Air and Water

Water: A valuable resource

- Only 3% of water is fresh water
- Most fresh water is locked up as ice in the Arctic and Antarctic
- We cannot survive without water for more than a few days
- Shortage of water can cause: harvest failure, animal death and risk of increases disease
- Water is used un the home for drinking, cooking, washing and cleaning
- In industry water is used as a solvent for many chemicals and as a coolant to stop industrial processes from getting too hot. It is also a cheap raw material for some chemical manufacturing processes. Water is also used for generating power either in hydro electrical power station or by turning into steam to drive turbines
- In agriculture, water is used on farms for watering crops and for animals to drink

Testing for water

- We use anhydrous copper (II) sulphate to test for water. When we add water and white anhydrous copper (II) sulphate it turns blue.

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4 \cdot 5H_2O(s)$$

Anhydrous copper (II) sulphate (white) + water →hydrated copper (II) sulphate (blue)

- We can also use anhydrous cobalt chloride which changes from blue to pink when water is added

$$COCl_2(s) + 6H_2O(l) \rightarrow COCl_2 \cdot 6H_2O(s)$$

Anhydrous cobalt (II) chloride (blue) + water → hydrated cobalt (II) chloride (pink)

- These tests show us that there is water present but it might not be pure water

Water purification

- Water from rivers and lakes are not pure, it contains dead animals and plants, dissolved in bacteria, many of which are harmful to health
- Cholera and typhoid are just two main diseases caused by bacteria in untreated water
- A modern water treatment plant removes insoluble materials and bacteria by filtration and chlorination
- Treating water is a complex process and there are many stages:

1. The water passes through metal grinds which collect objects such as twigs and leaves
2. In the sedimentation tank, particles of solids such as soil particles settle to the bottom of the tank
3. Aluminium sulphate is added to make small particles in water stick together, the particles fall to the bottom of the tank
4. The water then passes through a filter made of sand and gravel or crushed coal. This removes any small insoluble particles that were not removed in the other tanks
5. Chlorine is added to kill bacteria
6. The pH of the water is adjusted and the water is run off and stored or goes directly to homes and factories

- Although treated water appears clear, it still contains dissolved salts. So it is not pure

Air

Composition of air

Gas	Composition
Oxygen	21%
Nitrogen	78%
Other gases (argon with small amounts of carbon dioxide and other noble gases) [carbon is 0.04%]	1%
Water vapour (variable)	1% -4%

- Much of the air around us is polluted, it contains unwanted substances. The pollutants are dust particles and smoke as well as the gases sulphur dioxide and nitrogen oxide. Although these are present in small amounts, they have a big effect on our environment

Separating the gases

- Oxygen is used in welding, steel making and to support respiration systems in hospital
- Nitrogen is very unreactive it is used to provide an inert atmosphere for food packaging, chemical processes and silicon chip production. The gases in air are separated by fractional distillation in liquid air:

1. Water is removed from the air by passing it through a drying agent and carbon dioxide is removed by reacting it with sodium hydroxide solution
2. The air is then cooled to -23°C and compressed (squashed into a small space)
3. The cold compresses air is allowed to expand into a larger space. When it expands, the air is cooled. After this is repeated several times the temperature is cooled to -200°C. Most of the air is now liquid
4. Argon, neon and xenon are removed easily because they are still gases under these condition. This leaves us with a mixture of oxygen and nitrogen
5. When the liquid air is warmed, the nitrogen boils off first because it has a lower boiling point. Some of the nitrogen condenses at the top of the lower distillation column leaving a mixture of impure oxygen and nitrogen at the bottom. The mixture is then expanded into a gas
6. The oxygen-nitrogen mixture is then fed into the top column. The temperature is the top column is below the boiling point of oxygen and the above the boiling point of nitrogen. So the oxygen condenses at the bottom and nitrogen gas is removed at the top.

