Gases

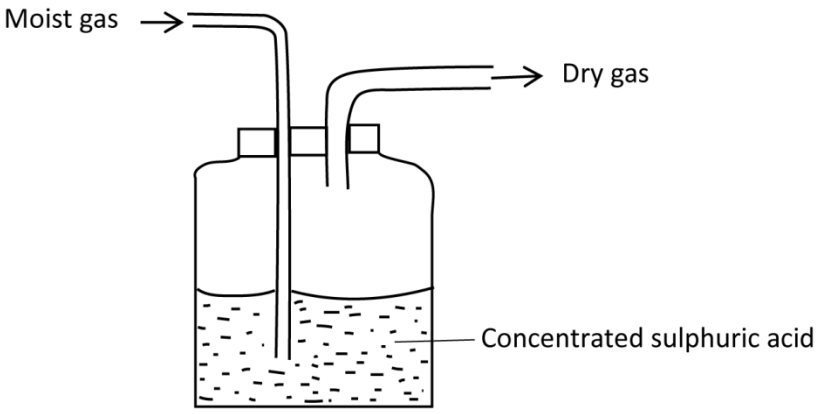
LABORATORY PREPARATION OF GASES

Four main stages involved when preparing a gas in the laboratory.

1. Production stage: here the reaction occurs in the reaction vessel to liberate a gas.
2. Purification stage; involves the removal any impurities from the gas.
3. Drying stage: it is often necessary to prepare dry gases.

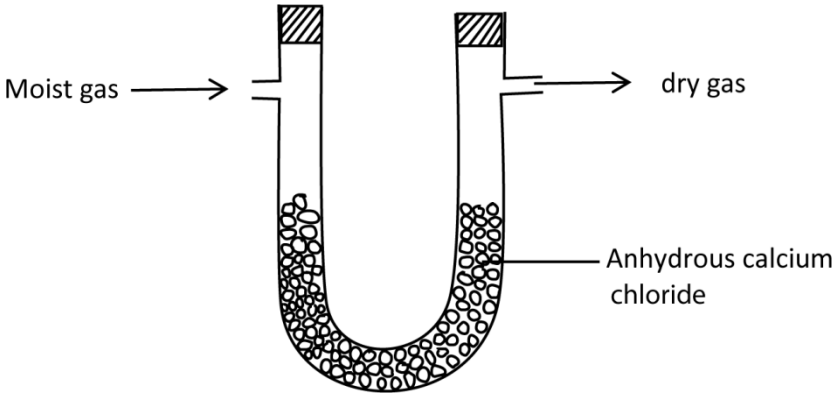
Common drying agents include:

i) Concentrated sulphuric acid (H_2SO_4).



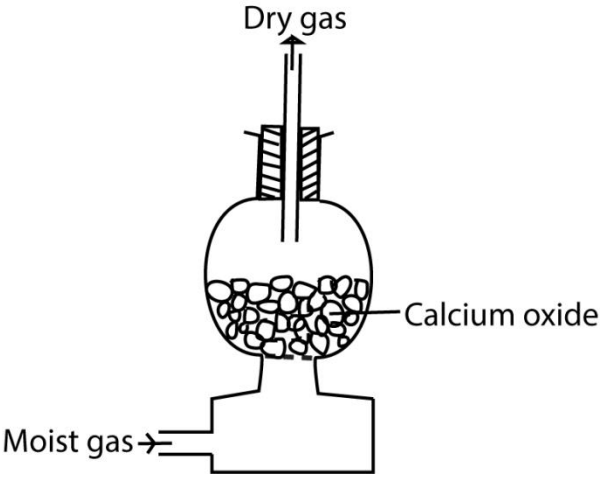
N.B: concentrated sulphuric acid is not used to dry ammonia because ammonia (NH_3) is basic can react with the acid.

ii) Anhydrous calcium chloride ($CaCl_2$).



