IGCSE CHEMISTRY 0620 · CHAPTER 10 NOTES · ~12 MIN READ

Chemistry of the environment

Safe drinking water, what fertilisers do (and the damage they cause), what is in the air, where pollutants come from — and the chemistry behind acid rain and climate change.

Water tests & treatment | Fertilisers | Air composition | Pollutants | Climate change | Acid rain

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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- **Tap water** is made safe by screening, sedimentation, filtering and **chlorination**. It is not pure — **distilled water** is.
- **Fertilisers** supply **nitrogen (N), phosphorus (P) and potassium (K)**. Too much washes into rivers and causes **eutrophication**.
- **Dry air** is about **78% nitrogen, 21% oxygen**, 0.9% argon and 0.04% carbon dioxide.
- **CO_2 and methane** cause **global warming**; **SO_2 and nitrogen oxides** cause **acid rain**. EXT explains how.

BY THE END YOU CAN

- Describe tests for water and the difference between tap water and distilled water.
- Describe how water is treated and the harm done by natural contaminants.
- Describe NPK fertilisers and the problems of fertiliser run-off.
- Give the composition of air, and the sources and effects of air pollutants.
- Describe strategies against climate change and acid rain.
- Explain the greenhouse effect and the role of catalytic converters. EXT

1 Water

Testing for water and checking purity

- **Anhydrous copper(II) sulfate** turns from **white to blue** when water is added. **Cobalt(II) chloride paper** turns from **blue to pink**. (See reversible reactions.)
- These tests show that water is **present** — not that it is **pure**. **Pure water** melts at exactly **0 °C** and boils at exactly **100 °C**. Impurities change these values (see testing purity).

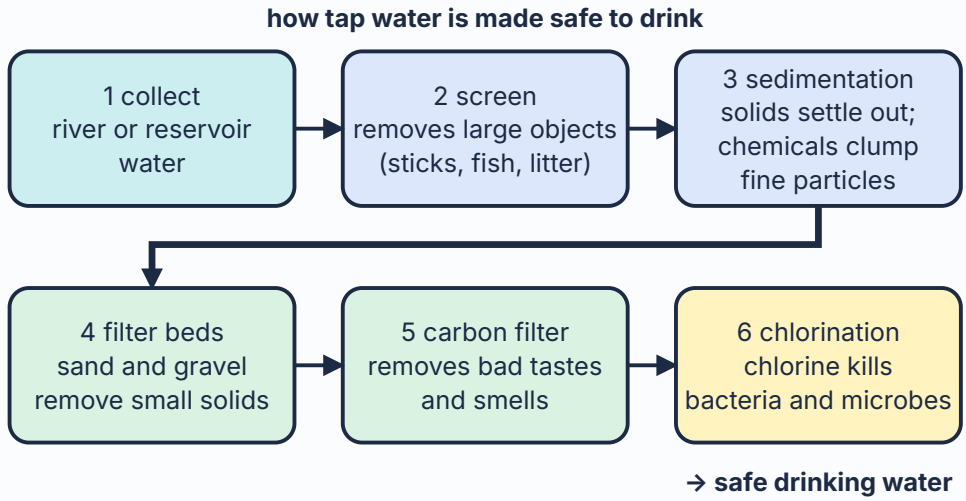
Distilled water — water that has been made pure by distillation. It contains no dissolved substances.

- **Distilled water** is used in chemistry experiments and in car batteries, because dissolved salts would interfere.
- **Tap water** has been treated to be safe to drink but still contains dissolved substances (calcium, magnesium and other salts, and chlorine).

What is in natural water?

Contaminant	Where from	Effect
dissolved oxygen	the air	needed by fish and other aquatic life (this is a **useful** substance)
harmful microbes	sewage and animal waste	cause disease, e.g. cholera and typhoid
nitrates and phosphates	fertilisers, sewage	**eutrophication** — see below
metal compounds (lead, mercury)	industry, old pipes	poisonous — damage the nervous system
plastics	litter, waste	harm and kill marine animals; break into microplastics

How water is made safe to drink



tap water still contains dissolved substances; distilled water is purer

The treatment of drinking water. Each stage removes something different. Chlorine kills microbes that remain.