Air pollution

- We burn fossil fuels such as coal, oil and gas in power stations and in the home
- We use hydrocarbons from the distillation of petroleum for transport-in cars, train, ships and aircraft.
- The gases given off when we burn fuels pollute the atmosphere and cause harmful effects in the environment
- These pollutant gases are carbon dioxide, carbon monoxide, sulphur dioxide and oxides of nitrogen.

- When we burn fuels, tiny particles of solids also get into the air. These are called particulates. Lead dust and soot are example of particulates

Carbon monoxide

- $C_4H_8 + 4O_2 \rightarrow 4CO + 4H_2O$
- Carbon monoxide is the product of incomplete combustion, due to the lack of oxygen
- Carbon monoxide is a poisonous gas
- It is colourless and odourless
- It combines with the red pigment in the cells of the blood that carry oxygen in the body
- Carbon monoxide poisoning prevents respiration i.e. it causes suffocation

Lead Compounds

- Lead was previously added to petrol to help it combust more efficiently
- Although it is no longer used in petrol it is still present in the environment as particulates
- This is because lead does not break down easily
- Lead Is also found in some paints and water pipes in old houses
- Lead is particularly hazardous if inhaled or consumed
- Lead accumulates in our body and does not escape easily
- Small quantities can lead to damage of the nervous system especially to brains of children

Sulphur dioxide and acid rain

- Rain is naturally acid due to dissolved carbon dioxide
- However, if the rain has a pH lower than 5 the rain is called acid rain
- Acid rain is formed when fossil fuels are burnt and the sulphur is oxidised and sulphur dioxide gas escapes into the atmosphere. (coal contains sulphur impurities and so does oil and natural gas)

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

- Volcanoes are also a natural source of sulphur dioxide, they produce about a third of the sulphur dioxide that pollutes the atmosphere
- The sulphur dioxide reacts with oxygen in the atmosphere to form sulphur trioxide
- The sulphur trioxide then reacts with water vapour in the air to form a solution of sulfuric acid

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

- When the acidic water vapour condenses, acid rain is formed
- Even if it does not rain, acidic gases in the atmosphere can dissolve on we surfaces and create the same effect as acidic rain, this is called dry deposition
- Sulphur dioxide is not the only source of acid rain. Nitrogen oxides from car exhausts also play a part

Adverse effects of acid rain

- Tree leaves (especially pine trees) can no longer photosynthesise
- Lakes and rivers become too acidic and marine life cannot survive
- Soil may become too acidic for crop growth, reactions with acid in soil cause some minerals to dissolve, high concentration of minerals in soil water is also harmful to crops
- Buildings made from rock carbonates will be eroded, especially limestone and marble buildings
- Metal structures such as bridges and iron railings corrode

The Nitrogen Oxide Problem

Oxide	Chemical Symbol
Nitrous oxide [nitrogen (I) oxide]	N_2O
Nitric oxide [nitrogen (II) oxide]	NO
Nitrogen dioxide [nitrogen (IV) oxide]	NO_2

Sources

- Most nitrogen oxides are formed in car engines. High temperature and pressure causes the reaction
- Formation of nitric oxide: $N_2(g) + O_2(g) \rightarrow 2NO(g)$
- Formation of nitrogen dioxide: $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$
- High temperature furnaces
- Thunderstorms, electric energy in lightning causes the formation of nitrogen oxides
- Denitrification: bacterial action in soil causes conversion of nitrates to nitrogen and nitrous oxide
- In the atmosphere nitrogen oxides can be converted from one another by oxidation or photochemical reactions
- Nitrous oxide is more stable and remains in the atmosphere for linger

Effects

- Nitrogen dioxide can cause acid rain: $2NO(g) + O_2 \rightarrow 2NO_2(g)$
- Nitrogen oxides combine with hydrocarbons and from smog, which traps other particulates in it. These harmful gases and particulates cause irritation in the throat and nose
- High levels of nitrogen oxides have been linked to certain medical conditions such as asthma

