Sulphur and its compounds

Sulphur

Sulphur occurs naturally in three forms:

1. Free form in Japan, Texas and Louisiana.

Extraction of sulphur

In order to extract this underground sulphur (the Frasch process), three concentric pipes are sunk deep into the ground as show in figure 1. Superheated water at 170^0C is forced down the outer pipe into the sulphur which is melted; compressed air is blown through the inner pipe forcing sulphur as a liquid to the surface, where it is allowed to solidify. Sulphur of about 99.5% purity is obtained by this process.

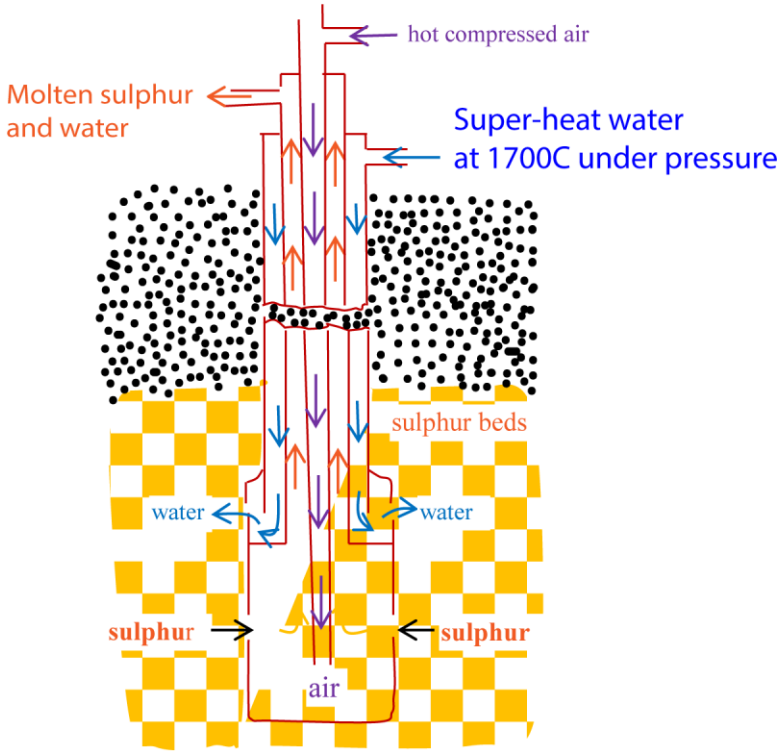


Fig.1. The Frasch process for extracting sulphur

2. In form of sulphides of zinc, lead, copper, iron, hydrogen and mercury.

   Sulphur dioxide is obtained as a by-product in the course of extraction of these metals. From hydrogen sulphide, sulphur can be obtained by first, burning hydrogen sulphide to form sulphur dioxide and this is then reacted with more hydrogen sulphide.

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

$$2H_2S\ (g) + SO_2\ (g) \longrightarrow 2H_2O\ (l) + 3S\ (s)$$

3. As metal sulphate, e.g., gypsum, $CaSO_4.2H_2O$, and epsom salt, $MgSO_4.7H_2O$.

The allotropy of sulphur

Sulphur exists in a number of allotropic varieties depending on the method of preparation and temperature (fig.2).

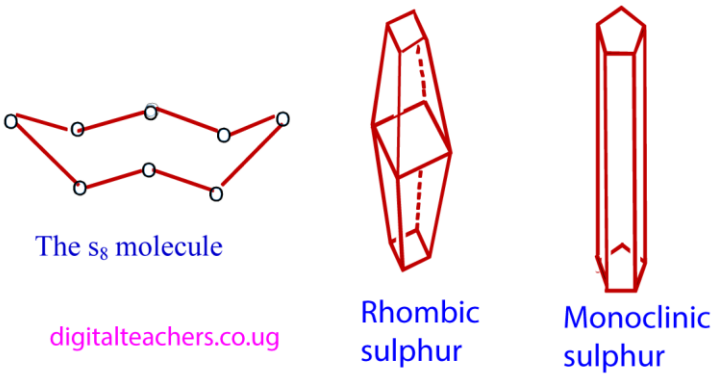


Fig 2. Shapes of allotropes of sulphur

The differences between Rhombic and monoclinic sulphur

Rhombic sulphur	Monoclinic sulphur
Stable below 96^0C	Stable below 96^0C
Octahedral crystals	Needle-shaped crystal
Bright yellow	Pale yellow
M.pt 113^0C	M.pt 119^0C
Density higher (2.06g/cm^3)	Density lower (1.98 g/cm^3)

Facts to prove that Rhombic and monoclinic sulphur are allotropes of sulphur

1. One gram of monoclinic slowly changes at room temperature into one gram of rhombic sulphur.
2. One gram of either form will burn in oxygen to yield the same mass (2g) of sulphur dioxide.