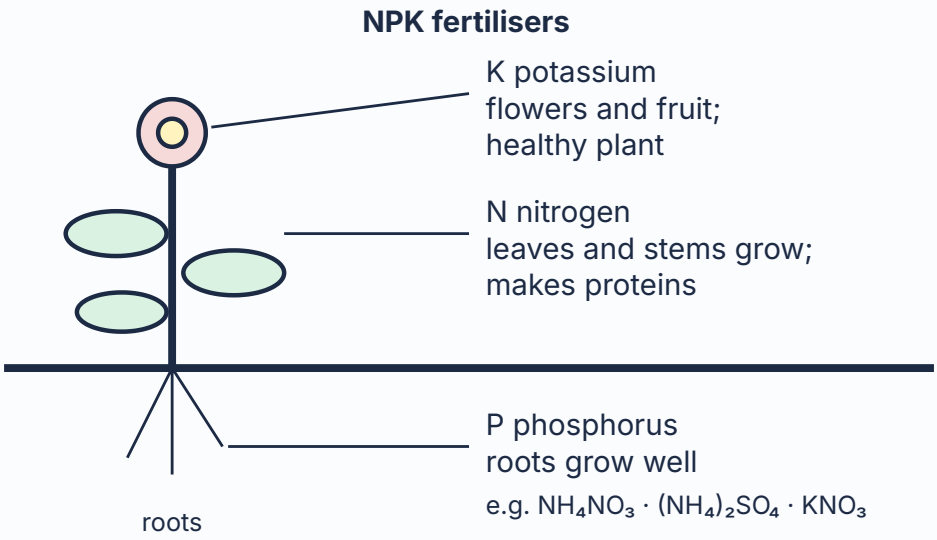
- **Screening:** metal grids remove large objects (sticks, fish, litter).
- **Sedimentation:** the water is left in tanks so that solids settle. Chemicals such as **aluminium sulfate** make the fine particles clump together and sink.
- **Filtration:** sand and gravel filter beds remove the smaller solid particles.
- **Carbon filter:** activated carbon removes the bad tastes and smells.
- **Chlorination:** a little chlorine is added to kill the bacteria and other microbes.
- Distillation gives pure water but takes too much energy to treat large amounts. It is only used where fresh water is very scarce (for example, desalination in some coastal countries).

COMMON MISTAKE

"Chlorine makes the water pure." Chlorine only **kills microbes**. Tap water still contains dissolved substances.

2 Fertilisers

Feeding the crops



The three main plant nutrients. Nitrogen helps leaves and stems grow, phosphorus helps roots, and potassium helps flowers and fruit and keeps the plant healthy.

- Crops remove nitrogen, phosphorus and potassium from the soil. Fertilisers **put them back**, so yields are higher and a growing population can be fed.
- **NPK fertilisers** contain all three elements (N, P and K).
- Common fertilisers are **ammonium salts and nitrates**: ammonium nitrate NH_4NO_3, ammonium sulfate $(NH_4)_2SO_4$, potassium nitrate KNO_3. They are made by **neutralising ammonia** with an acid, for example $NH_3 + HNO_3 \rightarrow NH_4NO_3$.
- Plants can only absorb nutrients in a **soluble** form, so fertilisers must dissolve in water.

$$\%\ \text{of nitrogen} = \frac{\text{mass of N atoms in the formula}}{M_r\ \text{of the fertiliser}} \times 100$$

