IGCSE Chemistry CIE

YOUR NOTES

10. Chemistry of the Environment

CONTENTS

YOUR NOTES

Chemical Tests for Water

Chemical tests for water

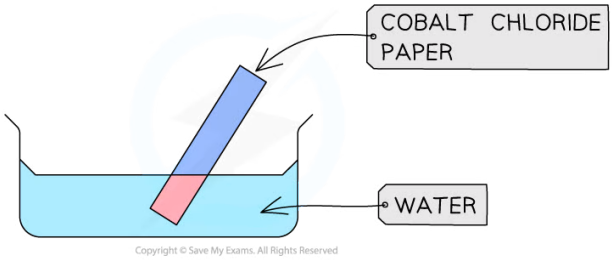
Using cobalt(II) chloride:

- Cobalt(II) chloride turns **blue** to **pink** on the addition of water. This test is usually done using cobalt chloride paper
- The equation is:

anhydrous cobalt(II) chloride + water ⇌ hydrated cobalt(II) chloride

$$CoCl_2\,(s) + 6H_2O\,(l) \rightleftharpoons CoCl_2.6H_2O\,(s)$$

blue pink



Test for water using cobalt chloride paper which turns pink in the presence of water

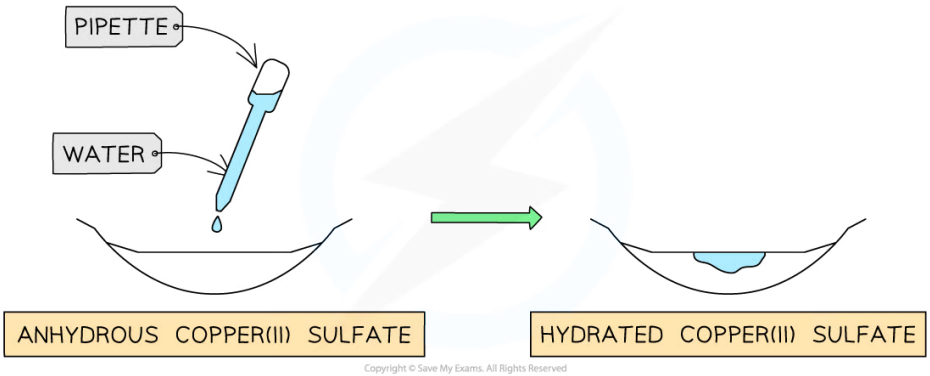
Using copper(II) sulfate:

- Anhydrous copper(II) sulfate turns **white** to **blue** on the addition of water
- The equation is:

anhydrous copper(II) sulfate + water ⇌ hydrated copper(II) sulfate

$$CuSO_4\,(s) + 5H_2O\,(l) \rightleftharpoons CuSO_4.5H_2O\,(s)$$

white blue



Test for water using anhydrous copper(II) sulfate which turns blue in the presence of water

YOUR NOTES

Exam Tip

Core students do **not** need to know the symbol equations.

Purity of Water

Testing for purity

- Pure substances melt and boil at specific and sharp temperatures
- Water has a boiling point of 100 °C and a melting point of 0 °C
- Mixtures have a range of melting and boiling points as they consist of different substances that melt or boil at different temperatures
- Melting and boiling points data can therefore be used to determine the purity of water
- Impurities tend to increase the boiling point of water, so impure water will boil at temperatures above 100 ^{o}C
- Impurities tend to decrease the melting point of water, so impure water will melt at temperatures below 0 ^{o}C

Distilled water

- Distilled water is water that has been heated to form a vapour, and then condensed back to a liquid
- It contains very few impurities
- Distilled water is used in practical chemistry because of its high purity
- Tap water contains more impurities which could interfere with chemical reactions so is typically not used

YOUR NOTES

Substances in Water from Natural Sources

- We use water in many aspects of our everyday life:
  - Domestic uses: for drinking, cooking, gardening and general sanitation
  - Agricultural uses: as a drink for animals and watering crops
  - Industrial uses: as a solvent, as a coolant and heated to make steam used to generate electricity
- Water is found in natural sources such as lakes, rivers and underground water sources (groundwater)
- A rock that stores water is known as an **aquifer**
- Water from natural sources may contain a variety of different substances, including:
  - Dissolved oxygen
  - Metal compounds
  - Plastics
  - Sewage
  - Harmful microbes
  - Nitrates from fertilisers
  - Phosphates from fertilisers and detergents
- Many of these substances enter water sources when rain falls and washes them into lakes, rivers or groundwater
- Some of these substances are naturally occurring but many are a direct result of human activities

Exam Tip

Despite the term 'natural source', water from these sources may contain lots of impurities and harmful substances and should not be confused with water which is clean and ready for use.

