FACTFILE:
GCSE DAS CHEMISTRY: UNIT 2.9

Rewarding Learning

Gas Chemistry

Learning outcomes

Students should be able to:

2.9.1 recall the composition of the gases in the atmosphere:

- about 78% nitrogen;
- about 21% oxygen;
- about 0.03–0.04% carbon dioxide;
- about 1% argon;
- small proportions of other noble gases; and
- varying proportions of water vapour;

2.9.2 recall the physical properties of nitrogen and describe its lack of reactivity due to its triple covalent bond;

2.9.3 demonstrate knowledge and understanding of using nitrogen as a coolant and in food packaging;

2.9.4 **demonstrate knowledge and understanding of the test for ammonia, using a glass rod dipped in concentrated hydrochloric acid and recall the use of ammonia in the manufacture of fertilisers by its reaction with acids;**

2.9.5 describe the laboratory preparation and collection of hydrogen using zinc (or other suitable metal) and hydrochloric acid and recall the physical properties of hydrogen and its uses, including its potential as a clean fuel;

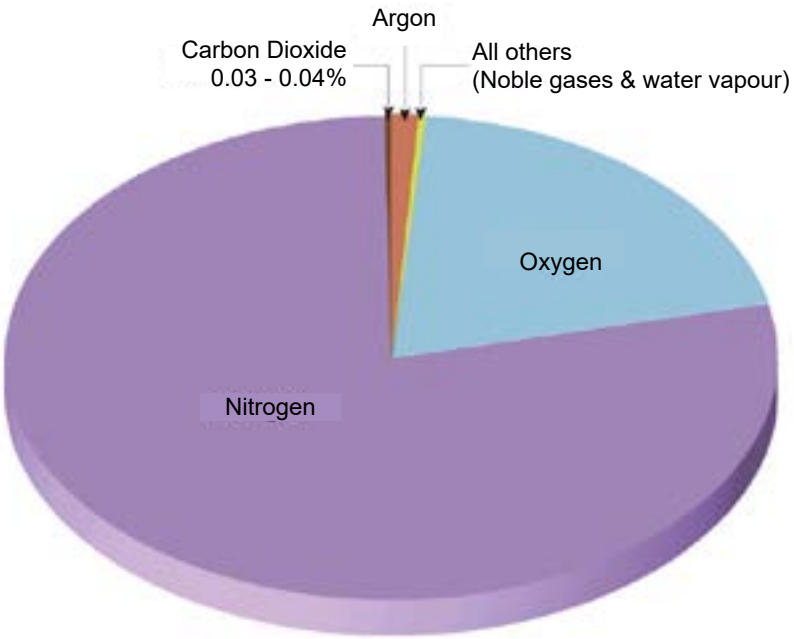
2.9.6 describe the laboratory preparation and collection of oxygen by the catalytic decomposition of hydrogen peroxide, and recall the physical properties of oxygen and its uses in medicine and welding;

2.9.7 describe the reaction of carbon, sulfur, magnesium, iron and copper with oxygen and classify the products as acidic or basic; and

2.9.8 describe the laboratory preparation and collection of carbon dioxide gas using calcium carbonate and hydrochloric acid, and recall the uses of carbon dioxide in fizzy drinks and fire extinguishers.

2.9.9 investigate the chemical reactions of carbon dioxide with water producing carbonic acid and with calcium hydroxide (limewater) until carbon dioxide is in excess.

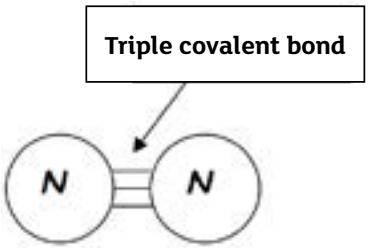
Gases in the Atmosphere



N_2	Nitrogen, at 78%, is the most abundant element in the Earth's atmosphere. Nitrogen is a diatomic molecule, in which the nitrogen atoms are held together by a triple covalent bond. This bond is very strong and so nitrogen takes part in very few reactions.

Physical properties of nitrogen:

- Nitrogen is a colourless, odourless, neutral gas. It is only very sparingly soluble in water.
- The triple covalent bond requires a lot of energy to break and so nitrogen takes part in very few reactions – it is relatively unreactive.