Catalytic converters

- Nitrogen oxides, carbon monoxide and unburnt hydrocarbons can be removed from car engine exhaust by catalytic converters
- Honeycomb structures coated in a layer of metals or a mixture of metals (platinum, rhodium and palladium)
- In the first part pf the catalytic convertor, metals catalyse the reaction of nitrogen oxides to nitrogen
- In the second compartment carbon monoxide is converted to carbon dioxide
- $2NO(g) \rightarrow N_2(g) + O_2(g)$
- $2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$
- $2CO_2(g) + O_2(g) \rightarrow 2CO_2(g)$
- Some of the carbon monoxide may react directly with the nitrogen oxides:
- $2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$
- $2NO_2(g) + 4CO \rightarrow N_2(g) + 4CO_2(g)$
- Unburned hydrocarbons may reduce the nitrogen oxides too
- The gases now leaving the pipe are not poisonous, however, they contribute to global warming

Prevention

- Chimneys are fitting with scrubbers which contain calcium carbonate
- Catalytic convertors fitted with honey combs which reduce harmful gases to harmless gases

Global Warming

Greenhouse gases

- A greenhouse gas is a gas that absorbs heat energy and stops heat from escaping into space. The main greenhouse gases are: carbon dioxide, methane, nitrous oxide and CFCs (chlorofluorocarbons)
- Greenhouse gases cause an increase in global warming by absorbing heat energy radiated from the earth's surface

Sources

- Carbon dioxide is the main greenhouse gas, it is mainly produced due to the burning of fossil fuels in power stations and cars, it is also produced in small amounts by industrial processes such as thermal decomposition of calcium carbonate to make cement and lime
- Methane is produced as a result of digestion in cows and sheep, rice paddy fields and the decomposition of vegetation (especially ins swampy areas)
- Nitrous oxide is produced by bacteria in soil
- CFCs are used in refrigerators and spray cans, although this has been stopped, they mainly cause ozone depletion

Effects

If we did not have greenhouse gases in the atmosphere, the earth would be very cold. The greenhouse effect works like this:

- UV rays from the sun have very short wave lengths. They get through the atmosphere easily and are not absorbed by carbon dioxide
- The UV rays hit the earth's surface
- The earth absorbs the UV rays and heats up
- Heat energy is lost from the earth's surface by infrared rays. (long wavelength radiation)
- Infrared rays can also be absorbed by carbon dioxide
- Some of the hear is re-radiated back to earth and some escapes into space

- The more carbon dioxide there is in the atmosphere, the more heat absorbed by this greenhouse gas.

Climate change and its results

- Air temperature increase, leads to the melting of the polar ice caps, increase in sea levels and cause flooding in low-lying areas
- Less rainfall leading to desertification and less food production
- Violent weather conditions

The Carbon Cycle

- The carbon cycle keeps the concentration of carbon dioxide in the atmosphere approximately constant
- The amount of carbon dioxide produced in respiration is balanced by that absorbed in photosynthesis