Beneficial & Harmful Substances in Water

YOUR NOTES

- Some of the substances which may be found in natural water sources are beneficial and others may have harmful effects
- Beneficial substances include:
  - Dissolved oxygen – essential for aquatic life
  - Metal compounds – some provide essential minerals which are necessary for life, such as calcium and magnesium
- Potentially harmful substances include:
  - Metal compounds – some are toxic like aluminium and lead
  - Some plastics – these may be harmful to aquatic life in many ways, e.g. getting trapped in plastic waste, dying of starvation as their stomach is filled with plastic
  - Sewage – contains harmful microbes which can cause disease
  - Nitrate & phosphates from fertilisers – these can promote the growth of aquatic plant life which leads to deoxygenation of water. Ultimately, this can cause damage to aquatic life in a process called eutrophication (you do not need to know the details of this process)

Exam Tip

Metal compounds can be both beneficial and harmful, it depends on the metal within the compound, e.g. calcium, magnesium, potassium and sodium are all metals which are essential for life. Harmful metals include lead, arsenic and mercury.

YOUR NOTES

Water Treatment

Water supply

- Water is taken from **rivers**, **reservoirs** or underground water sources (**groundwater**)
- A rock that stores water is known as an **aquifer**

Water treatment

- Untreated water contains **soluble** and **insoluble** impurities
- Insoluble impurities include soil, pieces of plants and other organic matter
- Soluble impurities include dissolved calcium, metallic compounds and inorganic pollutants
- Water is pumped into sedimentation tanks where the water is allowed to stand for a few hours
- Mud, sand and other particles will fall to the bottom of the tank due to gravity and form a layer of sediment, in a process called **sedimentation**
- **Filtration** is the process used to remove smaller particles by passing the water through layers of sand and gravel filters that trap solid particles
- Water can also be passed through **carbon** (in the form of charcoal) to remove tastes and odours
- Bacteria and other microorganisms are too small to be trapped by the filters so **chlorination** is used
- This involves the careful addition of **chlorine** to the water supply which kills bacteria and other unwanted microorganisms
- Cholera and typhoid are examples of bacterial diseases which can arise from the consumption of untreated water

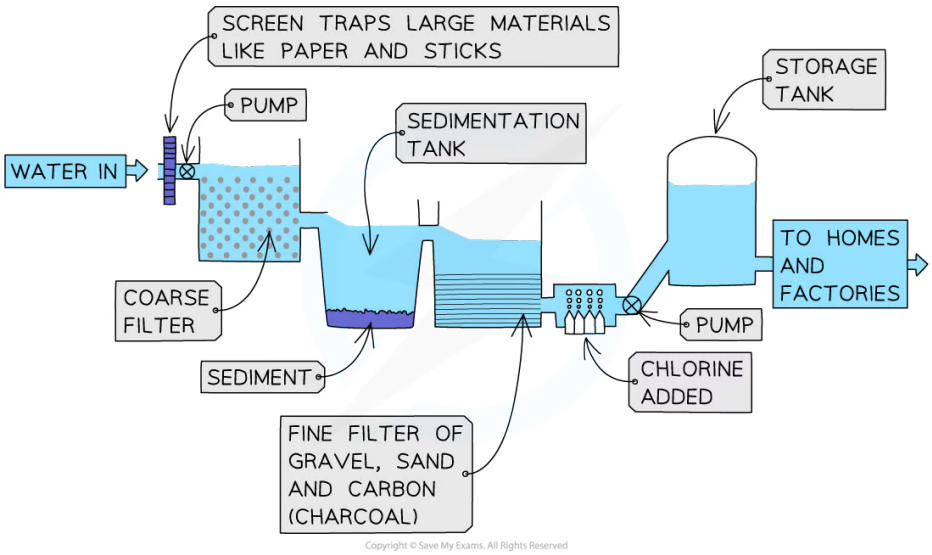


Diagram showing the stages in the treatment of water

Exam Tip

Exam questions on water treatment often focus on the purpose of each stage of the process.