Uses:

- Nitrogen is a coolant – when liquid nitrogen is vaporised, it absorbs large quantities of heat which makes it ideal for cooling or freezing food and other materials.
- Used in food packaging because it is inert (unreactive), e.g. in crisp packets.
- In the manufacture of Ammonia; nitrogen and hydrogen are mixed in a 1:3 ratio to make ammonia. They are reacted at 450 °C and a pressure of 200 atm. An iron catalyst is used.
- $N_2 + 3H_2 \rightleftharpoons 2NH_3$
- Ammonia is used in the production of fertilisers. It is present in fertiliser to provide nitrate ions to plants, which they need to produce proteins for growth. Without artificial fertilisers, we would be unable to produce sufficient crops to feed the world's population.

Ammonia gas will react with hydrogen chloride gas to form white fumes of ammonium chloride.
The equation for this is:

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$$

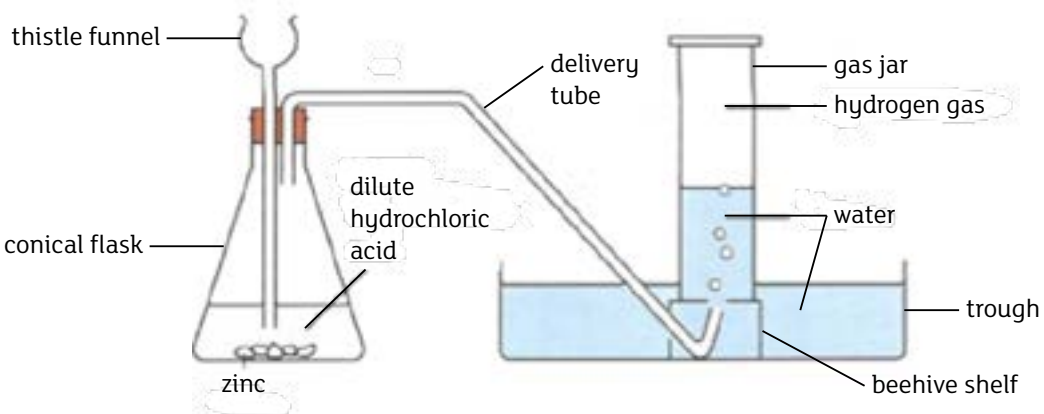
To test for ammonia gas, a glass rod is dipped in concentrated hydrochloric acid. The rod is applied to the gas and if ammonia is present white fumes are observed.

H_2

Hydrogen can be prepared by reacting a metal and an acid. The metal is usually zinc or magnesium reacting with hydrochloric acid or sulfuric acid.

zinc + hydrochloric acid ⟶ zinc chloride + hydrogen

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$



Test for Hydrogen: Place a lighted splint in a test tube containing the gas. If the gas is hydrogen, there will be a squeaky pop. This is a mini-explosion because the hydrogen burns very quickly in oxygen forming water (as steam) and releasing heat energy.

Physical properties of Hydrogen:

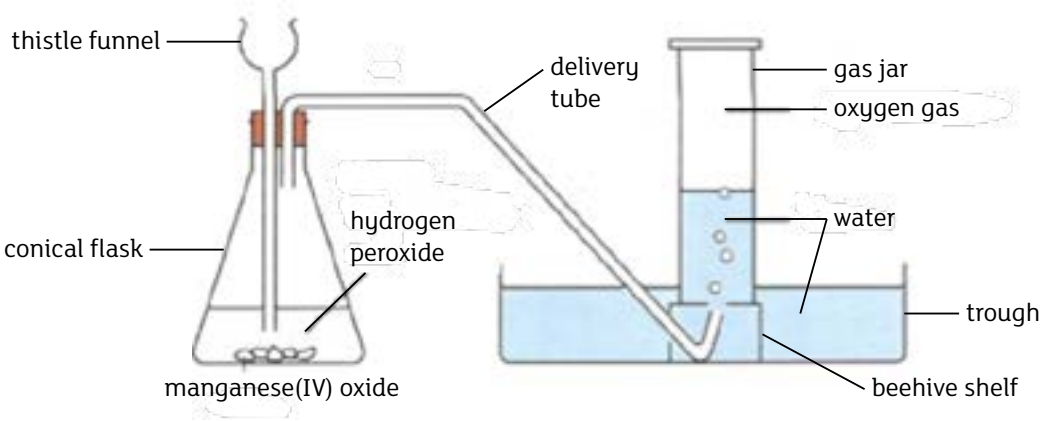
- Colourless and odourless
- Less dense than air
- Insoluble in water

