTRY PACKAGE (SSALONGO'S WORK)

SULPHUR AND ITS COMPOUNDS

Sulphur s a non- metal with atomic number 16, position 16, group VI and period 3 in the periodic table.

Occurrence; Occurs naturally as free Sulphur underground, as hydrogen sulphide in petroleum and in ores of metals as metal sulphides.

Extraction of Sulphur

- Is carried out by the Frasch process
- A hole is dung in the underground to reach the Sulphur bed.
- A Sulphur pump, consisting of three concentric tubes /pipes is sunk into the hole up to the Sulphur bed.
- In the outer most pipe, super- heated water under pressure is forced down to the Sulphur bed to melt the Sulphur.
- Hot compressed air under pressure is sent down the Sulphur bed through the innermost pipe.
- This pushes the molten Sulphur and water up through the middle pipe.
- Sulphur is then collected and water is evaporated off.

Diagram of Sulphur pump showing how it is used to extract Sulphur. (research and draw)

Allotropes of Sulphur

Allotropes are different forms of the same element existing in the same physical state.

Sulphur has up to 5 allotropes

Crystalline allotropes	Non-crystalline
Rhombic Sulphur (alpha)	Amorphous Sulphur
Monoclinic Sulphur (beta)	Plastic Sulphur
	Colloidal Sulphur

The most important allotropes are Rhombic Sulphur and monoclinic Sulphur. Rhombic Sulphur is only stable below 96℃. Above this temperature, it slowly changes to monoclinic Sulphur. Monoclinic Sulphur is only exists above 96℃. 96℃ is called the transition temperature of Sulphur.

Structure of Rhombic Sulphur (research & draw)

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Structure of monoclinic Sulphur (research & draw)

LESSON 2

Differences between rhombic and monoclinic Sulphur

Rhombic Sulphur	Monoclinic Sulphur
• Stable below °C96 • Bright yellow • Density is 2.08 g/cm^3 • Crystals are octahedral in shape	• Stable above 96 • Pale yellow • Density is 1.98 g/cm^3 • Crystals are needle shaped

Uses of Sulphur

- Used in the vulcanization of rubber.
- Used in the manufacture of drugs, ointments and fungicides used for treatment of skin diseases
- Used in the manufacture of sulphuric acid in the contact process.
- Used in the manufacture of gun powder, matches, and fireworks.
- Used in the manufacture of calcium hydrogen sulphide, a bleaching agent for wood pulp.
- Used for making paper.

Physical properties of Sulphur

- It is yellow non-metal solid at room temperature.
- It is insoluble in water
- It is a poor conductor of heat and electricity
- It is soluble in in carbon disulphide.

Evidence to show that monoclinic and rhombic Sulphur are allotropes of Sulphur

¾ When equal amounts / same mass of monoclinic and rhombic Sulphur are separately burnt in air they produce the same volume of Sulphur dioxide gas obtained in each case.

LESSON 3

Preparation of rhombic Sulphur

- Powdered Sulphur is shaken with carbon disulphide in a test tube for some time in absence of any flame around.
- The contents are filtered into a dry beaker through a dry filter paper placed in a funnel.
- A filter paper is fastened over the mouth of the beaker and some pin holes are made through it.
- The setup is placed near a window for some time to allow carbon disulphide to evaporate off slowly. Crystals of rhombic Sulphur are formed after evaporation of carbon disulphide

Preparation of monoclinic Sulphur

- Place powdered Sulphur in a very large crucible. Heat it and stir it gradually while adding some
- Sulphur until the crucible is full of molten Sulphur in absence of flame.
- Allow Sulphur to cool .After some time, a solid crust begins to form on the surface.
- When the crust has formed make two holes at wide separation using a glass rod on it and pour out the molten Sulphur from inside which is not crystallized
- Remove the crust and observe needle shaped crystals of monoclinic Sulphur formed beneath the crust and throughout the inner surface of the crucible

Chemical properties of Sulphur

1) ***Reaction with metals*;** Sulphur combines directly with heated metals e.g. iron, copper, magnesium, zinc to form metal sulphides.

For example; if finely divided iron is mixed with Sulphur powder and the mixture heated, the two elements react vigorously; a red glow appears and a black/ dark grey solid of iron (II) sulphide is formed. Equation

$$Fe(s) + S(s) \xrightarrow{heat} FeS(s)$$
$$Cu(s) + S(s) \xrightarrow{heat} CuS(s)$$
$$Mg(s) + S(s) \xrightarrow{heat} MgS(s$$
$$Zn(s) + S(s) \xrightarrow{heat} ZnS(s)$$

Research qn:

State three ways that can be used to distinguish between the original mixture of iron powder and Sulphur powder and the substance formed after heating.