N.B: anhydrous calcium chloride is suitable for drying most gases except ammonia which react with it.

iii) Quicklime (calcium oxide)



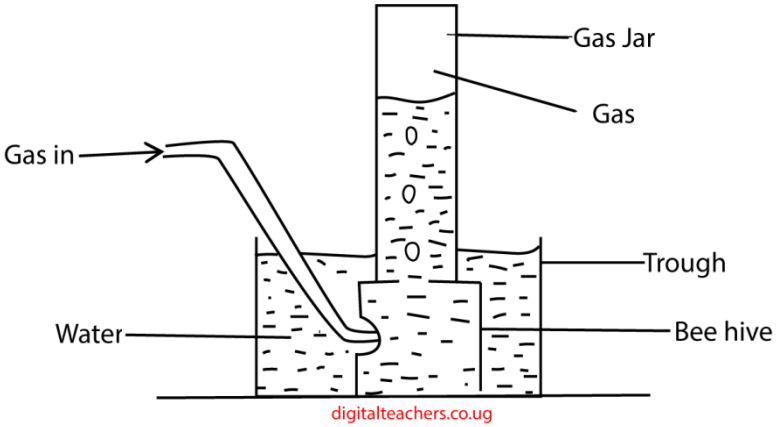
N.B: Calcium oxide (CaO) is usually used to dry ammonia (NH_3)

Dried gases must not be collected over water.

4. **Collection stage**: the method of collection depends on:
   - Density of the gas in comparison to air.
   - Solubility of the gas in water.

<u>Main methods of collecting gases</u>;

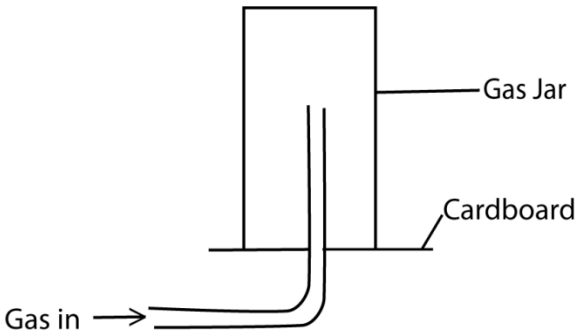
a) Over water



The gas displaces the water from the gas jar. This method is known as **down ward displacement of water.**

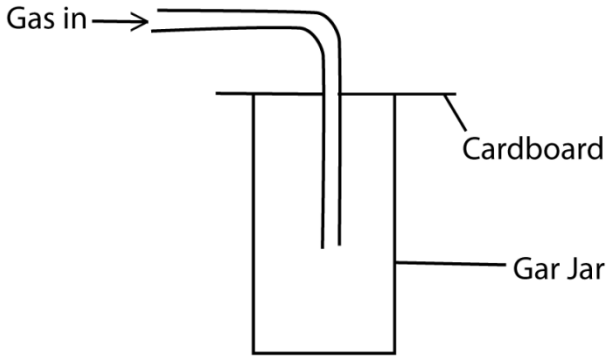
N.B: the method is used only if the gas is insoluble in water (such as hydrogen and oxygen and if not required to be dry.

(b) Upward delivery or downward displacement of air.



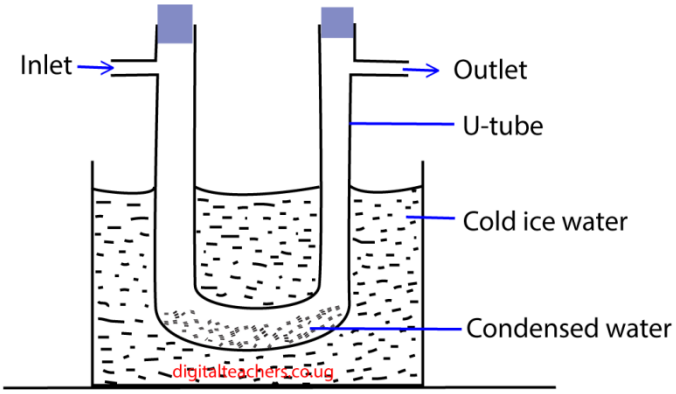
Ammonia gas and dry hydrogen are collected by the above method since they are less dense than air and ammonia is soluble in water.

(a) Downward delivery or upward displacement of air



Carbon dioxide (CO_2), sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), chlorine and hydrogen chloride (HCl) are collected by this method because they are denser than air and are soluble in water.

(b) By liquefaction and freezing



Nitrogen dioxide (NO_2) can be prepared in liquid state by using cool method.