YOUR NOTES

YOUR NOTES

Fertilisers

N, P, K Fertilisers

- Fertilisers contain **nitrogen, potassium** and **phosphorus**
  - Nitrogen makes chlorophyll and protein and promotes healthy **leaves**
  - Potassium promotes **growth** and healthy **fruit** and **flowers**
  - Phosphorus promotes healthy **roots**
- Fertiliser compounds contain the following water-soluble ions:
  - Ammonium ions, NH_4^+ and nitrate ions, NO_3^-, are sources of soluble nitrogen
  - Phosphate ions, PO_4^{3-} are a source of soluble phosphorus
  - Most common potassium compounds dissolve in water to produce potassium ions, K^+
- Common fertiliser compounds include:
  - Ammonium nitrate, NH_4NO_3
  - Ammonium phosphate, $(NH_4)_3PO_4$
  - Potassium sulfate, K_2SO_4
- Ammonium salts and nitrates are commonly used as fertilisers
- Different fertilisers contain different amounts of fertiliser compounds so each contains different proportions of nitrogen, potassium and phosphorous

Exam Tip

You may be asked to select a compound or combination of compounds from a list which would be the most effective as a fertiliser. Look for the compound or combination of compounds that contain the most elements from nitrogen, phosphorous and potassium.

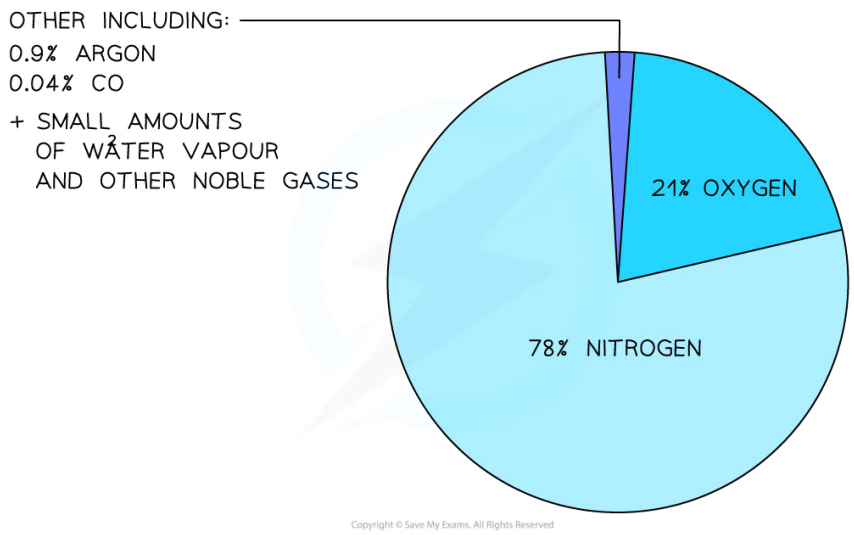
YOUR NOTES

10.2 Air Quality & Climate

10.2.1 Air

The Composition of Air

- The chart below shows the approximate percentages by volume of the main gases in unpolluted, dry air:



