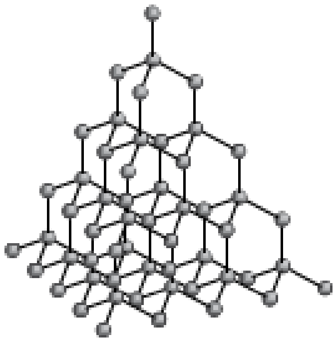

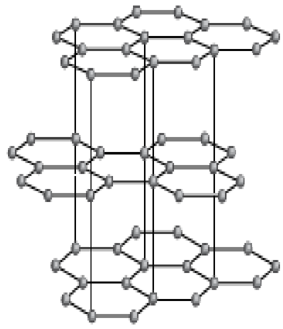

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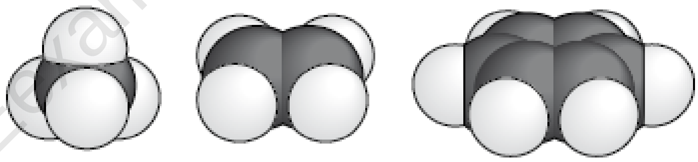
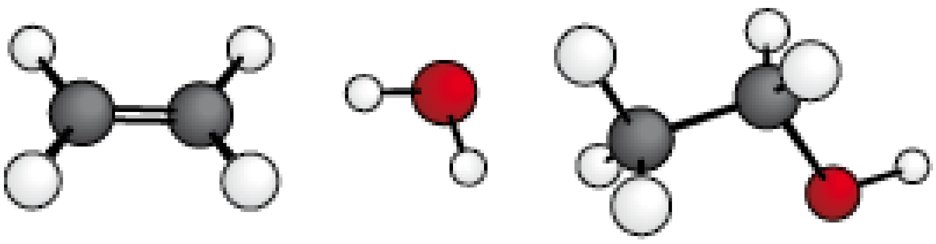


Chapter 11

Air and water



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Chapter 11: Air and water

- Air and water are two key natural resources.

- We need water in the *home* (for drinking, cooking, washing things and flushing toilet waste away), on the *farm* (for animal to drink and watering crops), in *industry* (as solvent, to wash things and to keep hot reaction tanks cool) and at the *power station* (to make steam to drive turbines that generate electricity).

- If a liquid contains water, it will turn white anhydrous **copper(II) sulfate** blue and turn blue **cobalt chloride** paper pink.

$$\underset{\text{white}}{CuSO_4(s)} + 5H_2O(l) \rightleftharpoons \underset{\text{blue}}{CuSO_4.5H_2O(s)}$$

$$\underset{\text{blue}}{CoCl_2(s)} + 6H_2O(l) \rightleftharpoons \underset{\text{red}}{CoCl_2.6H_2O(s)}$$

Both colour changes can be reversed by heating.

- ***Anhydrous*** means without water. Adding water turns anhydrous compound to the ***hydrated*** compound. The water molecules are called **water of crystallisation**.

- If the liquid boils at 100 ^oC and freezes at 0 ^oC then it is **pure water**.

- We depend on rain for our water supply. The rainwater runs over and through the ground, and reaches rivers, reservoirs, and natural underground stores called **aquifers**.

- Much of the water we use is taken from rivers. But some is pumped up from below ground, where water that has drained down through the soil lies trapped in rocks.

- This underground water is called **groundwater**. A large area of rack may hold a lot of groundwater, like sponge. This rock is called **aquifer**.

- River water is not clean. It will contain particles of mud, and animal waste, and bits of dead vegetation. But worst of all are the **microbes**: bacteria and other tiny organisms that can make us ill.

- Over 1 billion people around the world have no access to clean water. They depend on dirty rivers for their drinking water. And over 2 million people, mainly children, die each year from **diarrhoea** and diseases such as **cholera** and **typhoid**, caused by drinking infected water.

- Before the water is piped to homes, it is treated to make it fit to drink. This involves two main process:
  - removal of solid particles by **filtering** and **skimming**.
  - killing bacteria and other harmful microbes, using chlorine.

- Processes in a modern water treatment plant are:
  - The water is pumped in. A screen traps any big particles, such as twigs.
  - A **coagulant** is added – a chemical to make small suspended particles stick together. It could be iron(III) sulfate, for example.
  - Next, air is blown through the water in **flotation tanks**, to make the coagulated particles float to the top. They are skimmed off.
  - The water is passes through a bed of fine sand to filter it.
  - It may be filtered again with sand, or using **charcoal** to remove bad tastes and smells.
  - **Chlorine** is added to kill the bacteria and other microbes.
  - A **fluoride** compound may be added, to help fight tooth decay.
  - The water is pumped to the storage reservoir, ready for pumping to homes.

