4.9 Chemistry of the Atmosphere

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 N_2
- about one-fifth (approximately 20%) oxygen 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 (**O_2**).

Theories about what was in the Earth's early atmosphere and how the atmosphere was formed have changed and developed over time. Evidence for the early atmosphere is limited because of the time scale of 4.6 billion years.

Volcanoes also produced **nitrogen** which gradually built up in the atmosphere and there may have been small proportions of **methane (CH_4)** and **ammonia (NH_3)**.

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:

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

carbon dioxide + water → 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 nitrogen increased

- Volcanoes produced nitrogen
- Denitrifying bacteria produced nitrogen
- Ammonia reacted with oxygen to produce nitrogen

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 fuel**s 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.

Greenhouse Effect and Global Warming

Greenhouse gases and the Greenhouse effect
Greenhouse gases in the atmosphere maintain temperatures on Earth high enough to support life. They allow **short wavelength** radiation to pass through the atmosphere to the Earth's surface but **absorb** the **outgoing long wavelength** radiation from the Earth causing an increase in temperature.
Water vapour, carbon dioxide and methane are greenhouse gases

The greenhouse effect is a natural phenomena. Without it the earth would be too cold for life to exist

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.

It is difficult to model such complex systems as global climate change. This leads to simplified models, speculation and opinions presented in the media that may be based on only parts of the evidence and which may be biased.

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 CO_2 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 (CO_2), water (vapour), carbon monoxide (CO).**

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**.

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

Hydrocarbon + Oxygen → Carbon dioxide + Water
e.g. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

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

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 $S + O_2 \rightarrow SO_2$

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

Nitrogen oxides (NO_x)
Oxides of nitrogen (NO or NO_2) are produced by the reaction of **nitrogen** and oxygen **from the air** at the **high temperatures** involved when fuels are burned.
$N_2 + O_2 \rightarrow 2NO$ or $N_2 + 2O_2 \rightarrow 2NO_2$

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.**