Uses of sulphur

1. Manufacture of sulphuric acid
2. For dusting wines to prevent the growth fungus
3. For vulcanization of rubber
4. For manufacture of dye,
5. Sulphur dioxide bleaches sugar

Chemical properties

1. Sulphur burns in air to form sulphur dioxide.
   $S(s) + O_2(g) \rightarrow SO_2(g)$

2. It combines with metals and nonmetal when heated to give sulphides.

   $Mg\ (s) + S\ (s) \rightarrow MgS\ (s)$

   $Fe\ (s) + S(s) \rightarrow FeS(s)$

   $S\ (s) + 3F_2\ (g) \rightarrow SF_6\ (g)$

   $2S\ (s) + Cl_2\ (g) \rightarrow S_2Cl_2\ (g)$

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

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

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

3. Sulphur is oxidized by concentrated nitric and sulphuric acid to sulphuric acid and sulphur dioxide respectively.

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

   $S\ (s) + 2H_2SO_4\ (l) \rightarrow 2H_2O\ (l) + 3SO_2\ (g)$

Compounds of sulphur

Hydrogen sulphide

It is a bad smelling covalently bonded gas.

Preparation

By reaction between metal sulphides with aqueous hydrochloric acid.

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

Or $FeS(s) + H_2SO_4(s) \rightarrow FeSO_4(aq) + H_2S\ (g)$

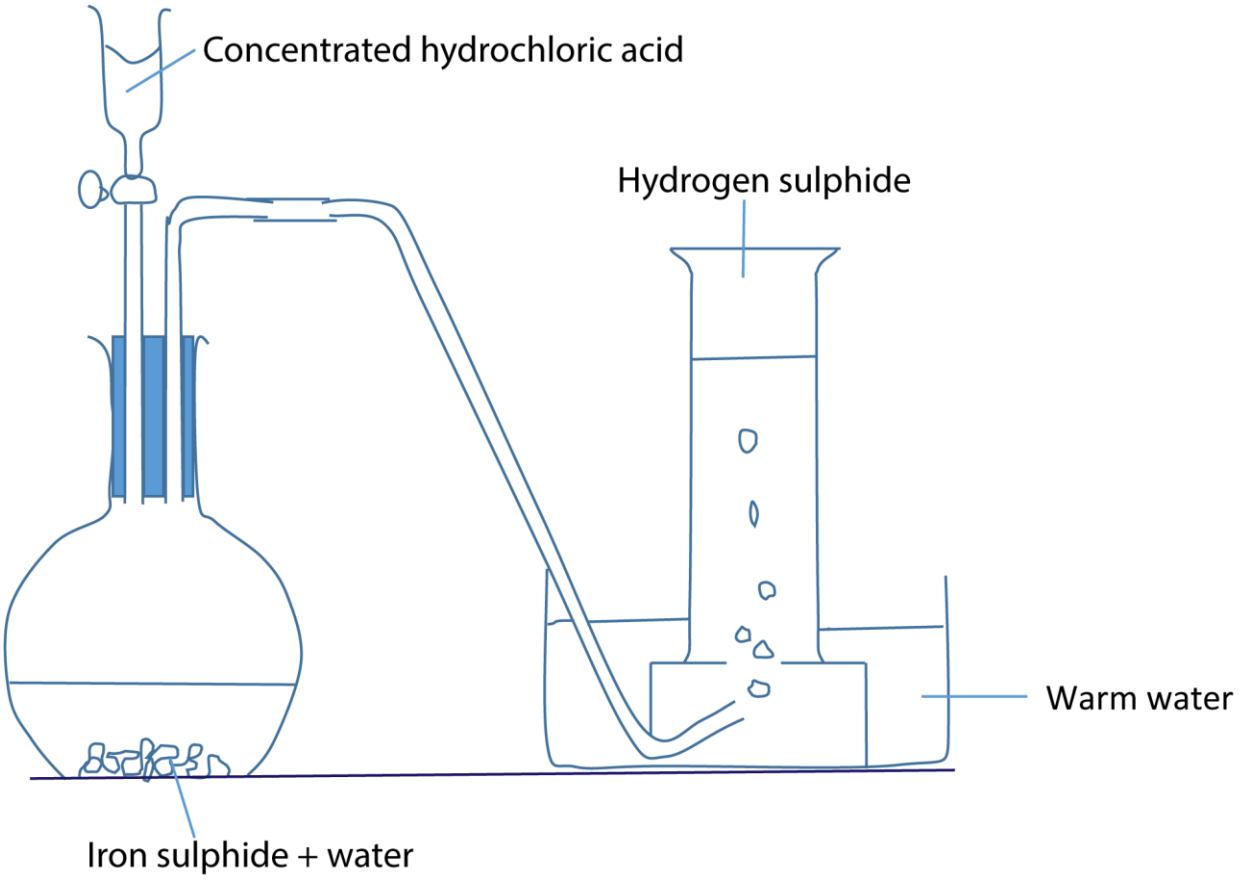


Fig. 3

Testing for hydrogen sulpide

Turns a strip of paper dipped in lead ethanoate solution brown or black

$Pb^{2+}(aq) + S^{2-}(aq) \longrightarrow PbS(s)$

