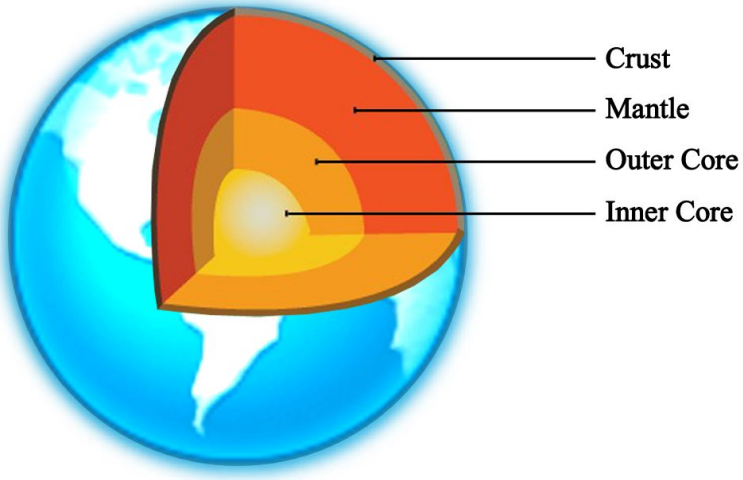
WJEC Wales Chemistry GCSE

1.4: The ever-changing Earth

Detailed notes

The structure of the Earth



There are 4 main layers to the Earth:

- Solid iron inner core - the very centre of the Earth is a solid metal ball 2,500 km wide that contains iron and nickel. Its temperature is between 5,000 - 6,000 °C.
- Molten iron outer core - the outer core is composed of liquid iron, nickel, sulphur and oxygen and is over 5,000 km deep. Its temperature is between 4,000 - 6,000 °C.
- Mantle - the mantle is made of very slowly moving solid and liquid rock. The mantle nearer to the core is hotter and is a slow moving liquid while the mantle nearer to the surface of the Earth is much cooler so is a solid. The slow movement of the mantle is what causes the crust to move. The lower mantle (closer to the coil) is around 3,000 °C while the upper mantle is between 1,500 - 3,000°C.
- Crust - this is the thinnest layer of the Earth, as thin as 7km and as thick as 80km.

The Earth's lithosphere is the solid, outermost part of the Earth, consisting of the Earth's crust and the upper part of the mantle. Above the lithosphere is the atmosphere which contains the gases surrounding the Earth.

Tectonic plate theory

Overview

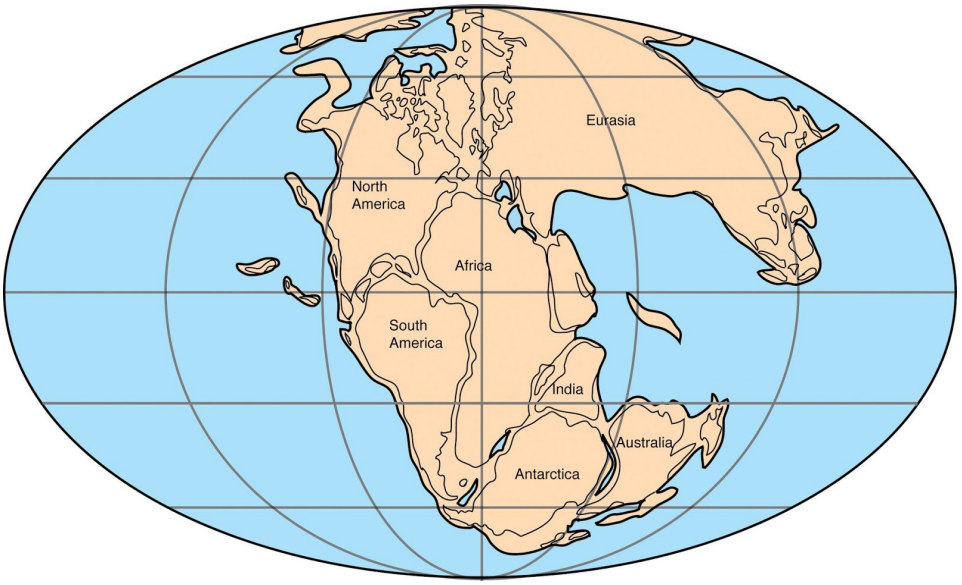
The theory of tectonic plates is the idea that the Earth's lithosphere is divided into separate parts, known as tectonic plates, that move over the mantle at a rate of a couple of centimetres per year, in a process known as continental drift. Continental drift is due to convection currents in the Earth's mantle, created by the difference in temperature between the inner core and surface of the Earth, causing slow movement of the mantle that in turn shifts the plates resting on it.

Alfred Wegener

This theory was first proposed by Alfred Wegener. He thought the continents all used to be joined together in a supercontinent called Pangaea and that the Earth's crust and upper mantle was made of sections that drifted apart over millions of years. Evidence to support this was:

- Visibly, the continents do look as though they once fit together like a jigsaw

- Fossils from the same species were found on continents that are now separate but were once connected in Pangaea
- The patterns of rock formation is similar on both sides of the Atlantic



The supercontinent Pangaea

Image from geologypage.com

Plate boundaries

Wegener's theory also gave an explanation for how mountains form when plates collide. Before his theory it was thought mountains formed as a result of the crust cooling; however mountains are not evenly distributed around the world, so this is not the case. There are 3 types of plate boundaries and different physical events occur at each of them:

Destructive/convergent boundaries

- This boundary occurs when 2 plates move towards each other.
- The more dense of the 2 plates is pushed beneath the other, causing it to melt.
- This forms magma which then rises up between the 2 plates, creating a volcano or causing an earthquake, depending on whether the surface of the crust is breached or not.
- The magma then cools and solidifies to form igneous rock.