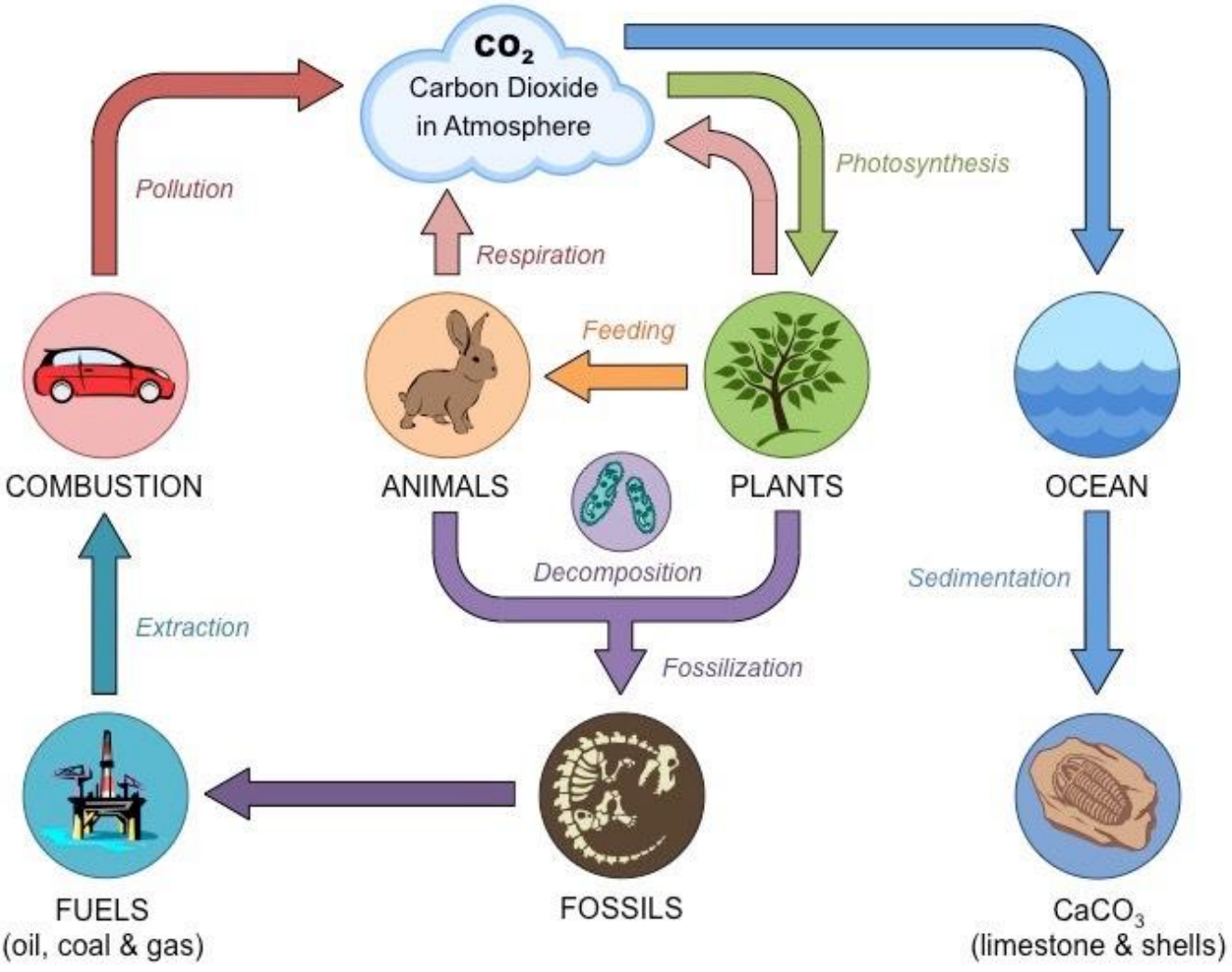
- Burning fossil fuels and deforestation may lead to an unbalance in the carbon cycle

How carbon dioxide gets in the atmosphere:

- Fuels produce carbon dioxide whilst burning: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O\ (l)$
- Respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- Smaller amounts are produced by the breakdown of swamps and the thermal decomposition of limestone and bacteria
- Huge amounts of carbon dioxide are dissolved in the oceans

How carbon dioxide is removed from the atmosphere

- Photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6CO_2$



Prevention of rust

Causes

- Chemicals in the air may attack metals causing the surface to get eaten away. We call this corrosion
- Rusting is the corrosion of iron and steel
- For rusting to occur both oxygen and water are needed
- $4Fe\ (s) + 3O_2(g) + 2H_2\ (l) \rightarrow 2Fe_2O_3 \cdot H_2O\ (s)$
- A layer of rust is very weak and flakes off the surface of the iron, the newly exposed surface begins to rust
- Rusting is speeded up by salt

Stopping rusting

- Paint
- A plastic coating
- Metal plating (galvanising)
- Greasing and oiling
- Sacrificial protection
- In sacrificial protection a more reactive metal is in contact with steel. The more reactive metal corrodes in preference to the steel
- Zinc is more reactive than iron and loses electrons forming Zn^{2+}
- If the zinc is scratched, the iron underneath will take up the lost electrons and therefore not oxidise
- The same application is used in ships with the protection of steel through the sacrificial protection of magnesium