Properties of hydrogen sulphide

- Has rotten egg smell

Sulphur dioxide, sulphur (IV) oxide

Preparation

By reacting copper with hot concentrated sulphuric acid

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

Or

By action of concentrated sulphuric or hydrochloric acid on sodium sulphite or hydrogen sulphite

$$Na_2SO_3\ (s) + H_2SO_4\ (aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + SO_2(g)$$

Setup of apparatus

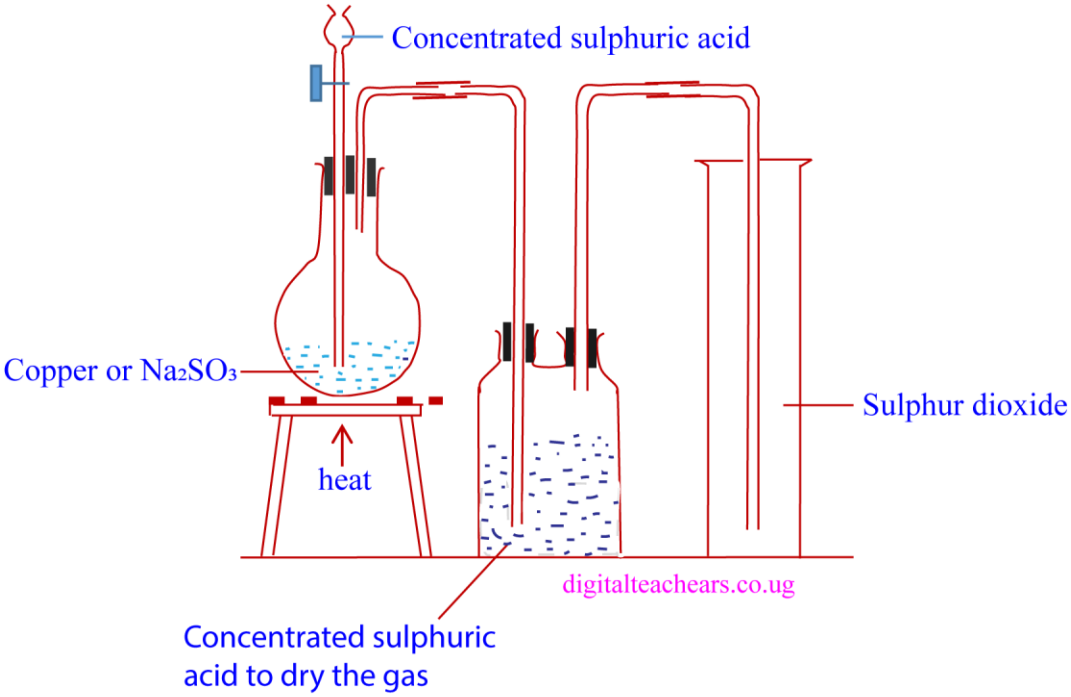


Fig.4

Testing for sulphur dioxide

1. It turns the color of acidified potassium dichromate from orange to green
2. Decolorizes acidified potassium permanganate

Uses

1. For the manufacture of sulphuric acid.
2. For bleaching silk, straw and sponges.
3. As a preservative for fruits, fruit juices and grains.

4. As an antichlor for removing chlorine from fabrics after bleaching.

5. For preparation of $NaHSO_3$ and $Ca(HSO_3)_2$.

6. For refining sugar and petroleum.

Sulphuric acid, H_2SO_4

Sulphuric acid is mainly manufactured by the contact process, in which sulphur dioxide is oxidised to sulphur trioxide, which is then reacted with water to give sulphuric acid.

$$2SO_2\,(g) + O_2\,(g) \leftrightarrow 2SO_3\,(g)$$

$$SO_3\,(g) + H_2O\,(l) \rightarrow H_2SO_4\,(l)$$

Sulphur dioxide is obtained by burning sulphur in air. Alternatively, it is obtained as a by product in the extraction of metals from sulphide ores.

