Modern Atmosphere
The proportions of different gases in the atmosphere
- For 200 million years, the proportions of different gases in the atmosphere have been much the same as they are today:
  - about four-fifths (approximately 80%) nitrogen \( \text{N}_2 \)
  - about one-fifth (approximately 20%) oxygen \( \text{O}_2 \)
  - small proportions of various other gases, including carbon dioxide, water vapour and noble gases.

Earth’s Early Atmosphere
One theory suggests that during the first billion years of the Earth’s existence there was intense volcanic activity that released gases that formed the early atmosphere and water vapour that condensed to form the oceans.
At the start of this period the Earth’s atmosphere may have been like the atmospheres of Mars and Venus today, consisting of mainly carbon dioxide with little or no oxygen gas (\( \text{O}_2 \)).

When the oceans formed carbon dioxide dissolved in the water and carbonates were precipitated producing sediments, reducing the amount of carbon dioxide in the atmosphere.

How oxygen increased
Algae and plants produced the oxygen that is now in the atmosphere by photosynthesis, which can be represented by the equation:

\[
6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

carbon dioxide + water \( \rightarrow \) glucose + oxygen
Algae first produced oxygen about 2.7 billion years ago and soon after this oxygen appeared in the atmosphere.
Over the next billion years plants evolved and the percentage of oxygen gradually increased to a level that enabled animals to evolve.

How carbon dioxide decreased
- Algae and plants decreased the percentage of carbon dioxide in the atmosphere by photosynthesis.
- Carbon dioxide dissolve in the newly formed oceans
- Carbon dioxide was also decreased by the formation of sedimentary rocks and fossil fuels that contain carbon.
- Limestone is a sedimentary rock, mainly calcium carbonate, formed from the shells and skeletons of marine organisms.
- Coal is a sedimentary rock formed from thick plant deposits that were buried and compressed over millions of years.
- The remains of plankton were deposited in muds on the sea floor and were covered over and compressed over millions of years producing crude oil and natural gas that became trapped in the rocks.

How nitrogen increased
- Volcanoes produced nitrogen
- Denitrifying bacteria produced nitrogen
- Ammonia reacted with oxygen to produce nitrogen
- Volcanoes also produced nitrogen which gradually built up in the atmosphere and there may have been small proportions of methane (\( \text{CH}_4 \)) and ammonia (\( \text{NH}_3 \)).
Increases in Greenhouse gases

Some human activities are contributing to an increase in greenhouse gases in the atmosphere. These include:

- carbon dioxide
  - combustion of fossil fuels
  - deforestation
- Methane
  - more animal farming (digestion, waste decomposition)
  - decomposition of rubbish in landfill sites.

The increase in the percentage of carbon dioxide in the atmosphere over the last 100 years correlates with the increased use of fossil fuels. Based on peer-reviewed evidence, many scientists believe that human activities will cause the temperature of the Earth's atmosphere to increase at the surface and that this will result in global climate change.

Global climate change

An increase in average global temperature is a major cause of climate change. The potential effects of global climate change include:

- sea level rise, which may cause flooding and increased coastal erosion
- more frequent and severe storms
- changes in the amount, timing and distribution of rainfall
- temperature and water stress for humans and wildlife
- changes in the food-producing capacity of some regions
- changes to the distribution of wildlife species

The carbon footprint and its reduction

The carbon footprint is the total amount of carbon dioxide and other greenhouse gases emitted over the full life cycle of a product, service or event.

Actions to reduce the carbon footprint include:

- increased use of alternative energy supplies
- energy conservation
- carbon capture and storage (where CO₂ is trapped in solvents and stored underground)
- carbon taxes and licences
- carbon off-setting including through tree planting
- carbon neutrality – zero net release.

Problems of reducing the carbon footprint include:

- scientific disagreement over causes and consequences of global climate change
- lack of public information and education
- lifestyle changes (people don’t want to give up their cars)
- economic considerations (it will cost money)
- incomplete international co-operation
Combustion of Fuels and Pollution

The combustion of fuels is a major source of atmospheric pollutants. The gases released into the atmosphere when a fuel burns may include carbon dioxide (CO₂), water (vapour), carbon monoxide (CO).

**Complete combustion**
Complete combustion of hydrocarbons occurs when there is a plentiful oxygen supply.

\[ \text{Hydrocarbon} + \text{Oxygen} \rightarrow \text{Carbon dioxide} + \text{Water} \]
\[ \text{e.g. CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]

**Incomplete combustion**
Incomplete combustion occurs if the oxygen supply is limited and carbon monoxide (CO) and soot (carbon) in particle form is produced as well as water. Carbon monoxide is a toxic gas. It is colourless and odourless and so is not easily detected. Carbon monoxide combines with haemoglobin in the blood reducing its capacity to carry oxygen.

**Pollution from Combustion**
The gases released into the atmosphere when a fuel burns may include carbon dioxide, water (vapour), carbon monoxide and sulfur dioxide and oxides of nitrogen. Solid particles and unburned hydrocarbons may also be released that form particulates in the atmosphere.

**Sulfur dioxide**
Some fuels may also contain sulfur. The sulfur impurities in the fuel burn and oxidise to produce sulfur dioxide:
\[ \text{S} + \text{O}_2 \rightarrow \text{SO}_2 \]

**Sulfur dioxide and oxides of nitrogen**
- Sulfur dioxide and oxides of nitrogen cause respiratory problems in humans and cause acid rain.
- Acid rain damages plants and buildings.

**Nitrogen oxides (NOₓ)**
Oxides of nitrogen (NO or NO₂) are produced by the reaction of nitrogen and oxygen from the air at the high temperatures involved when fuels are burned.
\[ \text{N}_2 + \text{O}_2 \rightarrow 2\text{NO} \quad \text{or} \quad \text{N}_2 + 2\text{O}_2 \rightarrow 2\text{NO}_2 \]

**Particulates**, such as carbon particles, cause global dimming, reducing the amount of sunlight that reaches the Earth’s surface. Particulates cause health problems for humans because of damage to the lungs.

**The advantages of complete combustion**
- less soot is made with complete combustion
- more heat per gram of fuel is released with complete combustion
- poisonous carbon monoxide is not produced with complete combustion

Most fuels contain carbon and/or hydrogen.

The combustion of hydrocarbon fuels releases heat in what is called an exothermic reaction. During combustion the carbon and hydrogen in the fuels are oxidised.

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