Chemistry of the Environment

Water and its tests, pollutants in natural water and the treatment of the domestic water supply, fertilisers, the composition of air, air pollutants and their effects, the greenhouse effect, acid rain, catalytic converters and photosynthesis.

10.1 Water

Tests for water

Water is detected by a colour change in an **anhydrous** compound:

Test	Result with water
anhydrous copper(II) sulfate (white powder)	turns **blue**
anhydrous cobalt(II) chloride (blue, often as paper)	turns **pink**

$$\mathrm{CuSO_4\,(s) + 5\,H_2O\,(l) \longrightarrow CuSO_4 \cdot 5\,H_2O\,(s)}$$

These tests show that water is **present**, but they do not show that it is **pure water**.

Testing the purity of water

A **pure** substance has a **sharp, fixed** melting point and boiling point. Pure water **boils at** $100\,^{\circ}\mathrm{C}$ and **melts (freezes) at** $0\,^{\circ}\mathrm{C}$ at normal atmospheric pressure. **Impurities** make the boiling point **higher** and the melting point **lower**, and the change of state happens over a **range** of temperatures.

Distilled water, not tap water, is used in practical chemistry because it contains **fewer chemical impurities** (dissolved salts and gases) that could interfere with the reactions or the tests.

Substances in natural water

Water from rivers, lakes and the ground can contain several other substances:

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Substance	Source or effect
dissolved oxygen	**beneficial**: aquatic animals and plants need it to live
metal compounds	some are **beneficial** (they provide essential minerals for life, such as calcium and magnesium), but **some are toxic**, for example compounds of lead and mercury
plastics	**harm aquatic life**, as animals can eat them or be trapped in them
sewage	contains **harmful microbes** that cause disease, such as cholera and typhoid
nitrates (from fertilisers) and **phosphates** (from fertilisers and detergents)	cause plants and algae to grow quickly, and when they die and decay, the microbes use up the oxygen. The water is **deoxygenated** and fish and other aquatic life die

Treating the domestic water supply

Stage	What it does
sedimentation	the water stands in a tank so the larger solid particles settle at the bottom. A chemical can be added to make small particles clump together and settle
filtration	passes through **beds of sand and gravel** to remove the remaining small solids
carbon (activated charcoal)	**removes tastes and odours** from the water
chlorination	**chlorine** is added to **kill microbes** (bacteria and viruses)

10.2 Fertilisers

Plants need the elements **nitrogen, phosphorus and potassium** to grow well. They take them from the soil as ions, and crops remove them, so **fertilisers** replace them.

- **Ammonium salts and nitrates** are used as fertilisers to supply nitrogen, for example ammonium nitrate, NH_4NO_3, ammonium sulfate, $(NH_4)_2SO_4$, and potassium nitrate, KNO_3.
- **NPK fertilisers** contain compounds of all three elements: **N**itrogen, **P**hosphorus and **K**(potassium). They give **improved plant growth** and a higher crop yield.

$$NH_3\,(aq) + HNO_3\,(aq) \longrightarrow NH_4NO_3\,(aq)$$

$$2\,NH_3\,(aq) + H_2SO_4\,(aq) \longrightarrow (NH_4)_2SO_4\,(aq)$$

NOTE

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If too much fertiliser is used, it is washed by rain into rivers and lakes, and the nitrates and phosphates cause **deoxygenation** of the water (see 10.1).

10.3 Air quality and climate

Composition of clean, dry air

Gas	Percentage by volume
nitrogen, N_2	about 78%
oxygen, O_2	about 21%
noble gases (mostly argon) and **carbon dioxide**, CO_2	the remaining 1% or so

Air pollutants

Pollutant	Source	Adverse effect
carbon dioxide, CO_2	**complete combustion** of carbon-containing fuels	a **greenhouse gas**: higher levels lead to **global warming** and **climate change**
carbon monoxide, CO	**incomplete combustion** of carbon-containing fuels	**toxic**: it stops the blood carrying oxygen
particulates (carbon)	incomplete combustion of carbon-containing fuels	increased risk of **respiratory problems and cancer**
methane, CH_4	**decomposition of vegetation** and waste, and gases from the **digestion in animals** (e.g. cattle)	a **greenhouse gas** that causes global warming and climate change
oxides of nitrogen, NO_x	**car engines**	**acid rain**, **photochemical smog** and respiratory problems
sulfur dioxide, SO_2	combustion of **fossil fuels that contain sulfur compounds**	**acid rain**

$$C(s) + O_2(g) \longrightarrow CO_2(g) \quad \text{(complete combustion)}$$

$$2\,C(s) + O_2(g) \longrightarrow 2\,CO(g) \quad \text{(incomplete combustion, with too little oxygen)}$$

The greenhouse effect

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- The **Sun's** radiation passes through the atmosphere and warms the Earth's surface.
- The warm Earth gives out **thermal (infrared) energy**.
- The **greenhouse gases**, **carbon dioxide and methane**, **absorb** some of this thermal energy and **emit** (and reflect) it in all directions, including back towards the Earth.
- This **reduces the thermal energy lost to space**, so the Earth's temperature increases. More greenhouse gas in the air means more warming: this is **global warming**, which leads to **climate change**.

Reducing the effects

Problem	Strategies
climate change	**plant trees** (they remove CO_2 by photosynthesis), **reduce livestock farming** (less methane), **decrease the use of fossil fuels**, and use more **hydrogen** and **renewable energy** (wind, solar)
acid rain	use **catalytic converters** in vehicles, burn **low-sulfur fuels**, and use **flue gas desulfurisation** with calcium oxide to remove SO_2 from power station gases

In flue gas desulfurisation the acidic sulfur dioxide reacts with basic calcium oxide:

$$CaO(s) + SO_2(g) \longrightarrow CaSO_3(s)$$

Oxides of nitrogen and catalytic converters

Oxides of nitrogen form in car engines because the **high temperature** (and the spark) makes **nitrogen and oxygen from the air** react:

$$N_2(g) + O_2(g) \longrightarrow 2\,NO(g)$$

A **catalytic converter** in the exhaust (with platinum and rhodium catalysts) converts the harmful gases into less harmful ones: for example, **carbon monoxide** and **nitrogen oxide** react to give **carbon dioxide** and **nitrogen**:

$$2\,CO(g) + 2\,NO(g) \longrightarrow 2\,CO_2(g) + N_2(g)$$

Photosynthesis

> **Photosynthesis is the reaction between carbon dioxide and water to produce glucose and oxygen, in the presence of chlorophyll and using energy from light.**

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$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{light}} \text{glucose} + \text{oxygen}$$

$$6\,CO_2\,(g) + 6\,H_2O\,(l) \longrightarrow C_6H_{12}O_6\,(aq) + 6\,O_2\,(g)$$

Photosynthesis removes carbon dioxide from the atmosphere and is **endothermic**, using energy from sunlight.

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