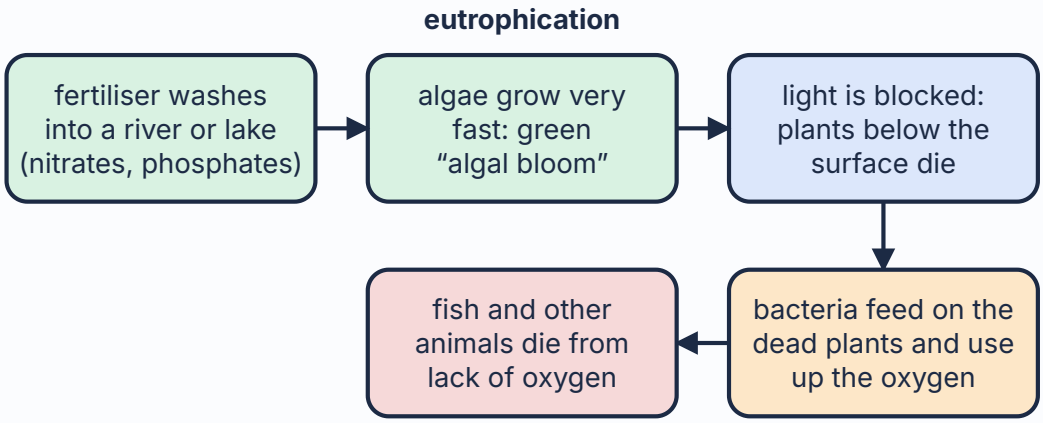
how to compare fertilisers

WORKED EXAMPLE

EXT **Which has the greater percentage of nitrogen, ammonium nitrate NH_4NO_3 or ammonium sulfate $(NH_4)_2SO_4$?**

1. $Mr(NH_4NO_3) = 14 + 4 + 14 + 48 = 80$; $N = 28 \rightarrow 28 \div 80 \times 100 =$ **35%**
2. $Mr((NH_4)_2SO_4) = 132$; $N = 28 \rightarrow 28 \div 132 \times 100 =$ **21%**
3. **ammonium nitrate has more nitrogen per kg**

The problem of eutrophication



prevent it: use less fertiliser · do not spread it before rain · treat sewage

Eutrophication. Fertiliser washes into a lake; algae grow wildly; dead plants rot; bacteria use up the oxygen; fish die.

- **Step 1:** nitrates and phosphates from fertilisers wash into rivers and lakes.
- **Step 2:** algae grow very fast (an **algal bloom**) and cover the surface.
- **Step 3:** light is blocked, so water plants below **die**.
- **Step 4:** bacteria feed on the dead plants and **use up the oxygen**. Fish and other animals **die** from lack of oxygen.
- **Prevention:** use **less fertiliser**, do not spread it just before rain, treat sewage before release.

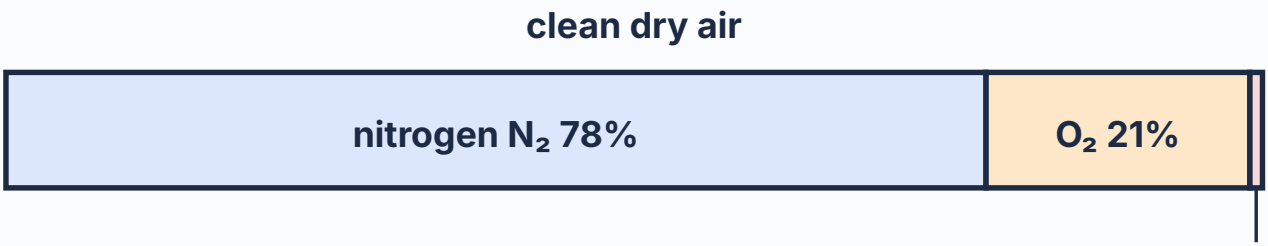
COMMON MISTAKE

Writing that fish die because of "poison". They die from **lack of dissolved oxygen**.

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3 Air

What is in clean, dry air?



argon 0.9% · carbon dioxide 0.04%
neon, helium, krypton, xenon: tiny amounts

the amount of water vapour varies with the weather
nitrogen is unreactive, so most of the air does not take part in burning or rusting

Composition of clean, dry air. Nitrogen and oxygen make up about 99%. The amount of water vapour in real air varies.