$$2ZnS\,(s) + 3O_2\,(g) \rightarrow 2ZnO\,(s) + 2SO_2\,(g)\ \text{(During roasting)}$$

The contact process

In sulphur dioxide is reacted with oxygen in presence of Vanadium (V) oxide (catalyst) to form sulphur trioxide. The conversion of sulphur dioxide and oxygen into sulphur trioxide (sulphur (VI) oxide) is an exothermic reaction with a decrease in gas volume.

$$2SO_2\,(g) + O_2\,(g) \leftrightarrow 2SO_3\,(g) \quad \Delta H^{\theta}_{m}\,(298\ K) = -197.6\ kJ\ mol^{-1}.$$

Condition for production of sulphur trioxide

Temperature: 420^0C

Catalyst : vanadium (V) Oxide

Preparation of sulphuric acid from sulphur trioxide

Sulphur trioxide is dissolve in 98% sulphuric acid to form *oleum*.

$$H_2SO_4\,(aq) + SO_3\,(g) \leftrightarrow H_2S_2O_7\,(l)\ \text{(oleum)}$$

The oleum is later diluted with water to produce sulphuric acid.

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

Note that sulphur trioxide is not dissolved in water directly because this produces a lot of heat and corrosive fumes.

Physical properties of sulphuric acid

Pure sulphuric acid is a viscous liquid with a density of 1.85 $g\ cm^{-3}$ and a freezing point of 10.5^0C. In the absence of water, it does not turn litmus red nor does it react with metals to form hydrogen. It decomposes on boiling (b.pt. 270^0C) to form sulphur trioxide and water, and a constant boiling mixture (azeotrope) is formed, containing 98.3% of acid.

Its high viscosity and boiling point are due to strong intermolecular hydrogen bonding.

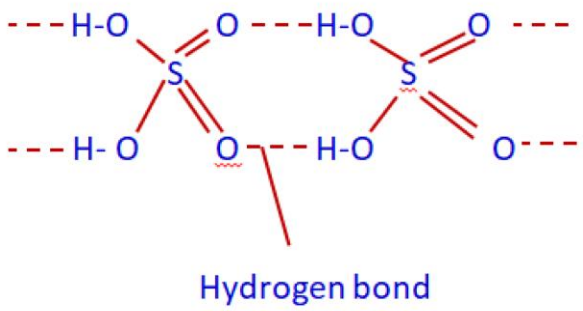


Fig. 5 Extensive intermolecular hydrogen bonds in sulphuric acid

Chemical properties

a) Acidity

Sulphuric acid ionises in water to form a strong dibasic acid.

$$H_2SO_4\ (l) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + HSO_4^-\ (aq)$$

$$HSO_4^-\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + SO_4^{2-}\ (aq)$$

It neutralizes bases to form hydrogen sulphate and sulphate. It displaces carbon dioxide from carbonates and reacts with strong electropositive metals to form salts and hydrogen.

$$H_2SO_4\ (l) + OH^-\ (aq) \rightarrow H_2O\ (l) + HSO_4^-\ (aq)$$

$$HSO_4^-\ (aq) + OH^-\ (aq) \rightarrow H_2O\ (l) + SO_4^{2-}\ (aq)$$

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

$$Ca\ (s) + 2H^+\ (aq) \rightarrow Ca^{2+}\ (aq) + H_2\ (g)$$

b) **As a dehydrating agent**

Concentrated sulphuric acid has such an affinity for water that is, it removes water from mixtures and compounds with evolution of much heat and because of this, **the acid should always be diluted by pouring it into water while stirring and not the other way round.**

The concentrated acid absorbs water vapour from moist air and other moist substances (i.e., it is hygroscopic). It is used as a drying agent for gases (except those that react with the acid) and in desiccators. When left exposed to air, it absorbs water and increases in volume

It dehydrates glucose and sugar to a black mass of carbon

$$C_6H_{12}O_6(s) \xrightarrow[-6H_2O]{\text{Conc. } H_2SO_4} 6C(s)$$

Fig. 6. A mass of carbon left when sugar is dehydrated with conc. sulphuric acid

It dehydrates ethanol to ethene

$$CH_3CH_2OH(s \xrightarrow[-6H_2O]{\text{Conc. } H_2SO_4} C_2H_4\ (g)$$

Being hygroscopic, it absorbs water from atmosphere and increases in volume.

(c) **Oxidizing properties.**

Hot sulphuric acid oxidizes hydrogen sulphide to sulphur.

$$3H_2S\ (g) + H_2SO_4\ (l) \rightarrow 4H_2O\ (l) + 4S\ (s)$$

It oxidizes carbon and sulphur to carbon dioxide and sulphur dioxide respectively

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

$$S\ (s) + 2H_2SO_4\ (l) \rightarrow 3SO_2\ (g) + 2H_2O\ (l)$$

It oxidizes copper to blue copper (II) sulphate.