HYDROGEN

Industrial preparation

By electrolysis of dilute sulphuric acid or acidified water using platinum electrodes. Hydrogen gas is liberated at the cathode and oxygen at the anode

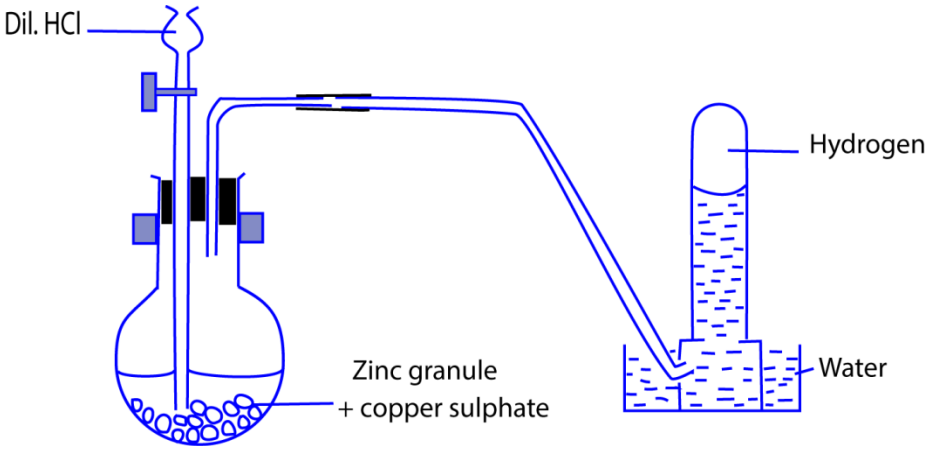
Reaction at the cathode

$2H^+(aq) + 2e \rightarrow H_2(g)$

Reaction at the anode

$4OH^-(aq) - 4e \rightarrow 2H_2O(l) + O_2(g)$

Laboratory preparation of hydrogen



METHOD

(i) Put some zinc granules in the conical flask. Carefully (do not drop), then fix a cork carrying a thistle funnel, and a delivery tube.

(ii) Arrange the apparatus pour some copper sulphate through the funnel, followed with hydrochloric acid and let it get in contact with the zinc.

(iii) Collect the gas

Test for the gas;

Method: Insert a burning splint into a jar full of hydrogen.

Observation: a pop sound

List three properties of the gas.

(i) Colourless
(ii) Odourless
(iii) Insoluble in water
(iv) Hydrogen is a reducing agent
- It reduces black oxide to copper to brown metal
  $CuO(s) + H_2(gas) \rightarrow Cu(s) + H_2O(l)$
- It reduces yellow lead II oxide to grey metal
- $PbO(s) + H_2(gas) \rightarrow Pb(s) + H_2O(l)$

Uses of hydrogen

(i) Used as rocket fuel
(ii) In nuclear reactors to generate energy
(iii) To harden vegetable oils

OXYGEN

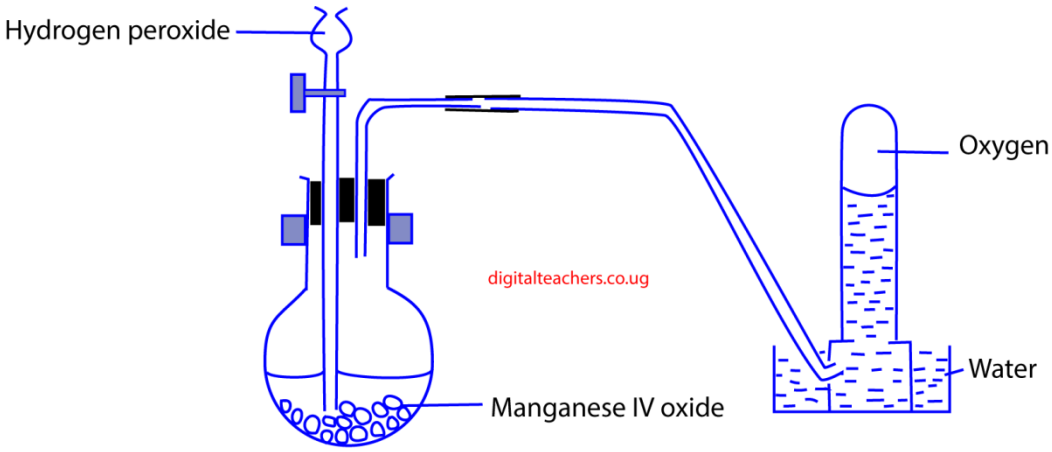
Oxygen is one of the most important gas found in air. It is used for many purposes e.g. breathing, rusting and burning.

Industrial preparation

By distillation of air of liquid air.
Air is passed through concentrated sodium hydroxide to remove carbon dioxide and then through silicon dioxide to remove the water vapour. The remaining air is rich in nitrogen and oxygen is compressed to about 200 atmospheres and cooled to a pale-blue liquid. The liquid air is fractionally distilled, nitrogen (b.pt. -196^oC) boils off first and blue liquid oxygen (b.pt. -183^oC) remain.