- This treatment can remove even the tiniest particles. And chlorine can kill all the microbes. But the water may still have harmful substances dissolved in it. For example, *nitrates from fertilisers* that can make babies ill.

- It is possible to remove dissolved substances, using special membranes. But that is very expensive, and is not usually done. The best solution is to find the cleanest source for the water supply.

- ∴ The type of treatment of water eventually depend on the source of water (dirty level) and the cost of treatment that can afford.

- **Air** is a mixture of gases. It is mainly nitrogen (78%) and oxygen (21%). The remaining 1% is mainly argon + a little carbon dioxide + a little water vapour + small amounts of the other noble gases (helium, neon, krypton and xenon).

- Industrially, nitrogen is obtained by liquefaction and **fractional distillation of air**. Air is compressed to about 200 atmospheres, cooled and freed from dust, moisture and carbon dioxide. The cooled compressed air is then liquefied. Nitrogen is extracted by fractional distillation of liquid air. Since ***nitrogen is more volatile*** (i.e. with a lower boiling point) than oxygen, fractional distillation gives gaseous nitrogen and liquid oxygen. Nitrogen obtained in this way contains about 1% of impurities, which are mainly argon and a little oxygen.

- Oxygen is used:
  - in oxygen tents in hospital, for people with breathing difficulties.
  - along with the hydrocarbon acetylene (ethyne, C_2H_2) in torches for cutting and welding metals; the burning mixture is so hot that it can melt steel.
  - as an oxygen supply for astronauts and deep-sea divers.
  - in steel works, to remove carbon from pig iron.

- Liquid nitrogen is very cold and it boils at – 196 ^oC. Nitrogen is used:
  - in hospitals to store tissue samples.
  - inside food packaging, to protect food from oxidation by the oxygen in the air.
  - to rinse out fuel storage tanks, where a mixture of air and fumes could be explosive.
  - to freeze liquid in pipelines, allowing the pipes to repaired.
  - to freeze food, and keep containers of food frozen during transport.

- The noble gases are unreactive or **inert**. This leads to many uses:
  - **Argon** provides the inert atmosphere in ordinary tungsten light bulbs. In air, the tungsten filament would quickly burn away.
  - **Neon** is used in advertising signs because it glows red when a current is passed through it.
  - **Helium** is used to fill balloons, since it is light, and safe.

- **Krypton** is used in laser – for example for eye surgery and in car headlamps.

- **Xenon** gives a light like bright daylight, but with a blue tinge. It is used in lighthouse lamps, lights for hospital operating rooms and car headlamps.

- Billions of tonnes of harmful gases are pumped into the air via burning of **fossil fuels**, causing air pollution.

- The **fossil fuels** are **petroleum** (or crude oil), **coal** and **natural gas**. They are called fossil fuels because they are the remains of living things (plants and animals) that lived millions of years ago.

- **Petroleum** formed from the remains of dead organisms that fell to the ocean floor and were buried under thick sediment. High pressure slowly converted them to petroleum over millions of years.

- **Coal** is remains of lush vegetation that grew in ancient swamps. The dead vegetation were buried under thick sediment. Pressure and heat slowly converted it to coal over millions of years.

- **Natural gas** is mainly <u>methane</u>. It is often found with petroleum. It is formed in the same way. But high temperatures and high pressures caused the compounds to break down to gas.

- Currently, natural gas and crude oil are our major sources of hydrocarbons. The majority of hydrocarbons release large amounts of energy on combustion and are used as fuels for electricity generation, industry, homes or transport.

- The **common pollutants** in the air are carbon monoxide, sulfur dioxide, oxides of nitrogen and lead compounds.

- Source of each of these pollutants:
  - **Carbon monoxide** from the incomplete combustion of carbon-containing substances.
  - **Sulfur dioxide** from the combustion of fossil fuels which contain sulfur compounds.
  - **Oxides of nitrogen** from car engines.
  - Lead compounds from leaded petrol.