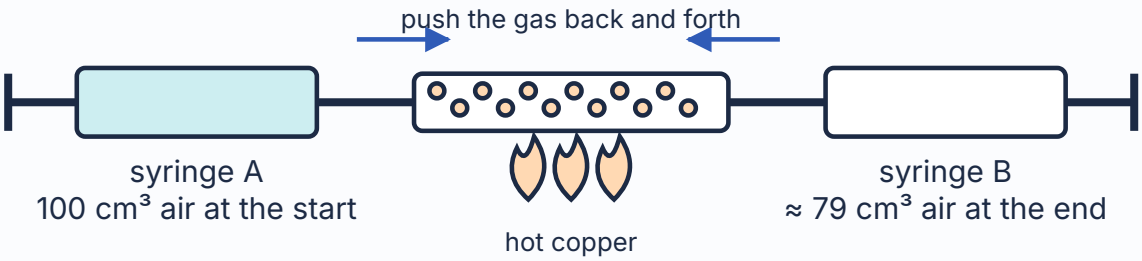
Gas	Percentage
nitrogen	78%
oxygen	21%
argon	0.9%
carbon dioxide	0.04%
neon, helium, krypton, xenon	tiny amounts

- Nitrogen is **unreactive**, so most of the air does not take part in burning or rusting.

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Finding the percentage of oxygen

finding the percentage of oxygen in air



$2Cu + O_2 \rightarrow 2CuO$ (the copper turns black as it uses up the oxygen)
100 − 79 = 21 cm³ of oxygen used

let the apparatus cool to room temperature before reading the final volume

Passing air over hot copper between two gas syringes. The copper turns black as it uses up the oxygen, and the volume of gas falls by about one fifth.

- Pass a known volume of air (100 cm³) over **heated copper** back and forth between two gas syringes. **$2Cu + O_2 \rightarrow 2CuO$** (the copper turns black).
- Let the apparatus **cool to room temperature** before reading the final volume. About **79 cm³** remains, so about **21 cm³** was oxygen.

WORKED EXAMPLE

120 cm³ of air is passed over hot copper until no further change. The final volume is 95 cm³. Find the percentage of oxygen in the air.

1. volume of oxygen used = 120 − 95 = 25 cm³
2. **percentage = 25 ÷ 120 × 100 = 20.8% (about 21%)**

COMMON MISTAKE

Reading the final volume while the apparatus is still hot. Hot gas takes up more room, so the volume that disappeared looks too small and the oxygen percentage comes out too low.

Air pollutants

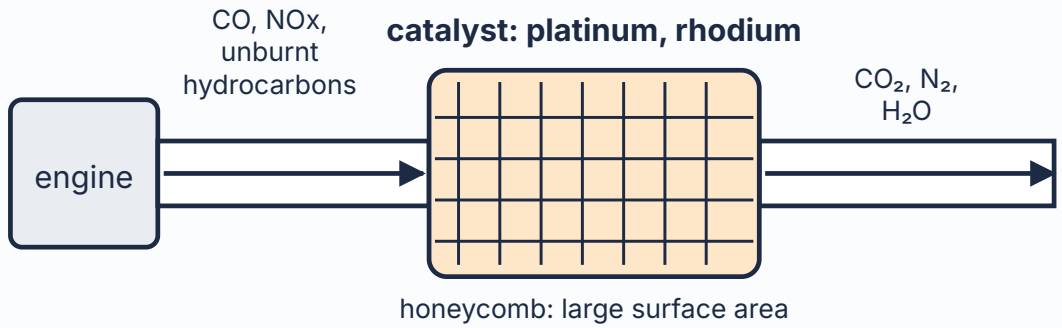
Pollutant	Main source	Effect
carbon monoxide CO	**incomplete combustion** of carbon fuels (car engines)	toxic — stops blood carrying oxygen
sulfur dioxide SO_2	burning fossil fuels that contain sulfur; volcanoes	**acid rain**; breathing problems
nitrogen oxides NO_x	car engines (hot air) and lightning	**acid rain**; breathing problems
unburnt hydrocarbons	car engines	contribute to smog
particulates (soot)	incomplete combustion of fuels	breathing problems
carbon dioxide CO_2	burning fossil fuels, deforestation	**global warming**
methane CH_4	cattle, rice paddies, rotting waste in landfill	**global warming**

- **Complete combustion:** plenty of oxygen → CO_2 + H_2O. **Incomplete combustion:** not enough oxygen → carbon monoxide (and soot) + H_2O. For example: **$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$**.