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

$$Zn\ (s) + 2H_2SO_4\ (l) \rightarrow ZnSO4\ (aq) + SO_2\ (g) + 2H_2O\ (l)$$

(98% acid)

d) **Displacement reaction.**

Because sulphuric acid is a strong acid and not easily vaporized, it displaces other more volatile acids on warming with their salts.

$$NaNO_3\ (s) + H_2SO_4\ (l) \rightarrow NaHSO_4\ (aq) + HNO_3\ (g)$$

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

Exercise

Questions 1 -12 circle the correct alternative

1. Which one of the following substances is the raw material used in the manufacture of sulphuric acid in contact process?

   A. Sulphur

   B. Sulphur dioxide

   C. Sulphur trioxide

   D. Carbon dioxide

2. The reaction between magnesium and dilute sulphuric acid to produce hydrogen shows the property of sulphuric acid as

   A. Oxidizing agent

   B. A dehydrating agent

   C. A drying agent

   D. an acid

3. Which of the following substances is formed when excess sulphur dioxide is passed through sodium hydroxide solution?

   A. Sodium sulphate

   B. Sodium sulphite

   C. Sodium hydrogen sulphite

   D. Sodium hydrogen sulphate

4. Which one of the following compounds contains the highest percentage of sulphur?

   A. $H_2S_2O_7$

   B. H_2SO_4

   C. SO_2

   D. H_2S

5. When concentrated sulphuric acid is added to sugar, a black substance is produced. This is because sulphuric acid is

   A. A strong corrosive acid

   B. A strong dehydrating agent

C. A strong reducing agent

D. A strong oxidizing agent

6. Which one of the following catalyst is used in the manufacture of sulphuric acid by the contact process.

A. A. vanadium (V) oxide

B. Manganese (IV) oxide

C. Platinum

D Iron

7. Which one of the following is not true about concentrated sulphuric acid?
Concentrated sulphuric acid

A. Reacts with copper to liberate hydrogen

B. Reacts with glucose to form carbon

C. Reacts with ethanol to form ethene

D. Removes water from hydrated copper (ii) sulphate

8. During the manufacture of sulphuric acid, sulphur trioxide is dissolved in

A. Cold water

B. Hot water

C Dilute sulphuric acid

D. Concentrated sulphuric acid

9. Which of the following substances react with ammonium sulphate to form a white precipitate

A. Silver nitrate

B. Sodium hydroxide

C. Hydrochloric acid

D. Barium chloride

10 Solid w dissolved in concentrated sulphuric acid with effervescence of a colorless gas that fumes in most air. The anion in W is likely to be a

A. Nitrate

B. Chloride

C. Sulphate

D. carbonates

11. Concentrated sulphuric acid reacts with ethanol to form ethene. This shows that

A. The acid is oxidizing

B. Ethene can be converted to ethanol

C Ethene has high affinity for water

D. Acid is dehydrating agent

12. Which of the following is used for testing sulphur dioxide?

A. Chlorine water

B. Acidified potassium permanganate

C. Cobalt chloride

D. Anhydrous copper sulphate

Each of the questions 13 to 21 consist of an assertion (statement) on the left hand side and a reason on the right hand side.

Select

A. If both assertion and reason are true statements and the reason is a correct explanation of the assertion.
B. If both assertion and reason are true statements and the reason is **not** a correct explanation of the assertion
C. If the assertion is true but the reason is not correct statement.
D. If the assertion is not correct but the reason is a correct statement.

Instruction summarized

Assertion	
A. True	**True and a correct explanation**
B. True	**True but not a correct explanation**
C. True	**Incorrect**
D. Incorrect	**Correct**

13. When a known volume of concentrated sulphuric acid is exposed to air for a few days, there will be an increase in volume of sulphuric acid because Concentrated sulphuric acid is hygroscopic

14..	Nitric acid can be prepared by reacting any nitrate with sulphuric acid	Because	Sulphuric acid is a stronger acid
15.	Sulphuric acid changes sugar color from white to black	Because	Sulphuric acid is oxidizing agent
16.	During the manufacture of sulphuric acid sulphur dioxide is converted to sulphur trioxide in presence of vanadium (V) oxide	Because	Vanadium (V) oxide increases the rate of formation of sulphur trioxide
17.	Sulphur dioxide turns acidified potassium dichromate green	Because	It is a reducing agent
18.	Concentrated sulphuric acid is used as drying agent	Because	Sulphuric acid has high affinity for water
19.	Concentrated sulphuric acid is used to prepare hydrogen chloride from sodium chloride	Because	Sulphuric acid is stronger than hydrochloric acid.
19.	Monoclinic sulphur is only stable at a temperature below 96^0C	because	Its atoms are arranged in a layer structure
20.	In contact process, sulphur trioxide is dissolved in concentrated sulphuric acid instead of water	Because	Sulphur trioxide fumes in water giving out a lot of heat
21.	Sulphuric acid is a strong acid	because	Sulphuric acid is highly molecular