Pie chart showing the composition of clean dry air

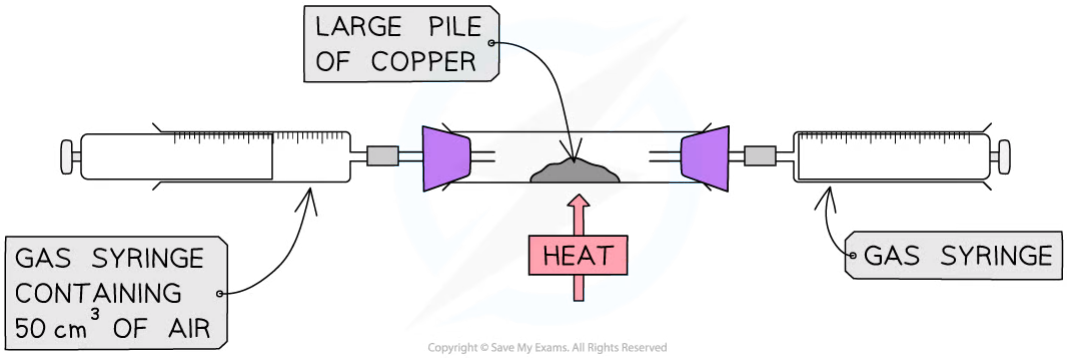
Uses of air

- The gases available in the air have many important applications
- The noble gases are used in many applications, e.g. helium is used to fill balloons, argon is used in tungsten light bulbs, krypton is used in lasers for eye surgery
- Oxygen is used in **steel** making, **welding** and **breathing** apparatus
- Nitrogen is used in **food packaging**, the production of **ammonia** and in the production of **silicon chips**
- Oxygen and nitrogen are separated from the air by fractional distillation

Investigating the percentage of oxygen in air

- The percentage of oxygen in the air can be investigated by passing a known quantity of air over a metal
- The oxygen in the air will react with the metal, forming a metal oxide
- The oxygen will be removed from the air and the volume of the air with the oxygen removed can be measured
- An example of the apparatus that can be used to investigate this is shown below:

YOUR NOTES



Method:

- Heat the copper using a Bunsen burner
- Push the plunger of the syringe containing air, forcing the air into the other plunger until all of the air has transferred
- Push the air back from the now filled plunger to the other plunger
- Repeat this several times for about 3 minutes
- The copper will turn black as copper reacts with the oxygen in the air and copper oxide is produced
- Allow the apparatus to cool
- Ensure all the gas is in one syringe and record the volume of gas
- The percentage of oxygen in the air can be calculated from the results

Worked Example

In the experiment above, the starting volume of air was 50.0 cm^3 of air and the final volume of air was 39.5 cm^3

Calculate the percentage of oxygen in the air.

Step 1 – calculate the volume of oxygen in 50.0 cm^3 of air

volume of oxygen in air = starting volume – final volume

= 50.0 – 39.5 = 10.5 cm^3

Step 2 – calculate the percentage of oxygen in air

$$\text{Percentage of oxygen in air} = \frac{\text{volume of oxygen in air}}{\text{starting volume of air}} \times 100$$

$$= \frac{10.5}{50.0} \times 100$$

$$= 21.0\ \%$$

Air Pollution

YOUR NOTES

- In addition to the gases present naturally in our atmosphere, other gases are present due to human activities and are classed as air pollutants

Carbon dioxide

- **Sources:** complete combustion of carbon-containing fuels such as fossil fuels, e.g. the complete combustion of methane:

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

- **Adverse effects:** increases global warming, which leads to climate change

Carbon monoxide

- **Sources**: incomplete combustion of carbon-containing fuels such as fossil fuels, e.g. incomplete combustion of gasoline:

$$C_8H_{18} + 9O_2 \rightarrow 5CO + 2CO_2 + 9H_2O$$

- **Adverse effects**: toxic, combining with haemoglobin in the blood and prevents it from carrying oxygen

Particulates

- **Sources:** incomplete combustion of carbon-containing fuels such as fossil fuels can also produce particulates of carbon (soot), e.g the incomplete combustion of methane can produce CO and C:

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$$

$$CH_4 + O_2 \rightarrow C + 2H_2O$$

- **Adverse effects**: respiratory problems and cancer

Methane

- **Sources:** waste gases from digestive processes of animals, decomposition of vegetation, bacterial action in swamps, rice paddy fields and landfill sites
- **Adverse effects**: increases global warming, which leads to climate change

Oxides of nitrogen

- **Sources**: reaction of nitrogen with oxygen in the presence of high temperatures, e.g. in car engines, high-temperature furnaces and when lightning occurs. It is also a product of bacterial action in the soil
- **Adverse effects**:
  - Produces photochemical smog
  - Dissolves in rain to form **acid rain** which causes corrosion to metal structures, buildings and statues made of carbonate rocks, damage to aquatic organisms. Pollutes crops and water supplies, irritates lungs, throats and eyes and causes **respiratory** problems