Uses of Hydrogen:

- **Meteorological balloons** – Measuring atmospheric conditions such as air pressure, temperature, humidity and wind velocity.
- **Rockets** – Hydrogen is a light and extremely powerful rocket propellant, it has the lowest molecular weight of any known substance and burns with extreme intensity (5,500°F).
- **As a clean fuel** – Hydrogen burns in Oxygen to form water. $2H_2 + O_2 \longrightarrow 2H_2O$

Water is a readily available and free resource which can be separated into oxygen and hydrogen. Combustion of hydrogen with oxygen releases energy and produces only water molecules as a waste product. Scientists spend a lot of time, energy and money figuring out how to use hydrogen to fuel cars etc. as this would reduce the world's dependence on fossil fuels which are running out. It would also drastically reduce the levels of CO_2 emissions which are contributing to the global warming problem.

O_2	Oxygen is the most abundant element in the Earth's crust and makes up approximately 21% of the Earth's atmosphere. Oxygen can be prepared in the laboratory by the catalytic decomposition of hydrogen peroxide.



Physical properties:

- Colourless and odourless
- About the same density as air
- Slightly soluble in water

Uses:

- Breathing apparatus
- Welding

Reactions:

1. **Combustion** – when a fuel burns in oxygen to produce heat, carbon dioxide and water.

fuel + oxygen ⟶ carbon dioxide + water (+ heat)

Energy is released so it is an exothermic reaction. Combustion will not occur without oxygen. To stop something burning one way is to prevent oxygen from reaching it.

2. **Respiration** – Oxygen is used in this process to give us energy.

3. Oxygen is extremely reactive and reacts directly with other elements to form compounds called oxides.

Element	Product	Add water and test with indicator
magnesium	**magnesium oxide** (white solid)	pH = 8 - **alkaline**
iron	**iron oxide** (black solid)	Insoluble
copper	**copper(II) oxide** (black solid)	Insoluble
carbon	**carbon dioxide** (colourless gas)	pH = 5 - **acidic**
sulfur	**sulfur dioxide** (colourless gas)	pH = 3 - **acidic**

METAL OXIDES ARE BASIC

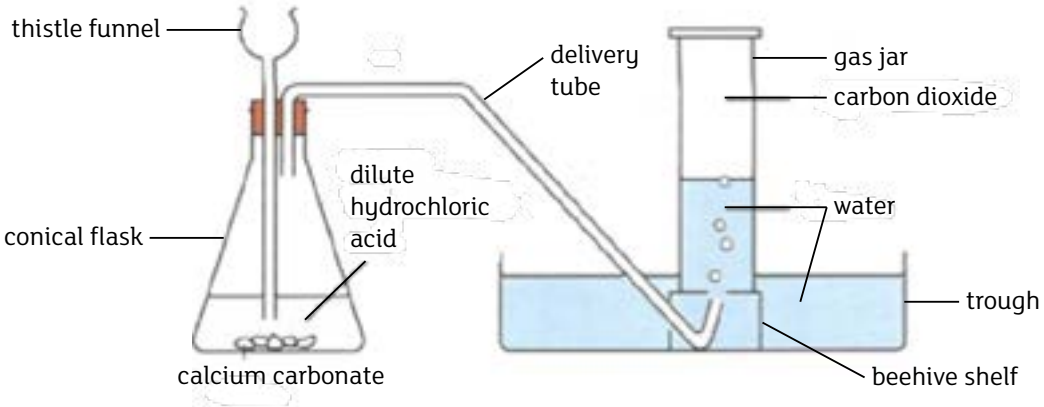
NON-METAL OXIDES ARE ACIDIC

CO_2

All life on earth is based on the element carbon. Carbon dioxide consists of simple molecules with one carbon atom covalently bonded to two oxygen atoms. Carbon burns in excess oxygen (complete combustion) to give carbon dioxide.

$$C + O_2 \longrightarrow CO_2$$

Carbon dioxide is prepared and collected in the laboratory from the reaction of calcium carbonate with hydrochloric acid using the apparatus shown below.