Pollutant	Source	Harmful effect
Carbon monoxide, CO, a colourless gas with no smell	Incomplete combustion (burning in insufficient air) of substances that contain carbon; for example petrol in car engines.	Poisonous even in low concentration. It reacts with the ***haemoglobin*** in blood, and prevents it from carrying oxygen around the body.
Sulfur dioxide, SO_2, an acidic gas with a sharp smell	Combustion of fossil fuels which contain sulfur compounds. Power stations are the main source of this pollutants.	Irritates the eye and throat, and causes respiratory (breathing) problems. Dissolves in rain to form ***acid rain***, which damages crops and forests, kills fishes, and attacks stonework and metal in buildings.
Oxides of nitrogen, such as NO and NO_2, acidic gases	Nitrogen and oxygen in the air react together inside hot car engines.	Cause lung damage, respiratory problems, and dissolve in rain to give ***acid rain***.
Lead compounds	A compound called tetra-ethyl lead used to be added to petrol, to help it burn smoothly in car engines. It is still added in some countries. On burning, it produces particles of other lead compounds.	Lead harms the body's nervous system; it can cause brain damage and behavioural problems. It also damages the kidneys.

- Oxides of nitrogen, collectively known as **NO_x**, occur in the exhaust fumes of motor vehicles. Some NO_x is also produced by electricity-generating stations and industries and from the combustion of (particular) coal and oil.

- Nitrogen gas is stable and has low reactivity. However, at high temperatures, such as in an **internal combustion engine**, it will combine with oxygen to form nitrogen monoxide:

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \qquad \Delta H = +180kJ$$

- Nitrogen monoxide is a primary pollutant in the lower atmosphere. Nitrogen dioxide is formed by reaction of nitrogen monoxide with oxygen. It is therefore a secondary pollutant:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = -113kJ$$

This reaction takes place as the **exhaust gases cool down**. At high temperatures, the equilibrium is displaced to the left as ΔH is negative and NO_2 is not produced.

- NO_x **damages the environment** in the following ways:
  - NO_2 reacts with H_2O to form a mixture of nitrous acid & nitric acid.

    $$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

    Nitrous acid is then oxidised by atmospheric O_2 to nitric acid.

    $$HNO_2 \xrightarrow{[O]} HNO_3$$

  - NO_x reacts with other air pollutants to form ozone which is irritates the eyes.

    $\therefore$ Acid rain & ozone produced from NO_2 are killing the trees in many European forests.

- The **pollutants in car exhaust gases** include carbon monoxide, nitrogen(II) oxide and unburnt hydrocarbons. If these gases are not removed by catalytic converters, they lead to the formation of low-level ozone and photochemical smog. Both low-level ozone and photochemical smog can be harmful to humans, animals and plants.

- **Photochemical smog** is a mixture of ozone, nitrogen dioxide and peroxacetylnitrate (PAN). It causes severe breathing difficulties.

- **Catalytic converters** are an effective way of reducing harmful emissions from motor vehicles. The catalysts are usually the transition elements platinum, palladium, and rhodium. They are coated onto a ceramic support to give a large surface area for the reactions.

- There are two forms of catalyst system:-
  - **Oxidation catalysts** can be used in conjunction with 'lean-burn' engines such as diesel to control carbon monoxide and hydrocarbon emissions. The exhaust gases of lean-burn engines are rich in oxygen. This enables unburnt hydrocarbons and carbon monoxide to be rapidly oxidised on the surface of the catalyst to give carbon dioxide and water at lower temperatures than normal (200 – 250 ^oC):

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

$$C_8H_{18} + 12\frac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$$

Octane, C_8H_{18} is a major constituent of petrol.

- **Three-way catalysts** work with conventional engines, controlling carbon monoxide, hydrocarbon and nitrogen oxide emissions. The nitrogen oxides are reduced to nitrogen:

  $$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$$

  Palladium and platinum catalyse the oxidation of carbon monoxide and unburnt hydrocarbons. Rhodium catalyses the reduction of nitrogen monoxide to nitrogen.

  $$2NO(g) \rightarrow N_2(g) + O_2(g)$$

- In a catalytic converter the metal catalysts catalyse the formation of nitrogen from nitrogen oxide, and carbon dioxide from carbon monoxide:
  - the pollutant reactant molecules are *absorbed* onto the metal atoms at the surface of the catalyst.
  - covalent bonds in the reactants (NO and CO) are weakened and broken.
  - new bonds form to give the product molecules (N_2 and CO_2) which are *desorbed* from the catalyst.

- **'Lead free' petrol** must be used because any lead present will poison the platinum catalyst, making it ineffective.

- Catalytic converter in motor car are **expensive** in 2 ways:
  - converter is quite expensive because platinum is a rare & expensive metal.
  - engines that use 'lead free' petrol are less efficient $\therefore$ more fuel is used.

- The amount of NO_x produced from burning fuel can be reduced by lowering the temperature $\therefore$This is done in power stations by spraying water into the burning fuel.