Sulfur dioxide

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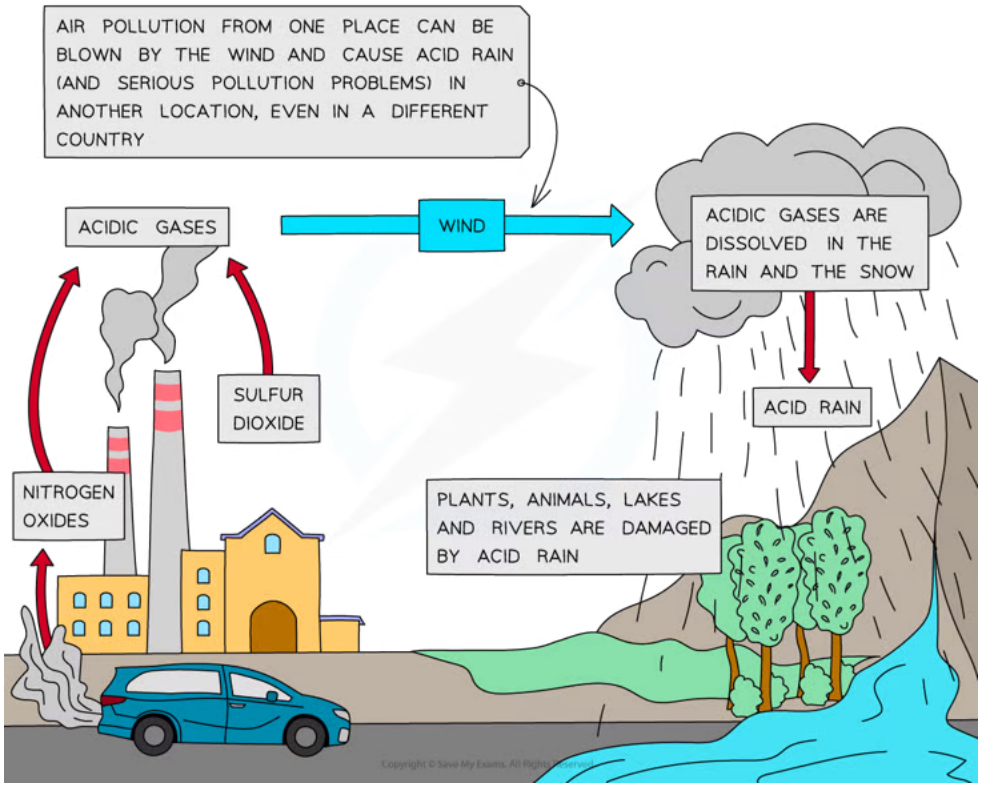
- **Sources**: combustion of fossil fuels containing sulfur compounds. Power stations are a major source of sulfur dioxide
- **Adverse effects**: dissolves in rain to form **acid rain** with similar effects as the acid rain caused by oxides of nitrogen



How acid rain is produced

Exam Tip

Complete and incomplete combustion of hydrocarbons produce different products. Complete combustion occurs in **excess** oxygen and produces **CO_2** and **H_2O**. Incomplete combustion occurs in **oxygen-deficient** conditions and produces **CO**, **H_2O** and sometimes particulates of **carbon** (soot).

YOUR NOTES

Effects of Greenhouse Gases

- The Sun emits energy in the form of radiation that enters the Earth's atmosphere
- Some thermal energy is reflected from the Earth's surface
- Most thermal energy is absorbed and re-emitted back from the Earth's surface
- The energy passes through the atmosphere where some thermal energy passes straight through and is emitted into space
- But some thermal energy is absorbed by greenhouse gases such as carbon dioxide and methane and is re-emitted in all directions
- This reduces the thermal energy lost into space and traps it within the Earth's atmosphere, keeping the Earth warm
- This process is known as the **greenhouse effect**
- As the concentration of greenhouse gases in the atmosphere increases due to human activity, more thermal energy is trapped within the Earth's atmosphere causing the Earth's average temperature to rise (global warming)
- This process is called the **enhanced greenhouse effect**