In each of the questions 22 to 26 one or more of the answers given may be correct. Read each questions carefully and then indicate the correct answer according to the following

A. **If 1, 2, 3, only are correct**
B. **If 1 and 3 only are correct**
C. **If 2 and 4 only are correct**
D. **If 4 only is correct**

22. Which of the following substances can be used to produce sulphur dioxide

1. Sulphur
2. Copper
3. Sodium Sulphate
4. Sodium Sulphite

23. In which of the following equation is sulphur dioxide (SO_2) behaving as a reducing agent?

1. $Cl_2(g) + 2H_2O(l) + SO_2(g) \rightarrow H_2SO_4(aq) + 2HCl(g)$
2. $2Mg(s) + SO_2(g) \rightarrow MgO(s) + S(s)$
3. $2HNO_3(l) + SO_2(s) \rightarrow H_2SO_4(aq) + 2NO_2(g)$
4. $2H_2S(g) + SO_2(s) \rightarrow 3S(s) + 2H_2O(l)$

24. When concentrate sulphuric acid is added to to sugar

1. Sugar turns black
2. Heat is evolved
3. Froathing is observed
4. Sulphur dioxideis evolved

25. Carbon is similar to sulphur in that both

1. Are not metallic solids
2. Exist in allotropic form
3. Form covalent compounds
4. Form neutral oxides

26. Which of the following substance(s) is/are commonly used to convert brown sugar to white sugar

1. Sulphur dioxide
2. Bleaching powder
3. Animal charcoal
4. Sodium hypochrite

27. (a) (i) With aid of a labeled diagram explain how pure sample of sulphur dioxide cab be prepared in the laboratory. (05marks)

(ii) Write equation leading to formation of sulphur dioxide (1½ marks)

(b) Name one reagent that would be used to confirm the presence of sulphur dioxide, and state what would be observed if the reagent you have named was treated with sulphur dioxide (02 marks)

(c) Write an equation to show the reaction between sulphur dioxide and

(i) Water (1 ½ marks)

(ii) Oxygen in the presence of hot platinum (1 ½ marks)

(d) The product of the reaction in (C) (ii) was mixed with water and barium nitrate solution added to the mixture

		(i)	State what is observed	(01mark)
		(ii)	Explain what took place (no equation required)	(2 ½ marks)
28.	(a)		State what would be observed when the following are reacted	
		(i)	Potassium nitrate and Concentrated sulphuric acid	(½ mark)
		(ii)	Lead (II) nitrate and dilute sulphuric acid	(1 ½ mark)
	(b)		State the condition for the reaction in (a)(i)	(½ mark)
	(c)		Write equation for the reaction in	
		(i)	(a)(i)	(1 ½ mark)
		(ii)	(a)(ii)	(1 ½ marks)
29.			State what would be observed and write equation for the reaction that would take palace if anhydrous iron (II) sulphate were heated?	(1 ½ marks)
30.	(a)		Describe briefly how copper sulphate crystals can be prepared from copper oxide	
	(b)		What would be observed if	
		(i)	Sodium hydroxide solution was gradually added to a solution of copper (II) sulphate until the alkali was in excess? Write the equation for the reaction that took place	
		(ii)	Hydrated copper crystals were heated strongly?	
31.	(a)	(i)	State the conditions under which sulphuric acid can react with sodium nitrate to form nitric acid	(1mark)
		(ii)	Write equation for the reaction in (a)(i) above	(1 ½ mark)
	(b)		Sulphur was warmed with concentrated nitric acid.	
		(i)	State what was observed	(1mark)
		(ii)	Write equation for the reaction	(1 ½ marks)
32.	(a)		sulphur dioxide can be prepared by roasting zinc sulphide in air according to the following equation $2ZnS(s) + 3O_2(g) \rightarrow 2SO_2(g) + 2Zn(s)$ Calculate the volume of sulphur dioxide evolved at room temperature when 9.7g of zinc sulphide is reacted with excess oxygen. (Zn = 65, S = 32; 1 mole of a gas occupies 24 dm^3 at room temperature and pressure)	
	(b)		During the manufacture of sulphuric acid by the contact process sulphur dioxide was heated with oxygen in the presence of a catalyst.	
		(i)	Name the catalyst	(1 mark)
		(ii)	write equation for the reaction between sulphur dioxide and oxygen	(1 ½ marks)
33.	(a)		Write an equation for the formation of sulphur dioxide from sulphuric acid and sodium sulphite	(1 ½ mark)
	(b)		Sulphur dioxide was bubbled through an acidified a solution of potassium dichromate.	
		(i)	State what was observed	(½ mark)
		(ii)	Explain your observation in (b)(i)	(01mark)
34.	(a)	(i)	Describe how a pure sample of iron (II) sulphate -7-water can be prepared in the laboratory.	(5 ½ marks)
		(ii)	Write equation for the reaction that took place	(1 ½ mark)
	(b)	(i)	State what would be observed when iron (II) sulphate-7-water was	(3marks)