Constructive/divergent boundaries

- This boundary occurs when 2 plates move away from each other.
- Magma from the mantle rises up and forms new rock to fill the gap created. In some cases, the pressure is high enough to cause a volcanic eruption.

Conservative boundaries

- This boundary occurs when 2 plates slide past each other.
- If the movement is sudden and large enough then there is an earthquake.
- No volcanoes occur at these boundaries.

The early atmosphere

Evidence of gas composition of the early atmosphere is limited because of the age of the Earth - 4.6 billion years. 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
  - At the start of this period, the atmosphere may have been like the atmospheres' of Mars and Venus today, mainly CO_2 with little or no O_2
  - Volcanoes also produced small proportions of methane and NH_3
- The Earth cooled, allowing water vapour to condense and form the oceans
  - CO_2 dissolved in the water and carbonates were precipitated producing sediments, reducing the amount of CO_2 in the atmosphere

Present atmosphere and its change over time

The proportions of different gases in the present atmosphere

- For 200 million years, the proportions of different gases in the atmosphere have been much the same as they are today:
  - 78% nitrogen
  - 21% oxygen
  - Small proportions of various other gases, i.e. CO_2 (0.04%), $H_2O(g)$ and noble gases (0.9% argon and a small amount of neon)
- The composition of gases in the present atmosphere is maintained by 3 main processes:
  - Combustion - the burning of fuels in oxygen releases stored carbon into the atmosphere as carbon dioxide. This increases CO_2 concentrations and decreases O_2 concentrations.
  - Respiration - in living cells the process of aerobic respiration uses oxygen gas and glucose to release energy; this in turn releases carbon dioxide and water:
    $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
    Glucose + oxygen $\rightarrow$ carbon dioxide + water
  - Photosynthesis - plants react carbon dioxide and water together using energy from sunlight to produce their own food in the following reaction:
    $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
    Carbon dioxide + water $\xrightarrow{\text{(light)}}$ glucose + oxygen

The composition of the present atmosphere is very different to that of the early atmosphere, with the large changes in the concentrations of carbon dioxide and oxygen.

How oxygen increased

- Algae and plants produced the O_2 that is now in the atmosphere by photosynthesis
- Algae first produced oxygen about 2.7 billion years ago
- Over the next billion years plants evolved and the concentration of oxygen gradually increased to a level that enabled animals to evolve

How carbon dioxide decreased

- Algae and plants decreased the concentration of CO_2 in the atmosphere by photosynthesis

- CO_2 was also decreased by the formation of sedimentary rocks and fossil fuels that contain carbon
- Carbon dioxide dissolved in the ocean

How methane and ammonia decreased

As oxygen levels increased:

- Ammonia reacted with oxygen to form nitrogen and water
  $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$
- Methane reacted with oxygen to form carbon dioxide and water
  $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Carbon dioxide

Up until the last 100 years, the processes of combustion, respiration and photosynthesis balanced each other out to keep the levels of carbon dioxide and oxygen constant. However, in the last 100 years the concentration of carbon dioxide has risen considerably. The reasons for this include:

1. Deforestation
   - The burning of forests itself releases carbon dioxide through the reaction of carbon-containing material in the plants with oxygen.
   - It also removes photosynthesising plants, so less carbon dioxide is removed from the atmosphere.
2. Increased burning of fossil fuels
   - The combustion of fuels for energy releases carbon dioxide as a byproduct
3. Population growth
   - Growing populations of humans and animals means more respiration
   - Increases the demand for energy and therefore increases the burning of fossil fuels
   - More land is needed for agriculture, so deforestation increases.

Global warming

The increase in levels of carbon dioxide and other greenhouse gases leads to global warming.

- An increase in average global temperature is a major cause of climate change
- There are several potential effects of global climate change
  - Destruction of animal habitats that may cause extinction of species
  - Rising sea levels due to the melting of polar ice caps
  - Increased risk of skin cancer due to more dangerous UV rays hitting the surface of the Earth
  - More extreme weather conditions (such as droughts)

Addressing the problems of global warming

If these effects want to be avoided in the future, then steps must be taken to reduce carbon dioxide levels.

- Reduce fossil fuel usage
  - This can be done by using renewable energy sources such as solar panels, wind turbines and geothermal energy

    - Advertising ways to use less energy such as turning off light switches and not leaving devices on standby.
    - More eco-friendly travel - driving electric cars, car sharing or using public transport
    - Recycling and reusing more. This requires much less energy and raw materials than having to make products from scratch again
    - Turning down the heating and instead wearing an extra layer of clothes
- Reforestation and creation of more green areas
- International deals and targets for emissions between countries

Sulfur dioxide

Most fuels, including coal, contain carbon and/or hydrogen and may also contain some sulfur

- When the fuels are burnt in oxygen, this sulfur can react to form sulfur dioxide:
  $S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$
- When sulfur dioxide dissolves in rainwater sulfuric acid, H_2SO_4, forms, making acid rain which:
    - Damages buildings and statues (made of limestone)
    - Causes corrosion of metal
    - Reduces the growth of or kills trees and crops
    - Lowers pH of water in lakes, killing fish
- To avoid this problem, sulfur scrubbing can be used. This is a technique that removes 95% of sulfur dioxide from gases released by burning fuels.

Chemical tests

Test for oxygen

A glowing splint will relight if placed into a test tube containing oxygen gas.

Test for carbon dioxide

When bubbled through limewater, carbon dioxide causes it to go cloudy due to the formation of a precipitate of calcium carbonate.