Laboratory preparation

By decomposition of hydrogen peroxide in presence of manganese (IV) oxide (MnO_2) as a catalyst.



Equation

$2H_2O_{2\,(aq)} \rightarrow 2H_2O\,(aq) + O_2\,(g)$

Test for the gas given off

Oxygen relight a glowing splint.

CATALYST

Is a substance that speeds up or alters a chemical reaction but it remains unchanged at the end of the reaction.

EXPERIMENT: To investigate the effect of a catalyst on the production of oxygen

You are provided with three test tube labelled A, B, C; to test tube

A put hydrogen peroxide
B put manganese dioxide
C put both manganese dioxide first followed with hydrogen peroxide

Allow the experiment to stand for 10 minutes.
Insert a glowing split in test tube A, B C respectively
Record your observation and conclusion.

Observation: in **A** oxygen was given off after a long period. The glowing splint kept on glowing.

In **B** no oxygen was given off.

In **C** oxygen was given off after a short time. The glowing splint busted into a flame

Conclusion: the manganese dioxide speeds up the production of oxygen from hydrogen peroxide.

Properties of oxygen
- Colourless gas
- Neutral to litmus
- Odourless gas
- Slightly soluble in water

Used of oxygen
- Breathing
- Burning
- Rusting

ACTION OF OXYGEN WITH METALS & NON – METAL:

Oxygen combine vigorously with many metals and non-metals forming basic and Acidic oxides respectively.

- METALS + OXYGEN → METALLIC OXIDES

Most of the oxides are basic in character (basic oxide react with acids to form salts if they are soluble, they form solutions that Red litmus blue

- NON – METAL + OXYGEN → NON – METALLIC OXIDE

Most of the oxides are acidic in character and turn blue litmus red.

EXPERIMENT: To investigate the action of heat on:

(a) Metals
(b) Non-metals

You are provided with metals and non-metals, burn sodium metal in air and dissolve the oxide in water and test the resultant mixture with litmus paper both blue and red. (Do this with sodium for metals and sulphur for non-metals).

Write your observation and conclusion. Continue burning the other metals

1. **Sodium (Na)**
   Burns with a bright yellow flame and form a yellowish solid
   $2Na_{(s)} + O_{2(g)} \rightarrow Na_2O_{2(s)}$
   $Na_2O_{2(s)} + H_2O(l) \rightarrow 2NaOH(aq) + O_{2(g)}$

2. **Calcium (Ca):** Burns with a bright red flame and form a white solid

$2Ca(s) + O_2(g)$ heat $2CaO_{(s)}$
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$

3. **Zinc:** On burning it decomposes to a yellow solid when hot and turns white on cooling.
$2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$

4. **Lead:** Melts and then forms yellow oxides when hot and yellow when cold
$2Pb(s) + O_2(g) \rightarrow 2PbO(s)$

5. **Magnesium:** burns in oxygen with a very bright light and forms a light white ash.
$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
$Mg(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$

6. **Copper:** burns with a green flame
$2Cu_{(s)} + O_{2(g)} \rightarrow 2CuO_{(s)}$

7. **Iron filings** (or wire): burn with a shower of bright sparks and forms a blue-black solid insoluble in water
$3Fe(s) + 2O_2(g) \rightarrow Fe_3O_4(s)$

NON-METALS

Burn sulphur in air and dissolve the gas in water test the resultant mixture with both red and blue litmus papers.
Write your observations and conclusion

1. **Sulphur:** Burns with a bright blue flame and forms cloudy fumes with a chocking smell
$S_{(s)} + O_{2(g)} \rightarrow SO_2(g)$
$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$

2. **Carbon:** burns with an orange flame and makes bright sparks

$C(s) + O_2(g) \rightarrow CO_2(g)$
$CO_2(g) + H_2O_{(l)} \rightarrow H_2CO_3(aq)$

TYPES OF OXIDES

- **Basic oxide:** is a metallic oxide, which react with acid to produce a salt and water only. When dissolved in waters, it forms an alkaline solution
i.e. $CaO_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_2(aq) + H_2O_{(l)}$
(salt) water