heated strongly

(ii) Write equation for the reaction in (b)(i) (1 ½ mark)

(c) Sodium hydroxide solution was added dropwise to a solution of iron (II) sulphate until there was no observable change.

(i) State what was observed (1 ½ mark)

(ii) Give a reason for your observation in (c)(i) (½ mark)

(ii) Write an equation for the reaction (1 ½ mark)

35. (a) (i) Name one substance that is reacted with hydrochloric acid to produce sulphur dioxide in the in the laboratory (1mark)

(ii) State the conditions for the reaction (2marks)

(iii) Name the substance that can be used to dry sulphur dioxide formed (1mark)

(iv) Write equation for the reaction leading to the formation of sulphur dioxide (1 ½ mark)

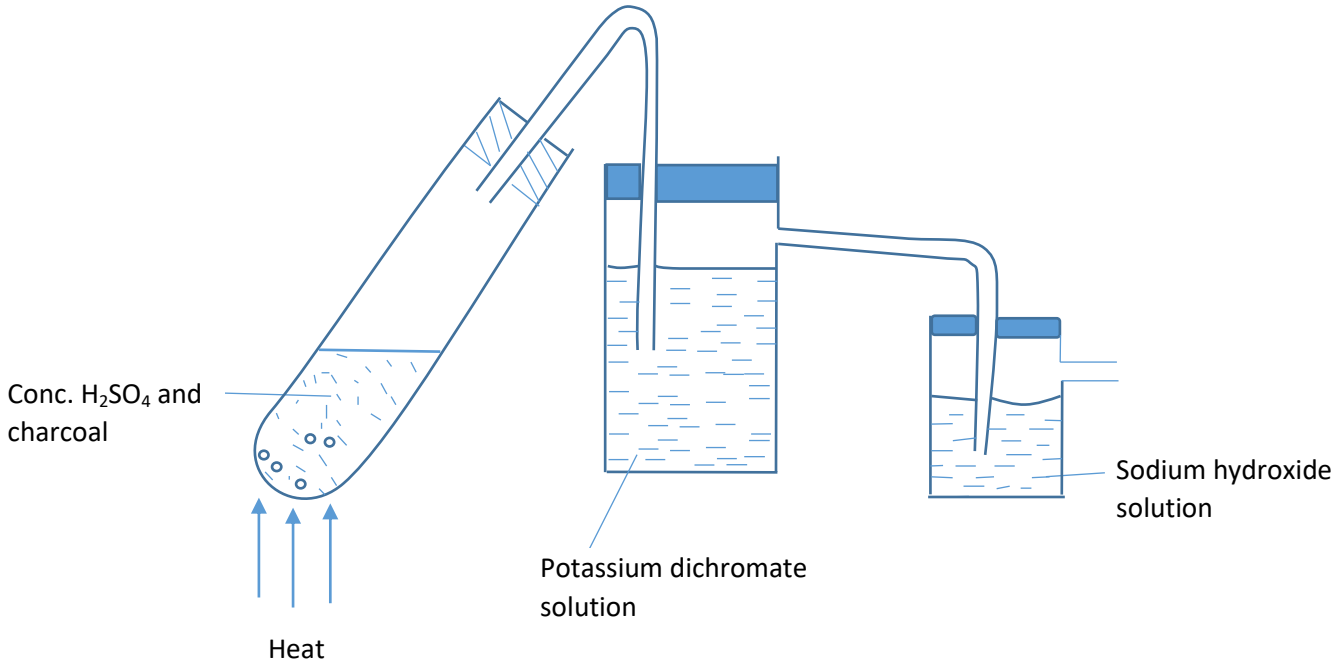
(b) State what would be observed and explain what would be observed when sulphur dioxide is passed through a solution containing

(i) Potassium dichromate

(ii) dye

(c) Briefly describe ow sulphur dioxide can be converted to sulphuric acid. Your description should contain conditions for the reaction and equations.