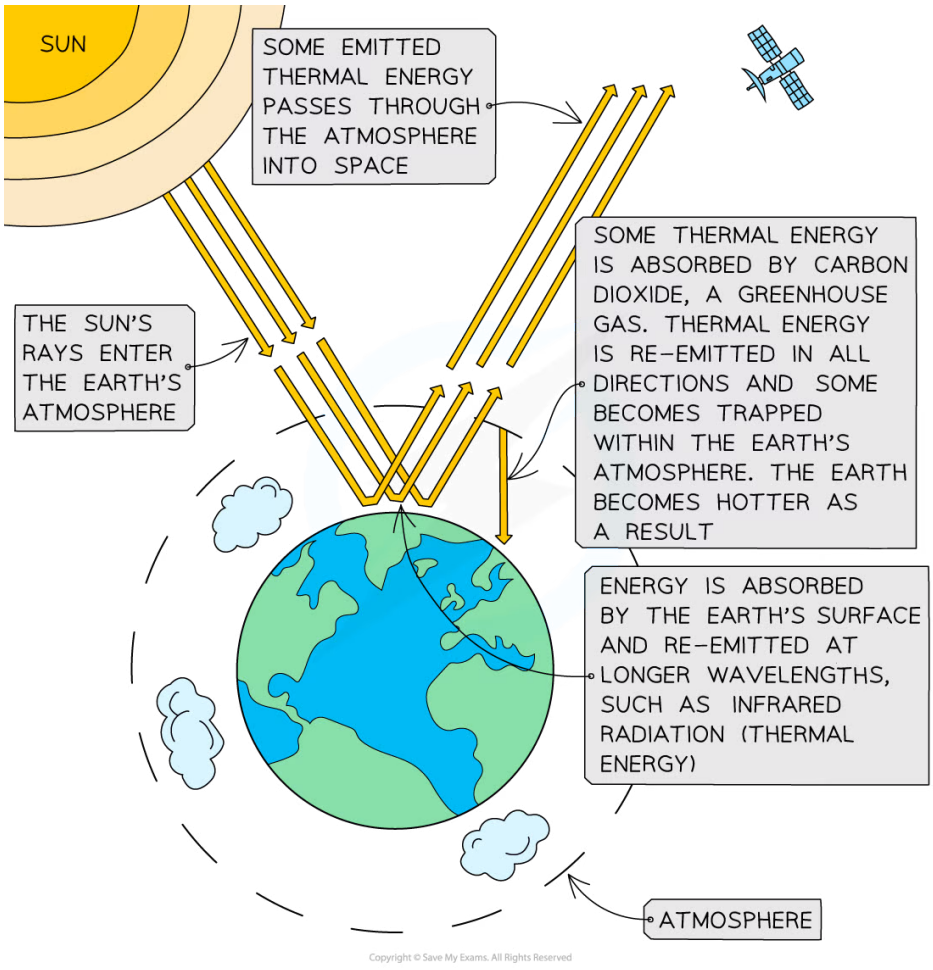


Diagram showing how the greenhouse effect occurs

YOUR NOTES

Consequences of global warming:

- Climate change due to the increase in Earth's temperature
- Water levels will rise as glaciers melt because of high temperatures, causing flooding in low-lying countries
- Extinction of species due to the destruction of natural habitats
- Migration of species as they will move to areas that are more habitable (no droughts)
- Spread of diseases caused by warmer climate
- Loss of habitat due to climate change (animals that live on glaciers or in low-lying countries)

YOUR NOTES

Reducing the Effects of Environmental Issues

- The effects of climate change and acid rain are far reaching and strategies are needed to reduce their impact

Dealing with Climate Change

- The production of greenhouse gases needs to be reduced drastically to avoid or at least slow climate change
- CO_2 emissions can be reduced by using hydrogen and renewable energy supplies such as solar or wind energy instead of burning fossil fuels
- Reducing the amount of livestock farming would decrease the methane emissions produced from digestion in animals
- Planting more trees would remove more carbon dioxide from the atmosphere

Dealing with Acid Rain

- Acid rain is caused by oxides of nitrogen and sulfur dioxide
- The effects of acid rain can be reduced by decreasing the amount of oxides of nitrogen and sulfur dioxide that are produced
- Catalytic convertors in vehicles can be used to remove oxides of nitrogen
- Emissions of sulfur dioxide can be reduced by either:
  - Using fuels which contain low levels of sulfur
  - Flue gas desulfurisation – this involves reacting the sulfur dioxide emitted from burning fuels containing sulfur, with calcium oxide therefore removing it from the flue gas

Exam Tip

There are many other ways that carbon dioxide, methane, oxides of nitrogen and sulfur dioxide can be reduced, e.g. by reducing energy usage to reduce CO_2 emissions but it is only the examples stated above that you need to know.