$CaO(s) + H_2O \rightarrow Ca(OH)_2$
Alkaline

- **An acidic oxide:** is a non-metallic oxide when combined with element of water produces an acid
  $SO_2(g) + H_2O_{(l)} \rightarrow H_2SO_3(aq)$

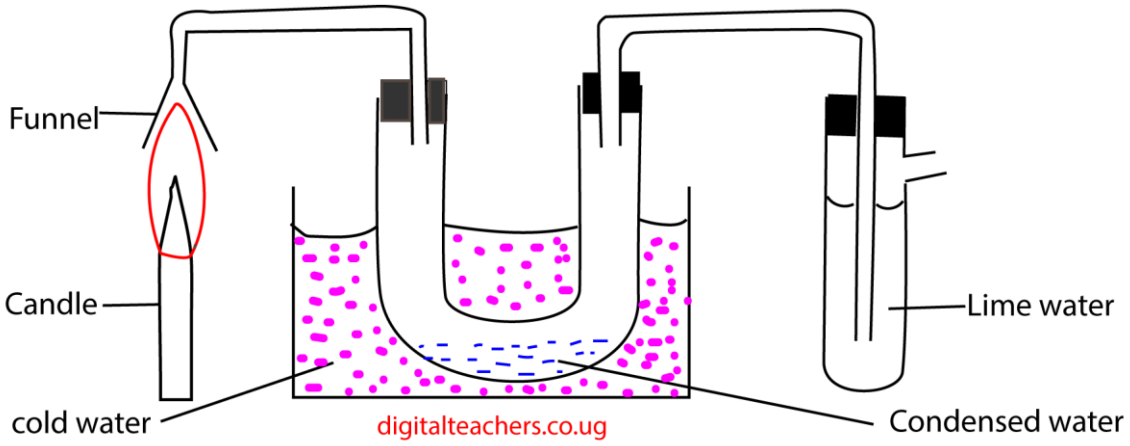
- **Amphoteric oxide:** is metallic oxide, which can show both basic and acidic properties. (it reacts with both acids and bases to produce water only and a salt e.g. ZnO, Al_2O_3, PbO

- **Neutral oxide:** - is an oxide which shows neither basic nor acidic character e.g. H_2O, CO

PRODUCTS FORMED WHEN A CANDLE BURNS IN OXYGEN

Candle wax is a mixture of hydrocarbons, which are compounds of hydrogen and carbon.

- To find the product formed light the candle, place it under the funnel and use a pump to suck the hot gases through lime water(calcium hydroxide solution) to absorb carbon dioxide. Arrange the apparatus as shown below. Allow the experiment to stand for 5 minutes, put out the candle.



Observations
The vapour condenses in the U-tube and lime water turns milky. When a drop of the condensed vapour is added to anhydrous copper sulphate. It turns from white power to blue crystals OR when the drop is added to anhydrous cobalt chloride, it changes from blue to pink.

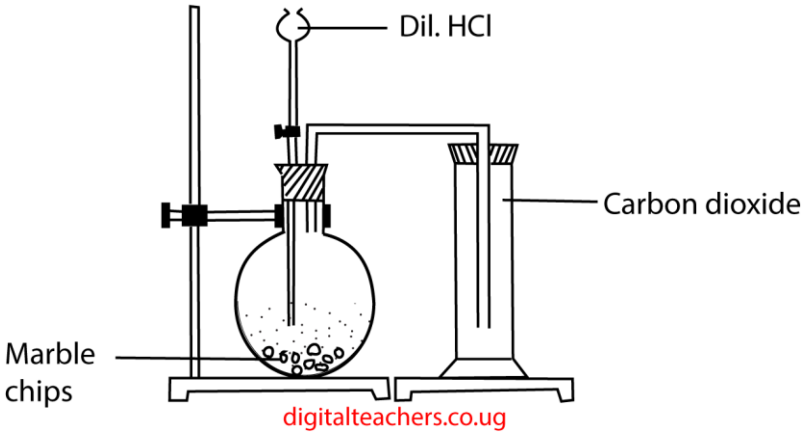
$CxHy + (x+\frac{y}{4})O_2(g) \rightarrow xCO_2(g) + yH_2O(l)$

Conclusion

Therefore, when a candle burns in oxygen, water vapour and carbon dioxide are produced. There is an increase in mass equal to the mass of oxygen that has combined with the wax.

Carbon dioxide
By reacting by reacting an acid and a carbonate. Usually hydrochloric acid and calcium carbonate (marble) are used because they are cheap.