36. Concentrated sulphuric acid was heated with charcoal in the apparatus shown in figure below



(a) Name the gases produced during the reaction of concentrated sulphuric acid and charcoal (01 mark)

(b) (i) State what is observed in the tube containing potassium dichromate (01mark)
(ii) what is the purpose of sodium hydroxide? (01mark)

(c) State two uses of one of the gases in (a) (01mark) END

Answers

1.	B	6.	A	11.	D	16.	A	21.	B	26.	B
2.	D	7.	A	12.	B	17.	A	22.	C		
3.	C	8.	D	13.	A	18.	A	23	B		
4.	D	9.	D	14.	A	19.	A	24.	A		
5.	B	10.	B	15.	B	20	A	25.	A		

27. (a) (i) Sulphur dioxide is produced by action of concentrated sulphuric acid on sodium sulphite. (diagram on page 5 of these motes)

(ii) $Na_2SO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l) + SO_2(g)$

(b) (i) Reagent: acidified potassium dichromate

(ii) Orange solution turns green

(c) (i) $H_2O(l) + SO_2(g) \longrightarrow H_2SO_3(aq)$

(ii) $2SO_3(g) + O_2(g) \longrightarrow 2SO_3(g)$

(d) (i) White precipitate

(ii) White insoluble barium sulphate formed

28. (a) (i) Brown fumes

(ii) White precipitate

(b) Heat, the acid is concentrated

(c) (i) $KNO_3(s) + H_2SO_4(aq) \xrightarrow{heat} KHSO_4(aq) + HNO_3(g)$

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

29. Chocking fumes are given off that turn damp blue litmus paper red

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

30. (a)
- Excess copper oxide is dissolved in sulpuric acid

  $CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$
- Undissolved copper oxide filtered off
- The solution si concentrated by evaporation and left exposed on petri dishes to evapoate and form crystals

(b) (i) Ablue precipitate insoluble in excess

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

(ii) Blue crystals turn white

$CuSO_4.5H_2O(l) \longrightarrow CuSO_4(s) + 5H_2O(l)$

31. (a) (i) Heat

Acid is concentrated

(ii) $NaNO_3(s) + H_2SO_4(aq) \quad NaHSO_4(aq) + HNO_3(g) + 2H_2O(l)$

(b) (i) Brown fumes

(ii) $S(s) + 6HNO_3(aq) \longrightarrow H_2SO_4(aq) + 6NO_2(aq) + 3H_2O(l)$

32. (a) Rfm of ZnS = 65 + 32 = 97

1mole of ZnS produces 1mole of sulphur dioxide

97g of ZnS produces $24dm^3$ of sulphur dioxide

⇨ 9.7g of Zns will produce 2.4dm3 of sulpur dioxide

(b) (i) Vanadium (V) oxide, V2O5

(ii) $2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$

33. (a) $Na_2SO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l) + SO_2(g)$

(b) (i) Orange color of potassium dichromate turn green

(ii) Sulphur dioxide reduces potassium dichromate to green chromium (III) ions

34 (a) (i) Excess iron fillings are reacted with 20% sulphuric acid at about 80^0C (but solution must not be boiled).
The solution is filtered and evaparated at 80^0C to concntrate it to form crystals.

(b) (i)
- Water of crystallization is given off and condenses on cool part of the test tube.
- On strong heating chacking gase is given off leaving a brown solid

(ii) FeSO4.7H2O(s) FeSO4 (s) + 7H2O(l)
Then
$2FeSO_4 \xrightarrow{heat} Fe_2O_3(s) + SO_2(g) + SO_3(g)$

(c) (i) Green precipitate insoluble in excess turns brown on standing

(ii) Insoluble iron (II0 hydroxide formed is oxidized to iron (III) salts

(ii) $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$

35 (a) (i) Na2SO3

(ii) Heat, the acid is concentrated

(iii) Concentrated sulphuric acid

(iv) $SO_3^{2-}(aq) + 2OH^-(aq) \longrightarrow SO_2(g) + H_2O(l)$

(b) (i) Orange acidified potassium dichromate turns green because it is reduced by sulphur dioxide to green chromium (III) ions.

(ii) The dye declorise because sulphur dioxide is a reducing agent.

36 (a) Carbon dioxide and sulphur dioxide

(b) (i) Orange solution turns green

(ii) To absorb carbon monoxide

(c) Sulphur dioxide is used to breach linen
It breaches sugar
It is a raw material for sulphuric acid
It is a disinfectant
Carbon dioxide is used in soft drinks
It is used in fire extinguishers