Oxides of Nitrogen in Car Engines

YOUR NOTES

EXTENDED

Oxides of nitrogen

- These compounds (NO and NO_2) are formed when nitrogen and oxygen react in the **high pressure** and **temperature** conditions of internal combustion engines and blast furnaces
- Exhaust gases also contain unburned hydrocarbons and carbon monoxide
- Cars are fitted with catalytic converters which form a part of their exhaust systems
- Their function is to render these exhaust gases harmless

Catalytic converters

- They contain a series of **transition metal catalysts** including platinum and rhodium
- The metal catalysts are in a **honeycomb** within the converter to increase the surface area available for reaction
- A series of redox reactions occurs which neutralises the pollutant gases
- Carbon monoxide is oxidised to carbon dioxide:

$$2CO + O_2 \rightarrow 2CO_2$$

- Oxides of nitrogen are reduced to N_2 gas:

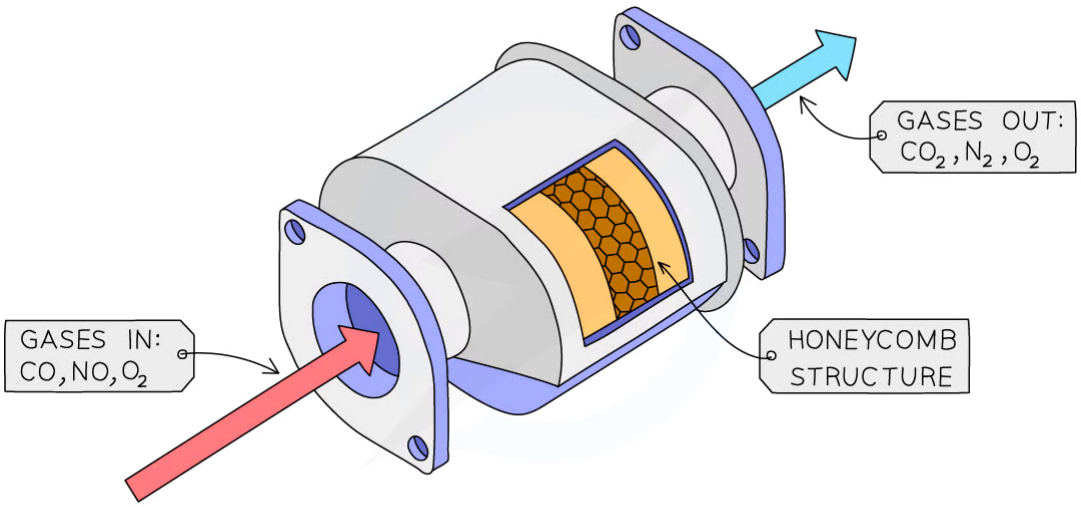
$$2NO \rightarrow N_2 + O_2$$

$$2NO_2 \rightarrow N_2 + 2O_2$$

- A single reaction can summarise the reaction of nitrogen monoxide and carbon monoxide within a catalytic convertor:

$$2NO + 2CO \rightarrow N_2 + 2CO_2$$

YOUR NOTES



Catalytic converters are designed to reduce the polluting gases produced in car exhausts

- Unburned hydrocarbons can also be oxidised to carbon dioxide and water:

$$C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$$

Exam Tip

Whilst carbon dioxide does not have direct adverse effects to our health, it is a greenhouse gas and is a major contributor to climate change

YOUR NOTES

Photosynthesis

Photosynthesis

- Photosynthesis is an endothermic reaction in which energy is transferred from the environment to the chloroplasts in green plants to make glucose
- The reactants for this reaction are carbon dioxide and water
- Glucose and oxygen are produced
- Chlorophyll (found in chloroplasts) and energy from light are required for this reaction to occur
- The word equation for photosynthesis is:

Carbon dioxide and water producing glucose and oxygen during photosynthesis

Symbol Equation for Photosynthesis

EXTENDED

Symbol Equation for Photosynthesis

- The balanced symbol equation for photosynthesis is:

Balanced symbol equation for photosynthesis