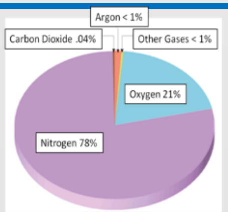
Topic 9 – Chemistry of the Atmosphere

science chemistry

Early atmosphere (4.6 billion years ago)

The Earth's early atmosphere mainly contained gases that came from volcanoes.
This early atmosphere is thought to have contained:
no oxygen (or very little)
large amounts of carbon dioxide
large amounts of water vapour
small amounts of other gases such as nitrogen and ammonia

Present day atmosphere



78% nitrogen
21% oxygen
0.04% carbon dioxide
<1% argon and other noble gases
and water vapour.
Small changes in today's atmosphere are still happening as a result of:

- volcanoes
- human activity (such as burning fossil fuels, deforestation and farming)
- Increases in CO_2 due to burning fossil fuels leads to global warming.

The greenhouse effect

Short wavelength radiation passes through atmosphere to Earth's surface. Earth's surface radiates different wavelengths some of which (longer wavelengths) are absorbed by greenhouse gases to produce temperature increases.
Main greenhouse gases are CO_2, CH_4 & H_2O

Consequences of climate change

- Sea level rise, flooding etc

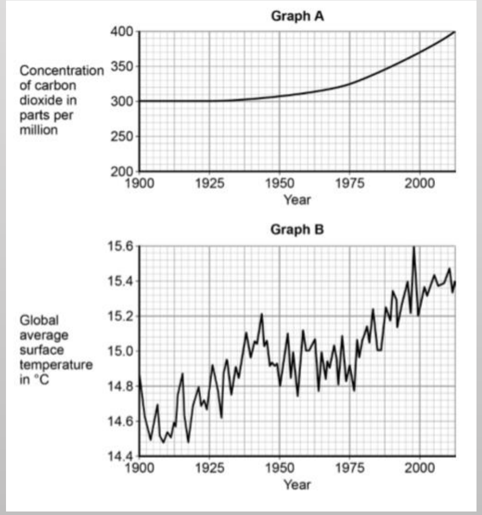
More storms
Changes to rainfall

- Changes in temperature
- Changes to food producing capacity
- Changes to distribution of wildlife

Why did the atmosphere change?

There are different sources of information about the development of the atmosphere. This makes it very difficult to be precise about how it changed. Some of the evidence from elsewhere in the solar system (such as the planet Venus or the moons of Saturn) is contradictory. Importance of peer review (evidence that is checked by other scientists)
The early Earth was very hot. When it cooled, much of the water vapour in the atmosphere condensed to form the oceans.
There is very little carbon dioxide in today's atmosphere so there must have been many ways in which the amount was reduced:
Much of the carbon dioxide dissolved in the oceans.
This dissolved carbon dioxide was used by sea organisms to make shells (which are mainly calcium carbonate). These shells later sank to the bottom to become part of sedimentary rocks such as limestone ("locked up" carbon refers to carbon that is in sedimentary rocks and fossil fuels).

When plants evolved, they used up some of the carbon dioxide in photosynthesis.
The first plants or algae were also able to produce oxygen by photosynthesis so the amounts of oxygen in the atmosphere gradually increased.
Carbon dioxide + water → glucose + oxygen
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$



Carbon footprint

Carbon footprint is the total amount of CO_2 and other greenhouse gases emitted over the full life cycle of the product / service.

Can be reduced using:

- Alternative energy supplies
- Energy conservation
- Carbon capture and storage
- Carbon taxes and licences
- Carbon off setting (e.g. tree planting)
- Carbon neutrality

Atmospheric pollutants

Combustion of fossil fuels (hydrocarbons) will produce water and then either carbon dioxide, carbon monoxide or carbon (soot)
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (complete combustion in a plentiful supply of oxygen)

$CH_4 + 1.5O_2 \rightarrow CO + 2H_2O$ (incomplete combustion in a limited supply of oxygen)
$CH_4 + O_2 \rightarrow C + 2H_2O$ (incomplete combustion in a limited supply of oxygen)

Carbon monoxide is a colourless, odourless, toxic gas which binds to your haemoglobin preventing respiration from occurring.

Particulates / carbon (soot) can lead to global dimming and also respiratory problems.

Coal also contains sulfur which when burnt produces SO_2

At high temperatures (inside an engine) nitrogen and oxygen from the air can react together to produce nitrogen oxides (NO_x)
$N_2 + O_2 \rightarrow 2NO$

Both these oxides of sulfur and nitrogen can lead to an increase in acid rain.

Unburnt fuels and soot called particulates can also cause breathing problems

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Topic 10 – Using Resources

1) Sustainable Development

Any development that meets the needs of current generations without compromising the ability of future generations to meet their own needs (without damaging the lives of future generations).
3 ways to improve sustainability are to **reduce** amount of raw materials used, **reuse** products or **recycle** them.