- Sources of sulfur dioxide (man-made sources) are
    - burning of sulfur-containing fuel

      e.g. coal & oil

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

    - release of SO_2 from industries

      e.g. roasting of metal sulfide ore in the extraction of metals.

- Sulfur dioxide is used as a **preservative in food** and is added to sauces & some drinks to kill any harmful micro-organisms that might breed in the food.

- Sulfur dioxide is also used as a bleach in the manufacture of wood pulp for paper.

- In modern power stations, the waste gas is treated with slaked lime (calcium hydroxide). This removes sulfur dioxide by reacting with it to give calcium sulfate. The process is called **flue gas desulfurisation**.

- Acid rain caused **mainly** by SO_2 in the atmosphere.

- Acid rain also caused by oxides of nitrogen in atmosphere.

- Rain is naturally **slightly acidic** because it reacts with CO_2 in the air to form carbonic acid.

- Natural rain-water has a **pH** at about **5.6** ∴ Acid rain has a **pH below 5.0**.

- SO_2 reacts with O_2 & H_2O in the air **to form H_2SO_4**, which becomes acid rain. This reaction is **catalysed by the oxides of nitrogen**.

  Stage 1: SO_2 reacts with NO_2 (from car exhausts).

  $$SO_2 + NO_2 \rightarrow SO_3 + NO$$

  Stage 2: SO_3 reacts with H_2O to form H_2SO_4.

  $$SO_3 + H_2O \rightarrow H_2SO_4$$

  Stage 3: NO from stage 1 reacts with atmospheric oxygen to produce more NO_2

  ∴ NO_2 react with more SO_2 to repeat stage 1.

  $$2NO + O_2 \rightarrow 2NO_2$$

- Nitrogen dioxide reacts with O_2 & H_2O in the air **to form nitric acid**, which also becomes acid rain.

$$2NO_2 + H_2O + \frac{1}{2}O_2 \rightarrow 2HNO_3$$

- **Rusting** is the special name for the corrosion of iron. It is an oxidation. Oxygen from the air reacts with iron in the presence of moisture. The product is hydrated iron(III) oxide, $Fe_2O_3.H_2O$, a brown flaky solid.

- Rusting requires oxygen and water:

$$4Fe(s) + 3O_2(g) + 2H_2O(l) \rightarrow 2Fe_2O_3.2H_2O(s)$$

- There are two approaches to prevent rusting:
  - ➢ cover the iron with paint, grease or another metal such as zinc to exclude oxygen and water.
    - ❖ Steel bridges and railings are usually painted.
    - ❖ Tools and machine parts are coated with grease or oil.
    - ❖ The iron is coated with a layer of zinc – which is above iron in the reactivity series to give galvanised iron for roofing. **Galvanised iron** by coating iron with zinc is done by dipping iron into molten zinc. The zinc coating keeps the oxygen away. If the coating does get damaged, the zinc will still protect the iron through *sacrificial protection*.
    - ❖ Steel is electroplate with zinc, for car bodies. ∴ **Galvanising** = way of using zinc to protect iron.
    - ❖ Steel is coated with ***tin*** by electroplating, for food tins.
  - ➢ sacrifice another metal in place of iron. A more reactive metal will prevent iron from rusting. For example, magnesium is above iron in the reactivity series. Therefore, block of magnesium are attached to the sides of ships and the legs of offshore oil rigs to protect the iron since rusting is faster in **salty water**.

Nitrogen and fertilisers

- Nitrogen is used to make ammonia, which is turn used to make nitric acid and fertilisers. **Fertilisers** are essential for growing crops to feed the world.

- Plants need a good supply of nitrogen, potassium and phosphorus from the soil.

- Plants need **nitrogen** for making chlorophyll, and proteins. **Potassium** helps them to produce protein, and to resist disease. **Phosphorus** helps roots to grow, and crops to ripen.

- ∴ A **fertiliser** is any substance added to the soil to make it more fertile. **Synthetic fertilisers** are made in the factories, and sprinkled or sprayed on fields.