- EXT **Nitrogen oxides** form in hot engines, where nitrogen and oxygen in the air react: **$N_2 + O_2 \rightarrow 2NO$** (an endothermic reaction — it needs the high temperature; see bond energies).

Catalytic converters

EXTENDED



honeycomb: large surface area

$2CO + 2NO \rightarrow 2CO_2 + N_2$ (harmful gases become harmless ones)

a catalyst speeds up the reaction without being used up

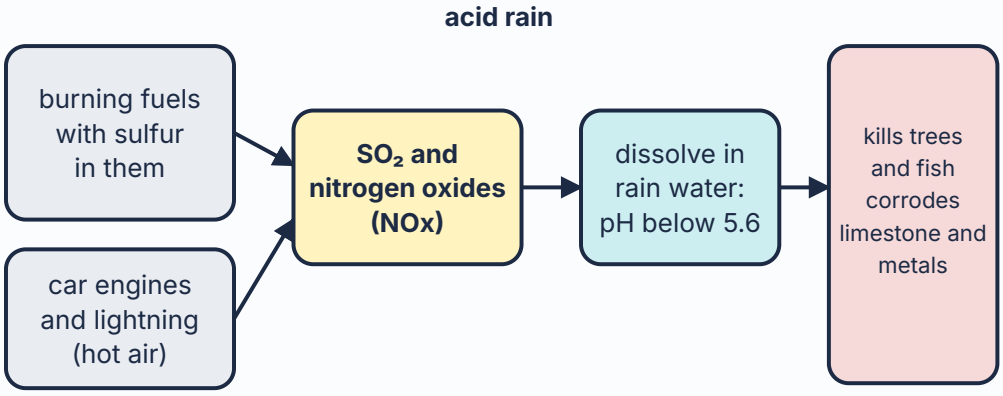
A catalytic converter. A honeycomb coated with platinum and rhodium turns harmful exhaust gases into harmless ones.

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

carbon monoxide and nitrogen monoxide become carbon dioxide and nitrogen

- The honeycomb has a **large surface area**. The catalyst (platinum and rhodium) speeds up the reaction without being used up.

Acid rain



fix it: remove sulfur from fuels · flue gas desulfurisation (calcium oxide reacts with SO_2) · catalytic converters on cars · burn less fossil fuel

Where acid rain comes from, what it does and how it can be reduced.

- **Sources:** SO_2 from burning fossil fuels containing sulfur; nitrogen oxides from car engines.
- They dissolve in rain, so that it has a **pH below 5.6**.
- **Effects:** kills trees and aquatic life (lakes become acidic), corrodes **limestone buildings, statues and metals**.
- **Solutions:** burn **low-sulfur fuel**, **flue gas desulfurisation** (calcium oxide or calcium carbonate reacts with SO_2: $CaO + SO_2 \rightarrow CaSO_3$), **catalytic converters** on cars, and **burn less fossil fuel** (renewable energy).