2) Finite and Renewable

- Finite resources are those being used up faster than they can be replaced (coal, oil, gas, nuclear).
- Renewable resources are those that can be replaced at the same rate (or faster) than they are being used up (biofuels).
- Biofuels are fuels derived from renewable sources such a plants (e.g. biodiesel).
- Examples of natural products that are supplemented / replaced by agricultural or synthetic products include wood with PVC and cotton with polyester.

3) Potable Water

- This is water that is safe to drink for humans. It should have sufficiently low levels of dissolved salts and microbes.

Potable water is not pure water (pure means nothing in it) as it contains dissolved substances.

In the UK, rain provides most of our fresh water that collects in the ground and in lakes and rivers. Most of our potable water is produced by using a suitable source of fresh water and…

- Passing the water through filter beds
- Sterilising (using chlorine, ozone or ultraviolet light).

If supplies of fresh water are limited, desalination of salt water (sea water) can be done by either:

- Distillation (boiling it to removed dissolved salts)
- Reverse osmosis (using membranes that only allows water molecules through).

Both these processes require lots of energy.

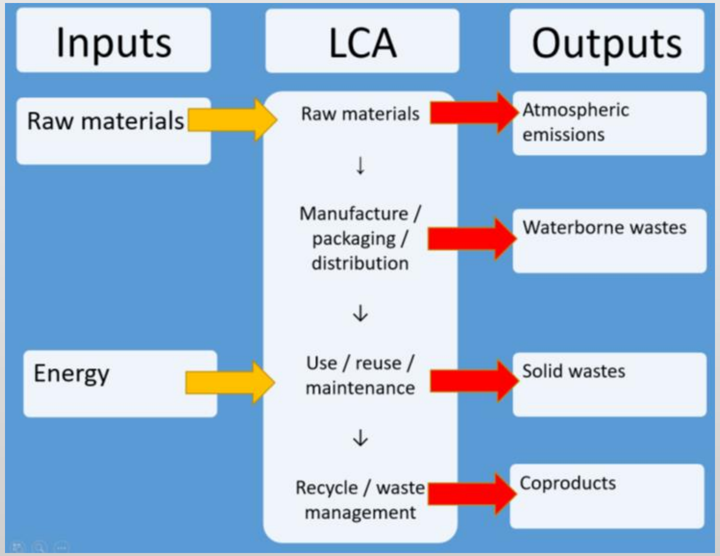
4) Life cycle assessment and recycling

Life cycle assessments (LCAs) are carried out to assess the environmental impact of a product over it lifetime. We consider each of these stages:

- Extracting and processing raw materials
- Manufacturing and packaging
- Use & maintenance during its lifetime
- Disposal at the end of its useful life.

Use of water, raw materials, energy sources and production of some wastes can be fairly easily quantified. Allocating numerical values to pollutant effects is less straightforward and could be biased by a person's opinion

Selective or abbreviated LCAs can be devised to evaluate a product but these can be misused to reach pre-determined conclusions, e.g. for positive advertising.



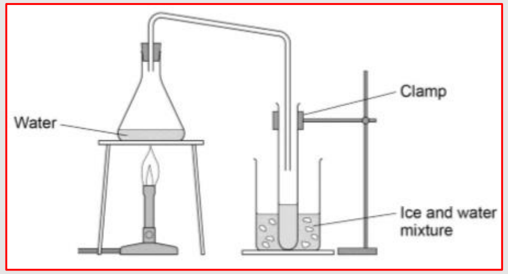
5) Waste water treatment

Sewage, agricultural and industrial waste water may require removal of organic matter, harmful microbes and chemicals.
Sewage treatment includes:

- screening and grit removal
- sedimentation to produce sewage sludge and effluent
- aerobic biological treatment of effluent (released back into river)
- anaerobic digestion of sewage sludge (used as fuel or fertiliser)

Required Practical – Water purification & analysis

- Measure the mass of the water before & after heating to dryness to determine the mass of dissolved solids.
- Universal indicator can be used to measure the pH.
- Cobalt chloride paper (goes from blue to pink in the presence of water) can be used to test for water but this does not test if the water is safe to drink.



6) Ways of reducing the use of resources

- The reduction in use, reuse and recycling of materials such as metals, glass, plastics) reduces the use of limited resources, energy sources, waste & environmental impacts.
- Much of the energy for the processes comes from limited resources. Obtaining raw materials from the Earth by quarrying and mining causes environmental impacts.
- Glass bottles can be crushed and melted to make different glass products.
- Metals can be recycled by melting and recasting / reforming into different products (e.g. scrap steel can be added to iron from a blast furnace to reduce the amount of iron ore used.

7) Alternative methods of extracting metals (HT only)

The Earth's resources of metal ores are limited. Copper ores are becoming scarce and new ways of extracting copper from low-grade ores are needed which avoid traditional mining methods of digging, moving and disposing of large amounts of rock.

- Phytomining uses plants to absorb metal compounds. The plants are harvested and then burned to produce ash that contains metal compounds.
- Bioleaching uses bacteria to produce leachate solutions that contain metal compounds.