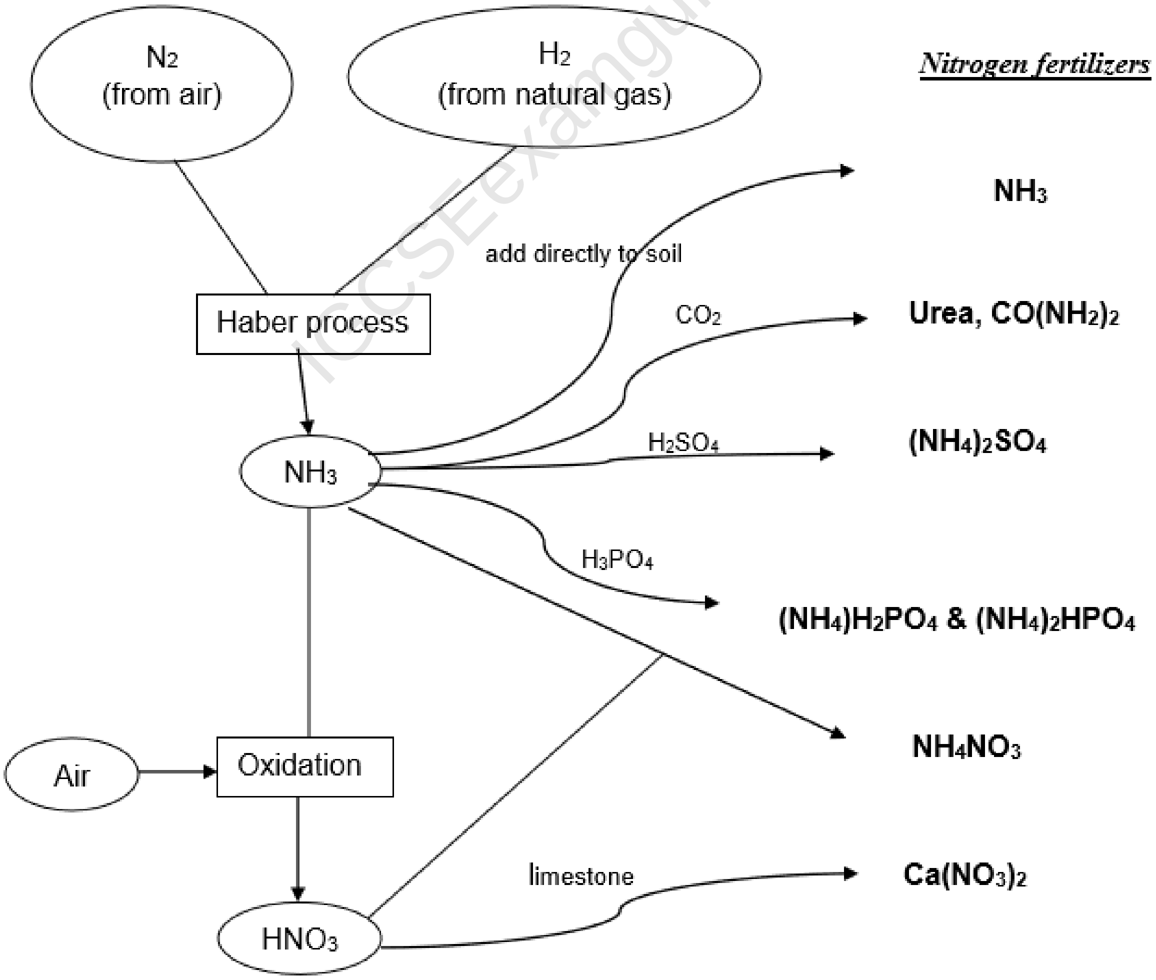
- Examples of reactions to make synthetic fertiliser:

  - Ammonia reacts with nitric acid to give ammonium nitrate. This fertiliser is an excellent source of nitrogen.

    $$NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$$

  - Ammonia reacts with sulfuric acid to give ammonium sulfate.

    $$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$



- Fertilisers can seep into rivers from farmland. In the river, they help tiny water plants called **algae** to grow. These can cover the water like carpet. When they die, bacteria feed on them, at the same time using up oxygen dissolved in the water: so fish suffocate.

- From rivers, the nitrate ions from the fertilisers can end up in our water supply. They are converted to nitrite ions in our bodies. These combine with **haemoglobin** in blood, in place of oxygen, so the blood carries less oxygen around the body. This can cause illness, especially in infants. Their skin may take on a blue tinge.

- So farmers should use fertilisers carefully. They should try to keep them away from river banks – and not spread them in wet weather.

- The method used to make ammonia in industry is called the **Haber process**. The *raw materials* are nitrogen and hydrogen.

- **Nitrogen** is a colourless, odourless, unreactive gas that makes up nearly 80% of the air. The oxygen is removed by burning hydrogen in the air, leaving nitrogen behind:

$$N_2(g) + O_2(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(l)$$

- **Hydrogen** is the lightest of all gases – about 20 times lighter than air. It is colourless, with no smell.

