Topic 9: Chemistry of the atmosphere

AQA GCSE Chemistry (8462), topic 4.9

Chemistry of the atmosphere: explain the evidence

- give the composition of today's atmosphere;
- explain one theory of how the early atmosphere formed and changed, and why the evidence is limited;
- explain how oxygen increased and carbon dioxide decreased;

Chemistry of the atmosphere: explain the evidence (2)

- explain the **greenhouse effect**, and judge evidence about climate change and its effects;
- calculate and compare carbon footprints;
- predict the products of burning fuels, and describe the effects of the pollutants and how to reduce them.

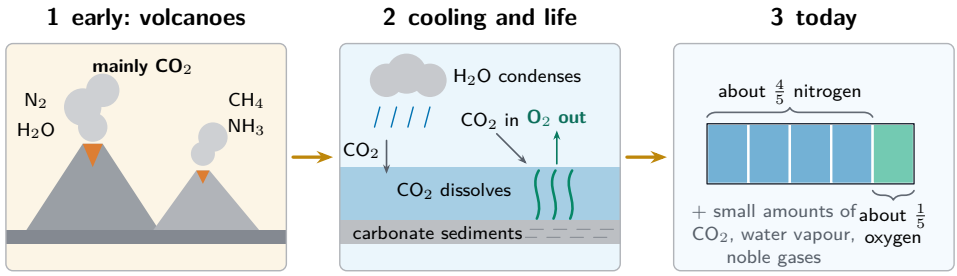
The atmosphere today

- For about the last 200 million years, the atmosphere has been roughly four-fifths (about 80%) nitrogen and one-fifth (about 20%) oxygen.
- The rest is small amounts of other gases: argon and the other **noble gases**, carbon dioxide (about 0.04%), and a varying amount of **water vapour**.
- **Worked example 1.** Estimate the volumes of nitrogen and oxygen in 250 cm^3 of air.
- Nitrogen $= \frac{4}{5} \times 250 = 200$ cm^3; oxygen $= \frac{1}{5} \times 250 = 50$ cm^3.

The early atmosphere

- Earth formed about 4.6 billion years ago.
- Nobody was there to measure the air, and rocks from that time have been changed or destroyed, so the evidence is limited.
- Scientists have theories, which change as new evidence is found.
- One theory is that during the first billion years, intense **volcanic activity** released the gases that formed the early atmosphere.

Figure: The early atmosphere



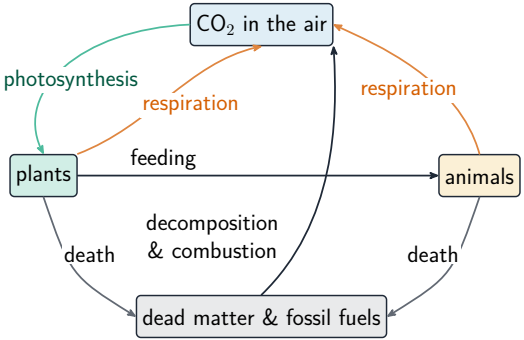
- Volcanoes: mainly CO_2, little or no oxygen.
- Oceans and **algae** later removed CO_2.

How oxygen increased and carbon dioxide decreased

- **Limestone** formed from the calcium carbonate shells and skeletons of sea creatures, which settled on the sea floor and became rock. The White Cliffs of Dover are made of chalk, a kind of **limestone**, formed from tiny shells in this way.
- **Coal** formed from plants that were buried in swamps before they could decay, then squeezed and heated over millions of years.
- **Crude oil** and **natural gas** formed from the remains of tiny sea creatures, buried in mud and changed by heat and pressure.