2) ***Reaction with oxygen/air***

Sulphur burns with a blue flame forming Sulphur dioxide gas (even in plentiful supply of oxygen)

$$S(s) + O_2(g) \xrightarrow{heat} SO_2(g)$$

3) ***Reaction with acids***

(a) With **concentrated sulphuric acid**, it oxidizes Sulphur to Sulphur dioxide and acid is

$$S\ s + 2H_2SO_4 \rightarrow 3SO_2 + 2H_2O$$

reduced to water.

(b) **With concentrated nitric acid**. When heated with Sulphur, reddish brown fumes of nitrogen dioxide gas are formed. Sulphur is oxidized to sulphuric acid.

$$S(s) + 6HNO_3(l) \rightarrow H_2SO_4(aq) + 6NO_2(g) + 2H_2O(l)$$

4) ***Reaction with hydrogen*;** when hydrogen gas is bubbled thorough molten Sulphur in a boiling tube. Hydrogen sulphide gas is given off.

$H_2(g) + S(l) \rightarrow H_2S(g)$

COMPOUNDS OF SULPHUR

1. Hydrogen sulphide gas

Laboratory preparation; It is prepared by reacting dilute hydrochloric acid or sulphuric acid with iron (II)
sulphide.

Set up of apparatus (A new Certificate chemistry by Holderness pg 425)

Procedure: Dilute hydrochloric acid is added to iron (II) sulphide in a flat bottom flask. The hydrogen sulphide produced is collected over warm water because it is more soluble in cold water. equationn $FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$

$S^{2-}(s) + 2H^+(aq) \rightarrow H_2S(g)$

Research: Describe how hydrogen sulphide can be prepared starting from Sulphur. Write an equation for the reaction of iron (II) sulphide and dilute sulphuric acid.

Physical properties of hydrogen sulphide gas

- It is colorless
- It is denser than air
- It has a characteristic smell of rotten egg
- It is fairly soluble in water and its solution in water is acidic i.e. turns blue litmus red.

Chemical properties of hydrogen sulphide gas

1) Reaction with oxygen (air). It burns in excess air to form sulphurdioxide and water.

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(l)$

In limited oxygen, yellow solid of Sulphur and water are formed.

$2H_2S\ g\ + O_2\ g\ \rightarrow 2S\ s\ + 2H_2O(l)$

2) Reaction concentrated sulphuric acid or concentrated nitric acid

$H_2S(g) + H_2SO_4(aq) \rightarrow 2S(s) + 2SO_2(g) + 2H_2O(l)$

$8HNO_3(aq) + H_2S(g) \rightarrow H_2SO_4(aq) + 8NO_2(g) + 4H_2O(l)$

3) Reaction with iron (III) chloride solution. Yellow colour of the solution changes to green due to formation f iron (II) chloride and yellow deposit of sulphur is formed.

$2FeCl_3(aq) + H_2S(g) \rightarrow 2FeCl_2(aq) + S(s) + 2HCl(aq)$

Note: In reaction 2 and 3, hydrogen sulphide behaves as a reducing agent.

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Testing for hydrogen sulphide gas in the laboratory

Reagent	Procedure	observation
Lead acetate solution or lead (II) nitrate solution	Filter paper soaked in lead acetate/lead (II) nitrate solution is dropped into a gas jar containing	The filter paper turns from white to black due to the formation of lead (II)

2. Sulphur dioxide (sulphur (IV) oxide)

Laboratory preparation; two main methods are used:

(i) From the reaction between copper metal and hot concentrated sulphuric acid

lab. set up of apparatus (research and draw)

$$Cu(s) + 2H_2SO_4(l) \rightarrow CuSO_4(aq) + SO_2(g) + 2H_2O(l)$$

Procedure

- Concentrated sulphuric is added to copper turnings in a round-bottom flask and the mixture is heated.
- Sulphur dioxide gas is produced according to the following equation:

$$Cu(s) + 2H_2SO_4(l) \rightarrow CuSO_4(aq) + SO_2(g) + 2H_2O(l)$$

- It is passed through concentrated sulphuric acid to dry it; and then collected by downward delivery because:
- it is denser than air.
- it is very soluble in water (hence even if it was not required dry, it would not be collected over water)

(ii) By reacting sodium sulphite with either concentrated sulphuric acid or concentrated hydrochloric acid

$$Na_2SO_3(s) + 2HCl(aq) \rightarrow NaCl(aq) + SO_2(g) + H_2O(l)$$
$$SO_3^{2-}(aq) + 2H^+(aq) \rightarrow SO_2(g) + H_2O(l)$$

Procedure

- Dilute sulphuric acid or hydrochloric acid is added to sodium sulphite crystals in a flat- bottom flask by means of a thistle funnel. It is then dried using concentrated sulphuric acid and collected by down ward delivery.