- Hydrogen is made in the lab by using a metal to drive it out or displace it from dilute acid. Zinc and dilute sulfuric acid are the usual choice.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

- Hydrogen also can obtained from the reaction between methane (natural gas) and steam or the cracking of hydrocarbon such as ethane. Both reactions require catalysts.

$$CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 4H_2(g)$$

$$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$$

- The Haber process for the manufacture of ammonia is based on the equilibrium.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = \text{negative value}$$

- In a closed system the reaction reaches equilibrium, with a mixture of ammonia, nitrogen and hydrogen present. The ***aim*** is shift the equilibrium to the right, giving more ammonia. Conditions are chosen to favour the forward reaction and make it fast enough. These are the ***optimum conditions***:

Condition		**Comment**
pressure	high pressure of 200 atmospheres	High pressure favours the side of the equation with fewer gaseous molecules.
temperature	moderate temperature of about 450 ^oC	➢ The forward reaction is exothermic, so a low temperature favours it. ➢ But at low temperatures, the reaction is too slow.
catalyst	Iron	Speeds up the forward and backward reactions equally. So equilibrium is reached faster.
remove product	the reaction mixture is cooled to remove ammonia as a liquid	Removing the ammonia prevents it from breaking down to nitrogen and hydrogen again.
recycle	unreacted gases are recycled	The gases are given another chance to react at the catalyst, so the overall yield improves.

- Ammonia forms when ammonium salts are heated with a strong base. The base **displaces ammonia from the ammonium salts**.

  E.g., $2NH_4Cl(s) + Ca(OH)_2(s) \rightarrow CaCl_2(s) + 2H_2O(l) + 2NH_3(g)$

  $NH_4Cl(s) + NaOH(s) \rightarrow NaCl(s) + H_2O(l) + NH_3(g)$

- This reaction can be used as a **test for ammonium compounds**. If an unknown compound gives ammonia when heated with a strong base, it must be an ammonium compound.

- Ammonia is a colourless gas with a strong, choking smell. It is less dense than air and reacts with hydrogen chloride gas to form a white smoke. The smoke is made of tiny particles of solid ammonium chloride.

  $NH_3(g) + HCl(g) \rightarrow NH_4Cl(g)$

- Most ammonia, NH_3 is used for fertilizers (e.g. ammonium sulphate, $(NH_4)_2SO_4$). Some NH_3 is oxidised to HNO_3 by the step below:

$$4NH_3(g) + 5O_2(g) \xrightleftharpoons{\text{Platinum catalyst \& } 900\ ^{o}C} 4NO(g) + 6H_2O(g) \qquad \Delta H = -ve$$

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

$$4NO_2(g) + O_2(g) + H_2O(l) \rightarrow 4HNO_3(aq)$$

- Uses of nitric acid:
  - ➢ Manufacture of nitrate fertilizers
    e.g. ammonium nitrate, NH_4NO_3
  - ➢ Manufacture of explosive
    e.g. 2, 4, 6-trinitromethylbenzene (TNT)
  - ➢ Manufacture of organic dyes (azo dyes)

<u>Carbon dioxide and methane</u>

- The gas **carbon dioxide**, CO_2 occurs naturally in the air. It is also a product in the these four reactions:
  - ➢ The complete ***combustion*** of carbon containing substances in plenty of air. For example, when natural gas (methane) burns in plenty of air; the reaction is:
    $$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$
  - ➢ ***Respiration***. This is the process that takes place in the cells of living body, to provide energy. It uses glucose, and produces carbon dioxide, which goes into the air.
    $$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$
  - ➢ The ***reaction between dilute acid and carbonates***. For example between hydrochloric acid and marble chips (calcium carbonate):
    $$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$
  - ➢ The ***thermal decomposition of a carbonate***. For example calcium carbonate decomposed by heat to form calcium oxide:
    $$CaCO_3(s) \xrightarrow[\Delta]{} CaO(s) + CO_2(g)$$

- Carbon dioxide is a colourless gas, with no smell. It is much heavier than air and is slightly soluble in water, forming carbonic acid, H_2CO_3.

- **Carbon monoxide**, CO forms when carbon compounds burn in too little oxygen. For example, when methane burns in insufficient oxygen:

$$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l)$$

- Carbon monoxide is a deadly poisonous gas. It binds to ***haemoglobin*** in red blood cells, and prevents it from carrying oxygen around the body. So victims die from oxygen starvation.

- Carbon monoxide has no smell, which makes it hard to detect. So gas-fuelled water heaters and boilers should be checked regular because hundreds of people are killed by carbon monoxide from faulty burners every year.