Laboratory preparation of carbon dioxide



Carbon dioxide is collected by downward delivery or upward displacement of air.

Note

1. that sulphuric acid is not normally used to react with marble because calcium sulphate is insoluble that it stop the reaction before much hydrogen is produced.
2. All carbonates other than those of sodium and potassium decompose to release carbon dioxide. For example
   $CaCO_3$ (s) $\rightarrow$ CaO(s) + CO_2 (g)
3. Hydrogen carbonates of potassium and sodium decompose to produce carbon dioxide
   $2NaHCO_3$ (s) $\rightarrow$ Na_2CO_3(s) + CO_2 (g) + H_2O(l)
4. All carbonates are insoluble in water apart from those sodium and potassium.

Testing for carbon dioxide

It turns lime water milky due to formation of insoluble calcium carbonate.

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

With excess carbon dioxide the milky substance dissolves to form a clear solution due to formation of soluble calcium hydrogen carbonate.

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

Physical properties

1. It is colourless
2. Odourless
3. Heavier than air
4. Slightly soluble in water to form acidic solution
   CO_2(g) + H_2O(l) $\rightarrow$ H_2CO_3(aq)

Chemical properties

1. Reacts with alkalis to form carbonates and in excess it forms hydrogen carbonates
   $2NaOH$ (aq) + CO_2 (g) $\rightarrow$ Na_2CO_3(aq) + H_2O(l)

Then

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

NB.

a. Sodium hydrogen carbonate is less soluble than sodium carbonate, thus prolonged addition of carbon dioxide in sodium hydroxide finally produces white crystals of sodium hydrogen carbonates.
b. Sodium and potassium hydrogen carbonates are the only solid hydrogen carbonate.

2. It reacts with magnesium to form white magnesium oxide powder and black carbon
   $2Mg(s) + CO_2(g) \rightarrow 2MgO(s) + C(s)$

3. Through photosynthesis by green plants it is converted to glucose
   $6CO_2(g) + 6H_2O(l)$ (photosynthesis) $\rightarrow C_6H_{12}O_6$ (glucose) $+ 6O_2(g)$

Uses of carbon dioxide

1. Used in refrigerator
2. In fire extinguishes
3. In soft drinks
4. For photosynthesis

Exercises

Questions 1 to 13 circle the correct alternative

1. Which of the gases relight a glowing splint
   - A. Carbon dioxide
   - B. Hydrogen
   - C. Nitrogen
   - D. oxygen
2. Which one of the following gases is removed when air is passed through sodium hydroxide during the manufacture of oxygen
   - A. Water vapour
   - B. Carbon dioxide
   - C. Rare gases
   - D. nitrogen
3. Which of the following oxide will dissolve in dilute nitric acid but not in dilute sodium hydroxide
   - A, Lead II oxide
   - B. Zinc oxide
   - C. Aluminium oxide
   - D. Iron III oxide
4. Which of the following metals react with cold water to produce hydrogen?
   - A. Aluminium
   - B. Calcium
   - C. Iron
   - D. Zinc
5. The rate of evolution of hydrogen during the reaction between zinc and sulphuric acid can be increased by
   - A. Using zinc granules
   - B. Using less concentrated acid
   - C. Reducing the temperature of the reaction mixture
   - D. Using a catalyst
6. Which of the following oxides will not react with water?
   - A. Sulphur dioxide
   - B. Nitrogen dioxide
   - C. Calcium oxide
   - D. Zinc oxide
7. Which one of the following substances is formed as a solid when a bottle of lime water is left open for a long time?
   - A. Calcium hydrogen carbonate
   - B. Calcium hydroxide
   - C. Calcium oxide
   - D. Calcium carbonate
8. Which of the following oxides is soluble in both dilute nitric and dilute sodium hydroxide solution?
   - A. Copper (II) oxide
   - B. Magnesium oxide
   - C. Calcium oxide
   - D. Zinc oxide

9. Which one of the following can cause greenhouse effect?
   A. Nitrogen
   B. Oxygen
   C. Carbon monoxide
   D. Carbon dioxide
10. Which one of the following processes does not affect the concentration of carbon dioxide in atmosphere?
   A. Baking of bread
   B. Photosynthesis
   C. Rusting of iron
   D. Respiration
11. Which one of the following statements about sodium hydrogen carbonates is correct?
   A. It decomposes to carbon dioxide and hydrogen
   B. It reacts with acids to yield carbon dioxide
   C. In solution turns milky in carbon dioxide
   D. It does not exist in solid form
12. Which one of the following salts is least soluble in water?
   A. $CaCl_2$ (s)
   B. $CaCO_3$(s)
   C. $Ca(NO_3)_2$(s)
   D. $CaSO_4$(s)
13. Which of the following gases is obtained by fractional distillation?
   A. Oxygen
   B. Ammonia
   C. Sulphur dioxide
   D. Hydrogen