Qn. Write an equation for the reaction of sodium sulphite and dilute sulphuric acid.

Physical properties of sulphur dioxide gas

- It is a colourless gas.
- It has a chocking irritating smell.
- It is denser than air.
- It is soluble in water forming sulphurous acid.

$$SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq)$$

Sulphurdioxide is therefore an acid anhydride
(an oxide of a non-metal that reacts with water to form an acid)

Test for sulphur dioxide in the laboratory

Reagents	Procedure	Observation
Acidified potassium permanganate solution	Bubble sulphur dioxide gas through a solution of acidified potassium permanganate.	The purple colour of the solution changes to
Acidified potassium dichromate	Bubble sulphur dioxide gas through a solution of acidified potassium dichromate	The orange colour of the solution changes to green

Chemical properties of sulphur dioxide gas

1) **It is an acidic oxide**; it turns damp blue litmus paper red and forms sulphurous acid when dissolved in water. Due to it acidic property, it reacts with sodium hydroxide (which is a base) to form sodium sulphite (normal salt) if it is in limited supply i.e

$$2NaOH(aq) + SO_2(g) \rightarrow Na_2SO_3(aq) + H_2O(l)$$

or sodium hydrogen sulphite (acidic salt) if it is in plentiful supply.

$$Na_2SO_3(aq) + H_2O(l) + SO_2(g) \rightarrow 2NaHSO_3(aq)$$

2) **As a reducing agent;** In its reaction with acidified potassium permanganate or acidified potassium dichromate, it behaves as a reducing agent.

3) **As an oxidizing agent**.

- Sulphur dioxide oxidizes hydrogen sulphide to sulphur as it is reduced to water.

$$H_2S(g) + SO_2(g) \rightarrow H_2O(l) + 3S(s)$$

Therefore when the two gases are mixed, a yellow deposit of sulphur is observed.

- It oxidizes magnesium to magnesium oxide. A yellow solid of sulphur and white solid of magnesium oxide are formed.

$$2Mg(s) + SO_2(g) \rightarrow 2MgO(s) + S(s)$$

White Yellow

- When a piece of magnesium ribbon is added to a gas jar of Sulphur dioxide, the ribbon continue burning with a bright flame and a white ash and a yellow solid are formed;

Mg(s) + SO2(g) → MgO(s) + S

(magnesium displaces Sulphur from its oxide and continues burning in oxygen forming white magnesium oxide and brown Sulphur)

- **Bleaching action**. Sulphur dioxide gas acts as a bleaching agent (a substance that removes colour) when dissolved in water. This is shown by dropping a

moist blue/red flower into a gas jar of sulphur dioxide. The flower loses their colour (turn white).

At first, sulphur dioxide reacts with water to form sulphurous acid;

$$SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq)$$

Sulphurous acid takes up oxygen atom from the pigment of the flower and in the process, the blue flowers become white (bleached).

$$H_2SO_3(aq) + (colouring\ matter + O) \rightarrow H_2SO_4(aq) + colouring\ matter$$

Blue White

As a single equation:

$SO_2(g) + H_2O(l) + [Dye + O] \longrightarrow H_2SO_4(aq)$

$+ Dye$ OR $SO_2(g) + 2H_2O(l) + Dye \longrightarrow$

$H_2SO_4(aq) + [Dye + 2H]$

NB. Sulphurdioxide bleaches by reduction (removing oxygen from the dye).

Uses of sulphur dioxide gas

- Used in the contact process for the manufacture of sulphuric acid.
- Used to bleach wool, straw and sponges which are damaged by chlorine.
- Used as a bleaching agent in paper industry.
- Used for fumigation due to its poisonous nature

Sulphuric acid

This is a strong dibasic acid because it ionizes completely to produce many hydrogen ions.

$$H_2SO_4(aq) \rightleftharpoons 2H^+(aq) + SO_4^{2-}(aq)$$

Industrial manufacture of sulphuric acid

On a large scale, sulphuric acid is manufactured by the contact process from sulphur.