- **Methane**, CH_4 is found in gas deposits in the ocean floor and on land, as *natural gas.*

- Methane also forms wherever bacteria break down plant materials, in the absence of oxygen. For example in paddy fields, and swamps, and landfill sites (rubbish dumps).

- Some animals give out methane as waste gas. They include cattle, sheep, goats, camel, and buffalo. Bacteria in their stomachs help to break down grass and other food, giving methane as one product.

- Carbon moves between compounds in the atmosphere, living things, the soil, and the ocean, in a non-stop journey called **the carbon cycle**.

- Carbon moves between the atmosphere, ocean, and living things, in the form of carbon dioxide.

- Carbon dioxide is
  - *removed* from the atmosphere by **photosynthesis**, and **dissolving** in the ocean;
  - *added* to it by **respiration**, and the **combustion** (burning) of fuels that contain carbon.

- In *photosynthesis*, carbon dioxide and water react in plant leaves, to give glucose and oxygen. **Chlorophyll**, a green pigment in leaves, is a catalyst for the reaction. **Sunlight** provides the energy:

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$$

- The plant uses the glucose to make other carbon containing compounds it needs. Then animals eat the plants. So the carbon compounds get passed along the **food chain**.

- Note that photosynthesis also go on in **phytoplankton**, tiny plants that float in the ocean. These are eaten by fish and other organisms. So carbon is passed along food chains in the ocean too.

- Some carbon dioxide from the air *dissolves in the ocean*. It provides carbonate ions, which shellfish use along with calcium ions from water, to build their shells as shells are made of calcium carbonate. Fish also use them in building their skeletons.

- But only a certain % of carbon dioxide will dissolve. A balance is reached between it concentration in the air and the ocean.

- *Respiration* is the process that takes place in the cells of living things to provide energy. It uses glucose, and produces carbon dioxide, which goes into air. Bacteria also produce carbon dioxide through respiration, using compounds from dead remains.

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) + \text{energy}$$

- *Combustion of fossil fuels* increase the carbon dioxide content in the air. For example when natural gas (methane) burns:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + \text{energy}$$

- In the ocean, the remains of dead organisms fall to the ocean floor, and are buried. Over millions of years their soft parts turn into **petroleum** (oil) and **natural gas**. Hard shells turn into **limestone rock**.

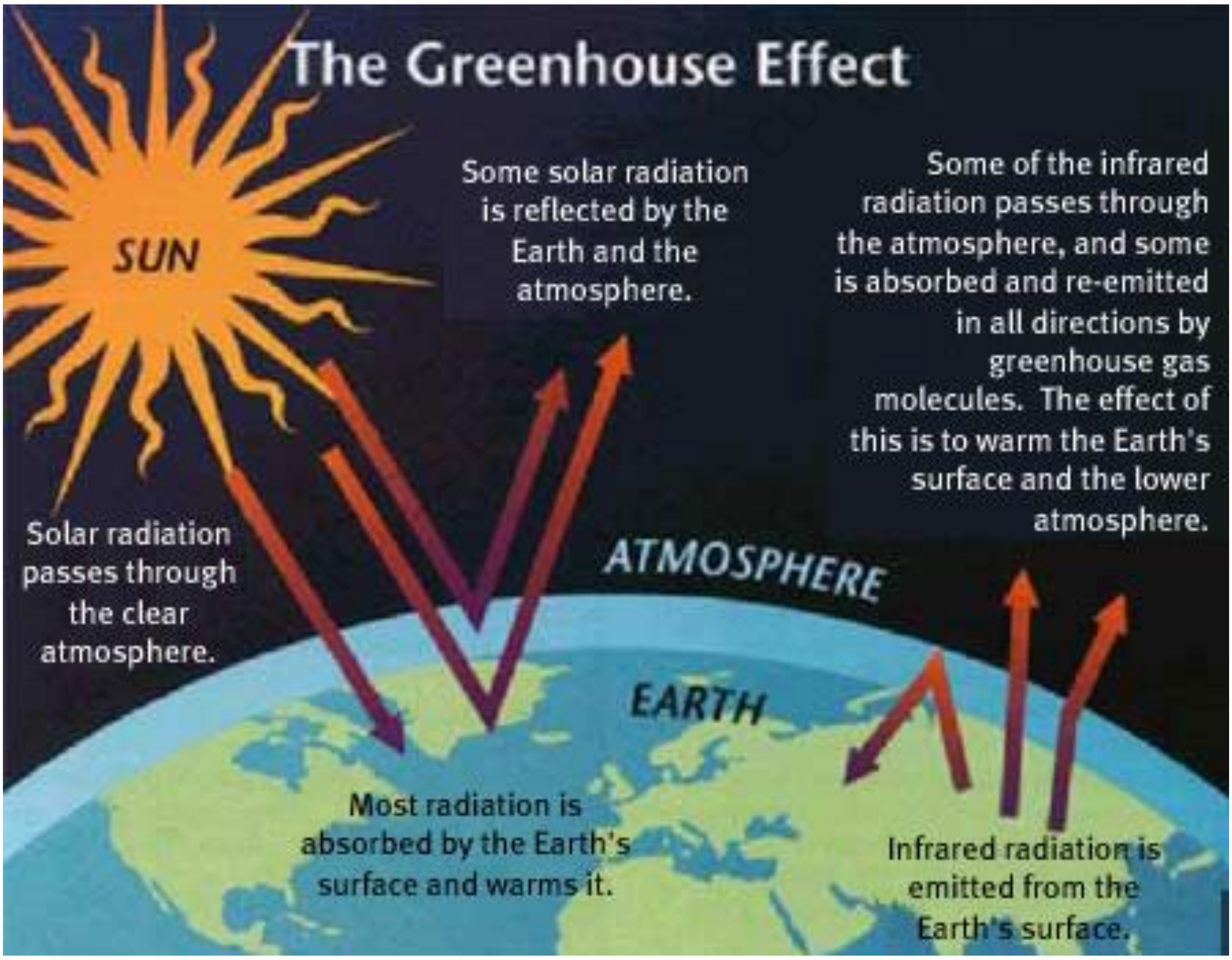
- **Global warming** = average air temperatures around the world are rising.

