Non-metals and Gas Preparation

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Non-metals and Gas Preparation

Non-metals occupy the right-hand side of the periodic table. Many are gases at room temperature; their chemistry is dominated by covalent bonding. The ability to prepare, collect, dry, and identify specific gases is a core laboratory skill tested in both Paper 02 and the SBA.

Properties of Non-metals

Unlike metals, non-metals typically:

Property	Non-metals
Electrical conductivity	Poor conductors (except graphite)
Thermal conductivity	Poor
Physical state	Many are gases at room temperature; some are solids (C, S, P); Br,is a liquid
Melting and boiling points	Generally low (molecular structures)
Lustre	Dull (not shiny)
Malleability	Brittle if solid
Bonding	Covalent (in molecules or giant covalent structures)

Important Non-metals

Oxygen (O)

- Colourless, odourless gas; supports combustion and respiration
- Test: relights a glowing splint
- Uses: medical oxygen therapy, oxy-acetylene welding, steel manufacture (basic oxygen process)
- Reacts with metals to form basic oxides; with non-metals to form acidic oxides

Nitrogen (N_2)

- Colourless, odourless, very unreactive gas (78% of air)
- Unreactivity due to the very strong $N \equiv N$ triple bond
- Uses: fertiliser manufacture (via Haber process), food packaging (inert atmosphere), cooling (liquid N_2), manufacture of ammonia

Chlorine (Cl_2)

- Yellow-green gas; pungent, toxic; oxidising agent
- Bleaches damp litmus paper (test for chlorine)
- Dissolves in water to form hydrochloric acid and hypochlorous acid (bleaching action)
- Uses: water purification (kills bacteria), manufacture of bleach (NaOCl), PVC, pesticides, pharmaceuticals

Sulfur (S)

- Yellow solid; poor conductor; burns with a blue flame to form sulfur dioxide

$$S + O_2 \rightarrow SO_2$$

- Uses: manufacture of sulfuric acid (Contact process), vulcanising rubber, fungicide, matches

Carbon (C)

Two main allotropes: diamond (hardest natural substance, insulator) and graphite (soft, conductor). Uses of carbon: graphite for electrodes and pencils, diamond for cutting tools, carbon black as a reinforcing filler in tyres. Also exists as fullerenes (e.g. buckyballs) and carbon nanotubes.

Hydrogen (H_2)

- Colourless, odourless, least dense gas
- Test: burns with a squeaky pop when a lit splint is applied
- Uses: manufacture of ammonia (Haber process), hydrogenation of oils, fuel cells, rocket propellant

Laboratory Preparation of Gases

Several of the non-metals above are prepared and tested in standard lab practicals. For each gas, the syllabus expects you to know the preparation reaction, collection method, drying agent, and identification test.

Oxygen

Preparation: decomposition of hydrogen peroxide using manganese(IV) oxide as a catalyst.

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2$$

Collection: upward displacement of air (oxygen is denser than air), or over water since oxygen is only slightly soluble.

Drying: pass through anhydrous calcium chloride or silica gel (NOT concentrated H_2SO_4 with excess H_2O).

Test: glowing splint relights.

Carbon Dioxide

Preparation: dilute hydrochloric acid reacted with marble chips (calcium carbonate). Dilute HCl is preferred because $CaSO_4$ forms an insoluble layer that stops the reaction if H_2SO_4 is used.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

Collection: upward displacement of air (CO_2 is denser than air). Cannot be collected over water — CO_2 dissolves.

Drying: concentrated sulfuric acid (NOT anhydrous $CaCl_2$, which reacts with CO_2).

Test: turns limewater milky: $Ca(OH)2 + CO2 \rightarrow CaCO3 + H2O$

Ammonia

Preparation: heating an ammonium salt with a base (e.g. ammonium chloride with calcium hydroxide).

$$2NH_4Cl + Ca(OH)_2 \xrightarrow{\Delta} CaCl_2 + 2H_2O + 2NH_3$$

Collection: downward displacement of air (ammonia is less dense than air). Cannot be collected over water — ammonia is extremely soluble.

Drying: through calcium oxide (CaO) — NOT concentrated H_2SO_4 (it would react with NH_3) and NOT anhydrous $CaCl_2$ (forms a complex with NH_3).

Test: turns damp red litmus paper blue.

> 📝 **Exam Tip**
> The three drying agents and why they cannot be used for certain gases are a favourite exam question. H_2SO_4 reacts with NH_3; anhydrous $CaCl_2$ reacts with both NH_3 and CO; CaO is the only safe drying agent for ammonia.