Physical properties of CO_2

- odourless gas
- denser than air
- slightly soluble in water
- sublimes at –78°C

Reactions:

1. With water:

In fizzy drinks, carbon dioxide dissolves in water and reacts to give the weak acid, carbonic acid:

$$CO_2(g) + H_2O(g) \longrightarrow H_2CO_3(aq)$$

2. With calcium hydroxide:

When carbon dioxide is bubbled into calcium hydroxide solution, calcium carbonate and water are formed.

carbon dioxide + calcium hydroxide ⟶ water + calcium carbonate **(white ppt)**

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

This is also an acid-base reaction with the carbon dioxide acting as an acid.

Test: When carbon dioxide is bubbled through limewater (calcium hydroxide) the limewater goes cloudy (or milky). The white precipitate is calcium carbonate.

If CO_2 continues to be bubbled into the solution, the precipitate will re-dissolve to form a colourless solution.

calcium carbonate + carbon dioxide + water ⟶ calcium hydrogencarbonate (colourless solution)

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

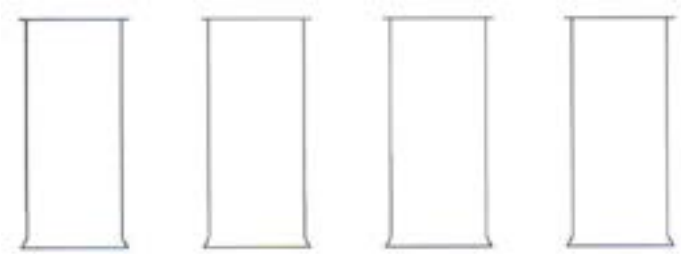
Uses:

Carbon dioxide is used in:

- Fire Extinguishers – CO_2 does not support combustion; it is heavier than oxygen so it smothers the fire.
- Carbonated Drinks – when CO_2 is dissolved in water, it makes the water "fizzy".
- Dry Ice – solid CO_2 sublimes (solid turns to gas), used to produce a fog effect on stage.

Revision Questions

1. (a) Below are four gas jars, each containing an element which is a gas.