Procedure used:

Sulphur is burnt in air to form sulphur dioxide in a sulphur burner

$S(s) + O_2(g) \longrightarrow SO_2(g)$

The sulphur dioxide formed is purified and dried in a cleaning and drying chamber.

Sulphur dioxide is then mixed with excess air (oxygen) and the mixture passed over vanadium pentoxide (V_2O_5) /platinum catalyst heated to a moderate temperature of 400-500℃ and under a pressure of 200 atmospheres. The two gases react to form sulphur trioxide gas.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The sulphur trioxide formed is dissolved in concentrated sulphuric to form a fuming liquid called oleum.

$$SO_3(g) + 2H_2SO_4(aq) \rightarrow H_2S_2O_7(aq)$$

The oleum is carefully diluted with water to form ordinary concentrated sulphuric acid.

$$H_2S_2O_7(aq) + H_2O(l) \rightarrow 2H_2SO_4(aq)$$

Scheme of the production process showing the different stages involved (research)

Think: Explain why sulphur trioxide is first dissolved in concentrated sulphuric acid instead of water

Answer:

In water, sulphur trioxide dissolves violently to form sulphuric acid with evolution of a lot of heat. Acid sprays are formed which results into loss of the acid during production and damaging of manufacturing equipment. This problem is overcome by dissolving sulphur trioxide in concentrated sulphuric acid.

Uses of sulphuric acid

- Used in the manufacture of fertilizers e.g. ammonium sulphate.
- Used in the manufacture of detergents e.g. omo, nomi
- Used in the manufacture of paint and pigments of dyes.
- Used in the manufacture of man-made fibers for making clothes e.g. nylon.
- Used in car batteries or accumulators as electrolyte.
- Used in making explosives.
- Used as a drying agent.
- Used in extraction of some metals.

Properties of sulphuric acid

These are divided into three categories;

1. **As an acid**

(a) Sulphuric acid only behaves as an acid when dilute. This is because in the presence of water, it ionizes to form hydrogen ions. It turns blue litmus paper red

$$H_2SO_4(aq) \rightleftharpoons 2H^+(aq) + SO_4^{2-}(aq)$$

- When fully concentrated, it has no acid properties because there is not water for it to ionize and form hydrogen ions.
- When water is added to concentrated sulphuric acid, a lot of heat is produced which makes the reaction violent.

(b) It reacts with metals above hydrogen in the reactivity series to form hydrogen gas and a salt.eg

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

(c) It reacts with carbonates and hydrogen carbonates to form carbon dioxide, water and a salt. e.g

$$MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + CO_2(g) + H_2O(l)$$
$$Mg(HCO_3)_2(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + 2CO_2(g) + 2H_2O(l)$$

(d) It reacts with bases forming salts and water only (neutralization reaction).eg

$$Mg(OH)_2(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + 2H_2O(l)$$

2. As a dehydrating agent

Concentrated sulphuric acid has a very high affinity for water hence it can remove it from air (drying agent) and other compounds. e.g

(a) It removes water from **hydrated copper (II) sulphate**. The blue crystals turn white due to formation of anhydrous copper (II) sulphate.

$$CuSO_4.5H_2O(s) \xrightarrow{conc\ H_2SO_4} CuSO_4(s) + 5H_2O(l)$$

Blue White

(b) It removes water from sucrose ($C_{12}H_{22}O_{11}$) or glucose ($C_6H_{12}O_6$);

When concentrated sulphuric acid added to sugar crystals (sucrose) in a beaker, the sugar turns brown and finally turns to a black spongy mass of carbon. The black spongy solid swells and fills up the beaker. Steam and a lot of heat are also formed.

Finally, a black solid that swells and fills up the beaker is formed.

$$C_{12}H_{22}O_{11}(s) \xrightarrow{conc\ H_2SO_4} 12C(s) + 11H_2O(g)$$

$$C_6H_{12}O_6\ s \xrightarrow{conc\ H_2SO_4} 6C(s) + 6H_2O\quad (\ )(g)$$

(c) Sulphuric acid also dehydrates ethanol (C_2H_5OH) to form ethene gas

$$C_2H_5OH \xrightarrow{conc\ H_2SO_4/170-180℃} CH_2 = CH_2(g) + H_2O(l)$$

3. **Oxidizing properties**. It behaves as an oxidizing agent when concentrated. Hot concentrated sulphuric acid oxidises

(i) copper to copper (II) sulphate.