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

Figure: How oxygen increased and carbon dioxide decreased

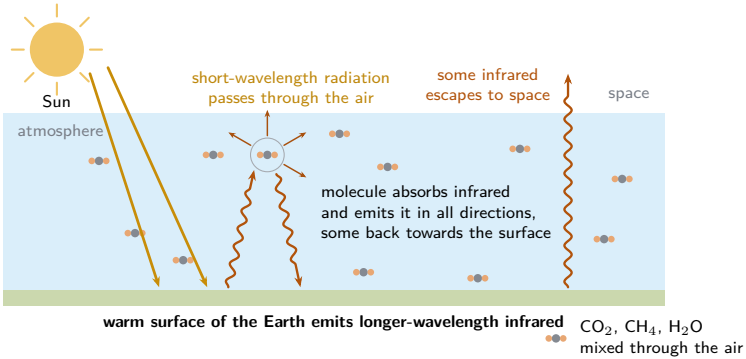


- The carbon cycle: **photosynthesis** removes CO_2; **respiration**, combustion and decay return it
- Match each part of the diagram to the text.

The greenhouse effect

- Each **greenhouse gas** , such as **water vapour**, carbon dioxide or **methane**, keeps the Earth warmer than it would otherwise be.
- Without any **greenhouse effect**, the average surface temperature would be about -18 °C instead of about 15 °C, too cold for most life.
- This is how the **greenhouse effect** works:
- 1.

Figure: The greenhouse effect



- Sunlight in; infrared out; gases absorb and re-emit.
- Less energy escapes, so the surface warms.

Human activities and climate evidence

- **Carbon dioxide** is increased by burning fossil fuels and by **deforestation**, which means fewer trees to remove carbon dioxide, and often burning or rotting wood. **Methane** is increased by cattle farming (cows release **methane** as they digest grass), by rice fields, and by organic waste rotting in **landfill** sites.
- **Judging evidence.** Most scientists agree that human activities are increasing the average global temperature.

Human activities and climate evidence (2)

- Their evidence comes from many independent measurements: temperature records, ice cores, sea levels and the Keeling curve.
- Their work goes through **peer review** : other experts check the methods and conclusions before a study is published.

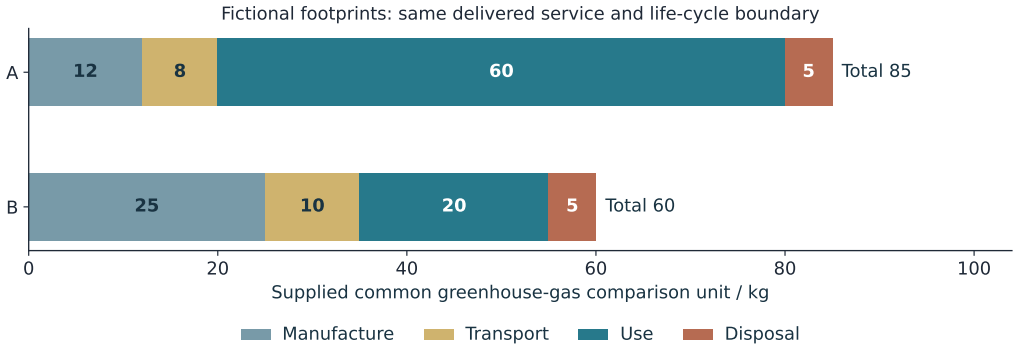
Effects of climate change

- rising sea levels, which can flood low-lying coasts and islands; sea level rises because water expands as it warms (**thermal expansion**) and because ice on land melts;
- more frequent and more severe storms, heatwaves and floods;
- changes in the amount and timing of rainfall, which can cause droughts or damage crops;
- changes to habitats, so that some species must move or die out, and pests and diseases can spread to new areas.

Carbon footprints

- Total for A $= 12 + 8 + 60 + 5 = 85$ kg; total for B $= 25 + 10 + 20 + 5 = 60$ kg.
- B is lower overall, even though it costs more carbon to make.
- Percentage reduction $= (85 - 60)/85 \times 100 = 29.4\%$.

Figure: Carbon footprints



- Equal-service life-cycle totals: A85kg and B60kg in supplied common unit.
- Match each part of the diagram to the text.