Each of the questions 14 to 15 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**

14.	When sodium peroxide is dissolved in water a gas is evolved	because	sodium peroxide reacts with water to form hydrogen
15.	Aluminium dissolves readily in aqueous sodium hydroxide dilution	because	Aluminium is highly electropositive metal.

For question 16 one or more of the answers given may be correct. Read each question 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

16.		Which of the following is/are properties of alkalis?
	1.	Turn red litmus paper blue
	2.	Contain hydroxide ions
	3.	Are soluble in water
	4,	Turn blue litmus red

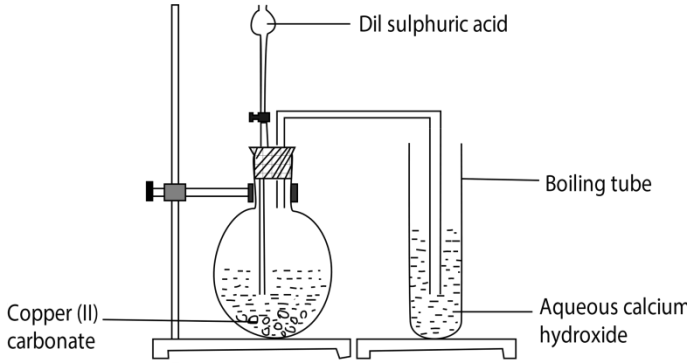
For question 17 answer the question on separate sheet of papers

17. With help of balanced equations or otherwise give the meaning of
    (a) Basic oxide
    (b) Acidic oxide
    (c) Amphoteric oxide
    (d) Neutral oxide

18. (a) (i) Write equation to show how hydrogen can be prepared using zinc and dilute sulphuric acid (1 ½ marks)
    (ii) State how hydrogen can be tested in the laboratory (01mark)
    (b) Hydrogen reacts with copper (II) according to the following equation
    $CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$
    (i) State what is observed when dry hydrogen is passed over heated copper (II) oxide (01mark)
    (ii) Calculate the volume of hydrogen at s.t.p. that would react with copper (II) oxide to form 3.20g of copper.
    (O = 16, H = 1, Cu = 64: one mole of a gas occupies $22.4dm^3$ at s.t.p.

19. Dilute sulphuric acid was added to copper carbonate and the gas evolved passed through calcium hydroxide solution as shown in the figure below. The addition of sulphuric acid was

continued until there was no further reaction



(a) State what is observed in the conical flask (1½ marks)

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

(i) Between sulphuric acid and copper (II) carbonate (1 ½ marks)

(ii) That took place in the boiling tube (03 marks)

20. Carbon dioxide can best be prepared by reacting calcium carbonate with dilute hydrochloric acid. The reaction proceeds according to the equation

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

(a) (i) Explain why sulphuric acid is not usually used instead of hydrochloric acid (2marks)

(ii) Calculate the mass of calcium carbonate that would liberate $250cm^3$ of carbon dioxide at room temperature (Ca =40; C= 12, O = 16; 1 mole of a gas occupies $24dm^3$ at room temperature) (2marks)

(b) Carbon dioxide was bubbled through lime water for a long time. State what was observed. (1 marks)

21. (a) Oxygen was prepared from hydrogen peroxide in presence of manganese (IV) oxide as a catalyst.

(i) Write equation for the reaction that took place (1 ½ mark)

(ii) State the conditions under which oxygen can be produced from hydrogen peroxide at fast rate without a catalyst. (01mark)

(b) (i) Write equation for the reaction between sulphur and oxygen (1 ½ marks)

(ii) State the condition for the reaction in (b)(i) (½ mark)

22. Explain the following observation (7 ½ marks)
A burning magnesium ribbon when lowered into a jar containing carbon dioxide, continues to burn to form a white powder and black particles.

23. (a) Calcium was burnt in air. Write equation for the reaction that took place (1 ½ mark)

(b) Few drops of water were added to the product in (a).