$$Cu(s) + +2H_2SO_4(l) \xrightarrow{heat} CuSO_4(aq) + SO_2(g) + 2H_2O(l)$$

(ii) carbon to carbondioxide

$$C(s) + 2H_2SO_4(aq) \xrightarrow{heat} CO_2(g) + SO_2(g) + 2H_2O(l)$$

(iii) Sulphur

$$S(s) + H_2SO_4(aq) \xrightarrow{heat} SO_2(g) + H_2O(l)$$

(iv) Hydrogen sulphide to sulphur

$$H_2S(g) + H_2SO_4(aq) \xrightarrow{heat} S(s) + SO_2(g) + 2H_2O(l)$$

Sulphates

1) **Solubility**. All are soluble in water except lead (II) sulphate, calcium (II) sulphate (sparingly soluble) and barium (II) sulphate.
2) **Action of heat**; Sulphates decompose on heating forming a metal oxide and sulphur trioxide gas except iron (II) sulphate and ammonium sulphate.

e.g

- **Zinc sulphate** decomposes to give yellow solid when hot and white when cold.

$$ZnSO_4(s) \xrightarrow{Heat} ZnO(s) + SO_3(g)$$

When blue crystals of hydrated copper (II) sulphate is heated gently, it turns to a white powder (anhydrous copper (ii) sulphate). On further heating, the white powder (anhydrous copper (ii) sulphate) decomposes to a black solid (copper (II) oxide) and white fumes of sulphur trioxide.

$$CuSO_4.5H_2O(s) \xrightarrow{Heat} CuSO_4(s) + 5H_2O(l)$$
$$CuSO_4(s) \xrightarrow{Heat} CuO(s) + SO_3(g)$$

Green crystals of hydrated iron (II) sulphate on gentle heating lose water of crystallization and turn white.

$$FeSO_4.7H_2O(s) \xrightarrow{Heat} FeSO_4(s) + 7H_2O(l)$$

On further (strong) heating, the white powder decomposes to reddish brown solid of iron (III) oxide, white fumes of sulphurtrioxide and sulphur dioxide gas.

$$2FeSO_4(s) \xrightarrow{Heat} Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

Testing for Sulphates and Sulphites

- Both sulphate ions and sulphite ions form white precipitates with;

(i) Barium nitrate/barium chloride solution followed with dilute nitric acid/hydrochloric acid.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$
$$Ba^{2+}(aq) + SO_3^{2-}(aq) \rightarrow BaSO_3(s)$$

However, barium sulphite dissolves in the acid with bubbles of a colourless gas to form a colourless solution

(ii) Lead (II) nitrate solution

Equations

$Pb^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow PbSO_4(s)$ $Pb^{2+}(aq) + SO_3^{2-}(aq) \longrightarrow PbSO_3(s)$

Therefore, Barium nitrate/barium chloride solution followed with dilute nitric acid/hydrochloric acid can be used to confirm the presence of sulphate ions.

O' level Chemistry
Sulphur and its compounds

1. (a) State what would be observed when the following are reacted.

(i) Potassium nitrate and concentrated sulphuric acid. (1/2 mark)

.....

(ii) Lead (II) nitrate and dilute sulphuric acid. (1/2 mark)

.....

(b) State the condition for the reaction in (a)(i). (1/2 mark)

.....

(c) Write equation for the reaction in

(i) (a) (i) (1 ½ marks)

.....

(ii) (a) (ii) (1 ½ marks)

.....

.....

P1/section A/ 2012

2. (a) State what would be observed when a mixture of iron filings and sulphur is warmed with

(i) carbon disulphide. ***(01 mark)***

(ii) dilute sulphuric acid. ***(02 marks)***

(b) A mixture of iron filings and sulphur was heated strongly.

(i) Name the substance that was formed. ***(½ mark)***

(ii) Write equation for the reaction between the substance you have named in (b) (i) and dilute hydrochloric acid. ***(1½ marks)***

P1/section A/ 2010

3. (a) Sodium chloride reacts with sulphuric acid to produce hydrogen chloride gas according to the followining equation:

$$NaCl(s) + H_2SO_4(aq) \rightarrow NaHSO_4(aq) + HCl\ (g)$$

(i) State the conditions for the reaction. ***(1½ marks)***

(ii) Calculate the volume of hydrogen chloride gas that would be produced at room temperature if 5.85 of sodium chloride was completely reacted with sulphuric acid. ***(02 marks)***

(b) Dry hydrogen chloride was passed over heated iron.

(i) State what was observed. ***(½ mark)***

(ii) Write equation for the reaction that took place. ***(1½ marks)***

P1/section A/ 2010

4. (a) (i) State the conditions under which sulphuric acid can react with sodium nitrate to form nitric acid.

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