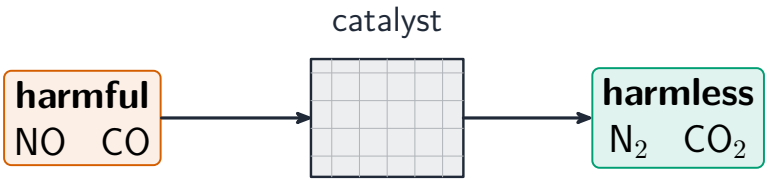
Pollutants from burning fuels

- Complete combustion of a **pure hydrocarbon** in plenty of oxygen gives carbon dioxide and water: $\mathrm{CH_4} + 2\mathrm{O_2} \rightarrow \mathrm{CO_2} + 2\mathrm{H_2O}$.
- **Incomplete combustion** , in too little oxygen, also gives **carbon monoxide** and **soot** , solid carbon particles. **Particulates** are small solid particles and unburnt hydrocarbons released into the air.

Pollutants from burning fuels (2)

- Sulfur in the fuel burns to form sulfur dioxide: $\mathrm{S} + \mathrm{O}_2 \rightarrow \mathrm{SO}_2$.
- In the high temperature of an engine, nitrogen and oxygen from the air react to form **nitrogen oxides** (NO_x). The nitrogen comes from the air, not the fuel.

Figure: Pollutants from burning fuels



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

- A **catalytic converter** uses **carbon monoxide** to reduce nitrogen monoxide to nitrogen, forming carbon dioxide
- Match each part of the diagram to the text.

Sources for this lesson

- AQA, *GCSE Chemistry (8462) specification*, section 4.9.
- C. D. Keeling, "The concentration and isotopic abundances of carbon dioxide in the atmosphere", *Tellus* (1960), and Scripps Institution of Oceanography / NOAA, Mauna Loa CO_2 record (May 2024 monthly mean).
- NASA Goddard Institute for Space Studies, *GISTEMP* global temperature analysis (2023 anomaly).

Sources for this lesson (2)

- Intergovernmental Panel on Climate Change, *Sixth Assessment Report: Summary for Policymakers* (2021).
- UK Met Office, "The Great Smog of 1952".

Common errors

- Saying the **greenhouse effect** is caused by the hole in the ozone layer; they are different problems.
- Saying greenhouse gases reflect heat like a mirror; they absorb and re-emit **infrared radiation**.
- Saying the greenhouse effect is entirely harmful; without it the Earth would be too cold for life.

Common errors (2)

- Confusing **carbon monoxide** (poisonous) with carbon dioxide (a **greenhouse gas**).
- Saying the nitrogen in **nitrogen oxides** comes from the fuel; it comes from the air.
- Counting only the use stage of a carbon footprint and forgetting manufacture, transport and disposal.
- Saying melting sea ice raises sea level; floating ice does not. Melting land ice and thermal expansion do.

Key terms

- **Photosynthesis**: the process in which plants and **algae** use light to make glucose and oxygen from carbon dioxide and water.
- **Fossil fuel**: **coal**, **crude oil** or natural gas, formed from the remains of living things over millions of years.
- **Greenhouse gas**: a gas, such as carbon dioxide, methane or water vapour, that absorbs and emits infrared radiation.

Key terms (2)

- **Carbon footprint**: the total greenhouse gases emitted over the full **life cycle** of a product, service or event.
- **Incomplete combustion**: burning in too little oxygen, which can produce **carbon monoxide** and **soot**.
- **Acid rain**: rain made acidic by dissolved sulfur dioxide or nitrogen oxides.
- **Global dimming**: the reduction in sunlight reaching the Earth's surface caused by particulates.

Check yourself

- 1.
- Roughly what fraction of today's atmosphere is oxygen? 2.
- Why is the evidence about Earth's early atmosphere limited? 3.
- Give two ways in which carbon dioxide was removed from the early atmosphere. 4.