Copper can be obtained from solutions of these metal compounds by displacement using scrap iron or by electrolysis.

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Topic 10 – Using Resources (Single Chemistry ONLY)

science chemistry

8) Corrosion and its prevention

- Corrosion is the destruction of materials by chemical reactions with substances in the environment.
- Rusting is an example of iron corrosion. Both air and water are needed.

- Corrosion can be prevented by applying a coating that acts as a barrier, such as greasing, painting or electroplating. Aluminium has an oxide coating that protects the metal from further corrosion.

- Some coatings are reactive & contain a more reactive metal to provide sacrificial protection, e.g. zinc is used to galvanise iron. Zinc is more reactive so will oxidise first so the iron doesn't form iron oxide

9) Alloys

- An alloy is a mixture of 2 or more metals.
- Most metals in everyday use are alloys (e.g. bronze is an alloy of copper & tin whereas brass is an alloy of copper & zinc).
- Gold jewellery is usually an alloy with silver, copper and zinc. The amount of gold in the alloy is measured in carats. 24 carat being 100 % (pure gold), and 18 carat being 75 % gold.

- Steels are alloys of iron that contain specific amounts of carbon and other metals.
- High carbon steel is strong but brittle.
- Low carbon steel is softer and more easily shaped.
- Steels containing chromium and nickel (stainless steels) are hard and resistant to corrosion.
- Aluminium alloys are low density (e.g. used in aircraft).

10) Glass & Ceramics

- Most glass is soda-lime glass, made by heating a mixture of sand, sodium carbonate and limestone. Borosilicate glass, made from sand and boron trioxide, melts at higher temperatures than soda-lime glass.

- Clay ceramics, including pottery and bricks, are made by shaping wet clay and then heating in a furnace.

11) Polymers

Properties of polymers depend on what they are made from and the conditions in which they are made.

- Low Density Polyethene (LDPE) is soft and flexible and the polymers are branched so they can't pack tightly together. LDPE made by heating ethene under very high pressure.
- High Density Polyethene (HDPE) is rigid as the polymers pack much more tightly together. HDPE is made by heating ethene at lower temp & pressure with a catalyst.

Low density polyethene LDPE

High density polyethene HDPE

- Thermosoftening polymers melt when they are heated. This is because the polymers consist of individual tangled polymer chains with weak forces between the chains.

- Thermosetting polymers do not melt when they are heated. This is because the polymers are cross-linked making them harder and less likely to change shape when heated.

12) Composites

- Most composites are made of two materials, a matrix or binder surrounding reinforcement fibres or fragments of the other material.
- Examples include fibreglass, concrete, carbon fibre, wood

13) The Haber Process

- The Haber process is used to manufacture ammonia (used to produce nitrogen-based fertilisers).
- The raw materials are nitrogen and hydrogen. Nitrogen comes from the air and most of the hydrogen is provided from natural gas.
- The purified gases are passed over a catalyst of iron at a high temperature (about 450°C) and a high pressure (about 200 atmospheres). Some of the hydrogen and nitrogen reacts to form ammonia.
- The reaction is reversible so some of the ammonia produced breaks down into nitrogen and hydrogen: $N_2 + 3H_2 \rightleftharpoons 2NH_3$
- On cooling, the ammonia liquefies and is removed. The remaining hydrogen and nitrogen are recycled.

From topic 6 we can apply the principles of dynamic equilibrium to the Haber process.

- Higher temp increases the rate but also favours the endothermic reaction lowering the yield. 450°C is a compromise temperature between a faster rate and a higher yield.
- Pressure is kept as high as possible (without becoming too expensive or dangerous) as increases the rate and the yield.

14) Production and uses of NPK fertilisers

Compounds of nitrogen, phosphorus & potassium are used as fertilisers to improve agricultural productivity. NPK fertilisers are formulations of various salts containing appropriate percentages of the three elements.
Used to replace essential elements in the soil.
Plants absorb through their roots so fertilisers must be soluble in water.
To grow well plants need nitrogen, phosphorus and potassium.
e.g. NPK 16-4-10 would mean 16% nitrogen and so on.

Ammonia is an alkaline gas that dissolves in water to produce ammonium hydroxide.
Ammonia can be mixed with nitric acid to make ammonium nitrate to increase the amount of nitrogen in the soil.

Ammonia + nitric acid → ammonium nitrate

$$NH_{3\,(aq)} + HNO_{3\,(aq)} \rightarrow NH_4NO_{3\,(aq)}$$

Potassium chloride, potassium sulfate and phosphate rock are obtained by mining, but phosphate rock cannot be used directly as a fertiliser.
Phosphate rock is treated with nitric acid or sulfuric acid to produce soluble salts that can be used as fertilisers.
e.g. The rock can be treated with nitric acid (HNO_3) to produce phosphoric acid (H_3PO_4) and calcium nitrate ($Ca(NO_3)_2$).
If sulfuric acid was used instead, phosphoric acid and calcium sulfate ($CaSO_4$) would be produced instead.

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