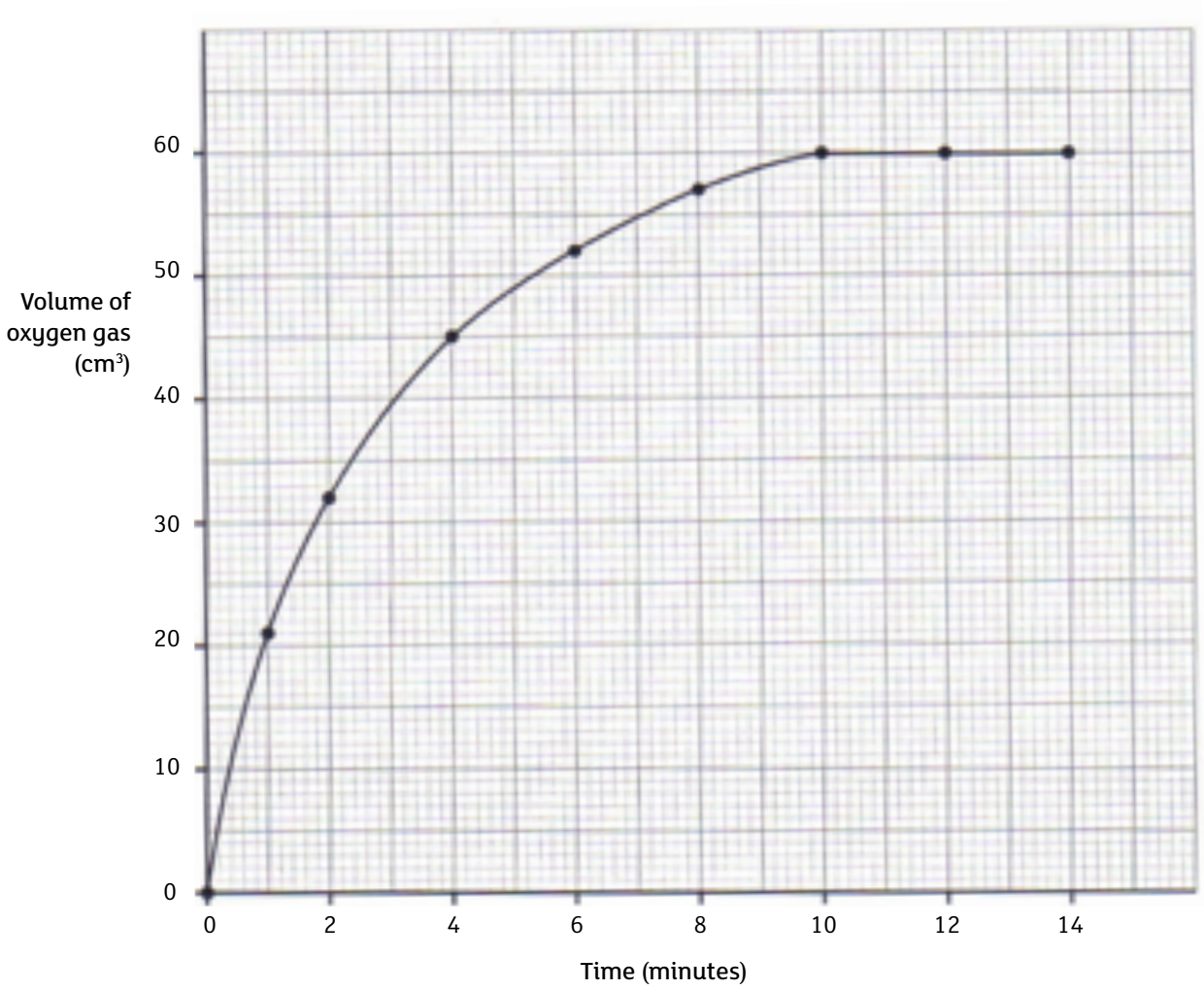


Helium **Nitrogen** **Oxygen** **Chlorine**

(i) Which one of these gases is chemically inert? _____ [1]

(ii) Which one of these gases is used to make ammonia? _____ [1]

2. (d) A group of students investigated how 25 cm^3 of hydrogen peroxide solution breaks down to produce oxygen. The volume of oxygen collected was measured every minute and a graph drawn is shown below.



(i) Name a piece of apparatus which would be suitable to collect the oxygen gas.

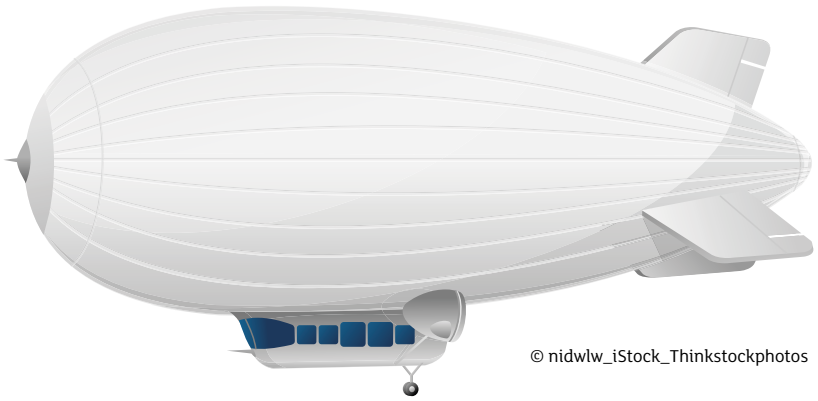
_____ [1]

(ii) The students repeated the experiment but the only change was to add 10 cm^3 water to 25 cm^3 of the hydrogen peroxide solution. On the same grid sketch the curve you would expect for this reaction and label it with the letter B. [2]

(iii) Why might a catalyst be added to the hydrogen peroxide solution?

_____ [1]

3. The first airships were filled with hydrogen gas. Now helium is used in airships.



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(a) What property do hydrogen and helium have in common which makes them useful in airships?

_____ [1]

(b) Explain why helium is now used and hydrogen is no longer used.

_____

_____ [2]

(c) Write a balanced symbol equation to show what happens when hydrogen burns in oxygen gas.

_____ [2]