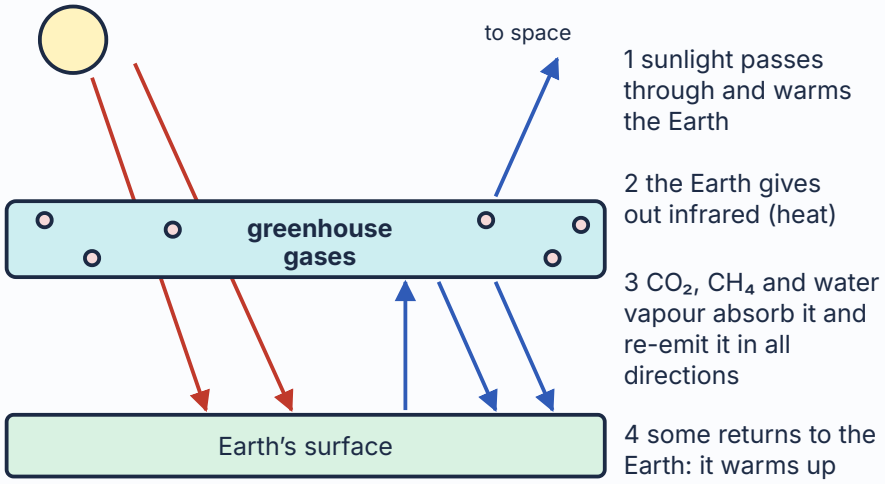
COMMON MISTAKE

Mixing acid rain up with the greenhouse effect. Acid rain is caused by SO_2 and NO_x. Global warming is caused by CO_2 and CH_4.

4 Climate change

The greenhouse effect

EXTENDED



The greenhouse effect. Sunlight warms the Earth. The Earth gives out infrared. Greenhouse gases absorb some of it and re-emit it in all directions, and some returns to Earth.

- The Sun's radiation passes through the atmosphere and **warms the Earth's surface**.
- The warm Earth gives out **infrared radiation** (thermal energy).
- **Greenhouse gases** (CO_2, CH_4 and water vapour) **absorb** some of this infrared and **re-emit** it in all directions. Some of it comes back to the Earth, which warms up further.
- More CO_2 and CH_4 in the air → **enhanced greenhouse effect → global warming and climate change**: melting ice, rising sea levels, extreme weather, changed habitats.
- **CO_2 sources:** burning fossil fuels, deforestation (fewer trees to take in CO_2), making cement. **CH_4 sources:** cattle, rice paddies and rotting waste.

What can we do?

- Use **renewable energy** (wind, solar, hydroelectric) instead of fossil fuels.
- Improve **energy efficiency**, and use public transport, so that less fuel is burned.
- **Plant trees** (afforestation) and stop deforestation: trees take in CO_2 by photosynthesis.
- Capture CO_2 from power stations and store it underground.

Photosynthesis

$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen}$$

word equation (needs light and chlorophyll)

EXT $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

symbol equation

- Photosynthesis takes CO_2 **out** of the air, and respiration and burning put it back. The balance keeps the amount of CO_2 steady — until humans burn fossil fuels and cut down forests. See plant nutrition.

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5 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. What is the difference between tap water and distilled water?
2. Give the order: sedimentation, chlorination, screening, filtration.
3. What do the letters N, P and K stand for in fertilisers?
4. Give the approximate percentages of nitrogen and oxygen in air.
5. Name the pollutant that causes acid rain.
6. Which gas is produced by incomplete combustion and is toxic?
7. EXT What happens to infrared radiation in the greenhouse effect?
8. EXT What does a catalytic converter do?

EXAM-STYLE

9. Explain how fertilisers can cause fish to die in a lake. [4]
10. Describe how water is treated for drinking. [4]
11. EXT Explain how an increase in carbon dioxide can cause global warming. [3]
12. Describe two ways to reduce acid rain. [2]

Show answers

1. tap water contains dissolved salts and chlorine; distilled water is pure
2. screening, sedimentation, filtration, chlorination
3. nitrogen, phosphorus, potassium
4. 78% nitrogen, 21% oxygen
5. sulfur dioxide (also nitrogen oxides)
6. carbon monoxide
7. absorbed by greenhouse gases and re-emitted in all directions, some back to Earth
8. converts CO and NO_x into CO_2 and N_2
9. nitrates and phosphates wash into the lake
   algae grow very quickly and block light so plants die
   bacteria feed on the dead plants and use up oxygen
   fish die from lack of oxygen
10. screening to remove large objects
    sedimentation (with chemicals that clump particles)
    filtering through sand and gravel
    adding chlorine to kill bacteria
11. the Earth emits infrared radiation
    CO_2 absorbs infrared radiation and re-emits it in all directions
    some returns to Earth, so the temperature increases
12. remove sulfur from fuels / flue gas desulfurisation
    catalytic converters on cars / burn less fossil fuel

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