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

(ii) Write equation for the reaction that took place. (1 ½ mark)

(c) Name one compound which when heated forms the same product as that in (a)(i) above (½ mark)

24. (a) Name one compound that when reacted with dilute hydrochloric acid can produce carbon dioxide (01mark)

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

(i) State what is observed (01mark)

(ii) Write equations for the reactions that took place. (03marks)

25. (a) Oxygen is produced form hydrogen peroxide in the presence of catalyst only.

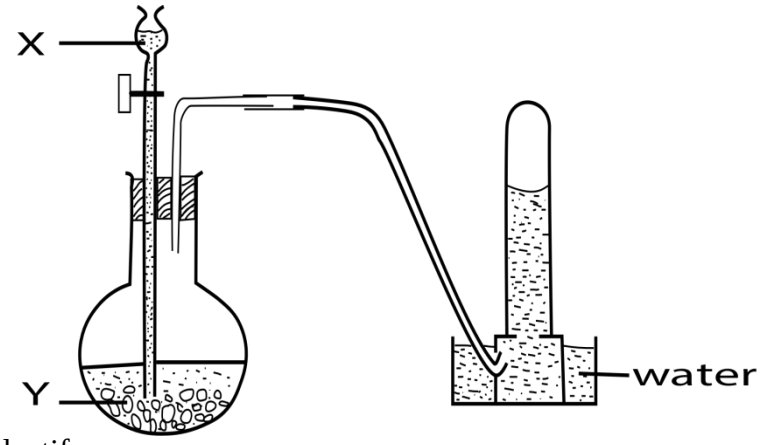
(i) Name the catalyst (1mark)

(ii) Write equation for the formation of oxygen (1 ½ mark)

(b) (i) What is meant by the rate of formation of oxygen? (½ mark)

(ii) State three ways in which the rate of formation of oxygen is increased (3marks)

26. The figure below is a set up for preparation of hydrogen



(a) Identify

(i) X

(ii) Y

(b) Write ionic equation for formation of hydrogen

(c) Hydrogen was passed over heated copper (II) oxide

(i) State what is observed

(ii) Write equation for the reaction

Marking guide

1.	D	4.	B	7.	D	10.	C	13.	A	16.	D
2.	B	5.	D	8.	D	11.	B	14.	C		
3.	D	6.	D	9.	D	12.	B	15.	B		

18. (a) (i) $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

(ii) Produce a pop sound with a burning splint

(b) (i) Black solid turns brown

(ii) 64g of Cu require 22.4 dm^3 of hydrogen

∴ 3.2g of copper require $\frac{22.4\ x\ 3.2}{64} = 1.12cm^3$

19. (a) A milky substance dissolves to form a clear solution

(b) (i) $CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$

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

Then,

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

20. (a) (i) Sulphuric acid give la low yield of carbon dioxide because insoluble calcium sulphate stop th[illegible]n

(ii) $CaCO_3$ = 40 + 12 + 16 x 3 = 100g

⇨ $24000cm^3$ require a 100g of calcium carbonate

⇨ $250cm^3$ require $\frac{100\ x250}{24000} = 0.0417g\ of\ calcium\ carbonate$

(b) Milky suspension turns colourless

21. (a) (i) $2H_2O_2(aq) \xrightarrow{MnO_2} O_2(g) + 2H_2O(l)$

(ii) By heating

By using concentrated hydrogen peroxide

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

(ii) Heat

22. Magnesium burns in carbon dioxide to form white powder of magnesium oxide and black carbon particles

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

23. (a) $2Ca(s) + O_2(g)$ $2CaO(s)$

(b) (i) White solid dissolves to form colorless solution

(ii) $CaO(s) + H_2O(l)$ $Ca(OH)_2(aq)$

(c) Calcium carbonate

$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$

24. (a) Calcium carbonate (but almost all carbonates)

(b) (i) A colorless solution then white pecipitate

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

Then

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

25. (a) (i) Manganese dioxide, MnO_2

$2H_2O_2(aq) \xrightarrow{MnO_2} O_2(g) + 2H_2O(l)$

(b) (i) The amount of oxygen formed perunit time

(ii) Increase temperature of reaction mixture

Increase concentration of hydrogen peroxide

Use a catalyst

26. (a) X = HCl

Y = Zn + $CuSO_4$

(b) $Zn\ (s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2\ (g)$

(c) (i) Black solid turns brown

(ii) $CuO(s) + H_2O\ (l) \longrightarrow Cu(s) + H_2O(l)$