- Greenhouse gas = gas that absorbs heat energy in the atmosphere, and prevents it from escaping into space.

- **Greenhouse gases** (CO_2 and CH_4) are almost the certainly the main cause to global warming.

- CO_2 and CH_4 are added to the atmosphere, through human activity. There is much more CO_2 than CH_4 in the atmosphere. But the levels of both are rising.

Greenhouse gas	Human activities that increase its level
Carbon dioxide, CO_2	➢ Combustion of fossil fuels and other carbon-based fuels, in power stations, factories, car engines, and homes. ➢ Cement production, in which limestone break down, giving off carbon dioxide.
Methane, CH_4	➢ Putting decaying organic matter in landfill sites; as the buried materials rots, methane forms and can escape to the air. ➢ Livestock farming; cattle and sheep 'belch' methane from their digestive systems.



- The concentration of carbon dioxide in the lower atmosphere (**troposphere**) depends on photosynthesis, plant and animal respiration, the dissolving of carbon dioxide in surface waters and the quantity of carbon dioxide emitted during the combustion of fossil fuels.

- The amount of CO_2 in the atmosphere is almost constant because the rate of addition = the rate of removal.

- The Earth is heated by radiation from the Sun. Some heat from the Earth is radiated back into space as infrared radiation. However, some heat is also absorbed by molecules in the atmosphere instead of being lost to space.

- This absorbed heat raises the temperature of the Earth's surface and lower atmosphere and is known as the **greenhouse effect** or **global warming**.

- The greenhouse effect is a natural phenomenon which keeps the Earth's surface warm.

- Gases which allow most of the Sun's ultraviolet and visible radiation to enter but prevent some of the Earth's infrared radiation leaving are called **greenhouse gases**.

- Apart from CO_2, H_2O and CH_4, other greenhouse gases include N_2O, CFCs and tropospheric (lower-level) O_3.

- Increased emissions of carbon dioxide, methane, CFCs and other gases are enhancing the greenhouse effect and causing the Earth's surface to warm up. This global warming may result in climate change.

- The greenhouse effect of a gas depends on its concentration in the atmosphere and its ability to absorb infrared radiation.

- The extent to which an atmospheric gas absorbs infrared radiation relative to the same amount of carbon dioxide is called its '**greenhouse factor**'. Carbon dioxide is given a value of 1.

<table>
<tr><th>Gas</th><th>Greenhouse factor</th><th>Concentration in troposphere/ppmv</th><th>Overall contribution/%</th></tr>
<tr><td>CO_2</td><td>1</td><td>358</td><td>60</td></tr>
<tr><td>CH_4</td><td>30</td><td>1.7</td><td>15-20</td></tr>
<tr><td>N_2O</td><td>150</td><td>0.3</td><td rowspan="3">20-25</td></tr>
<tr><td>O_3</td><td>2000</td><td>0.1 (varies)</td></tr>
<tr><td>CFCs</td><td>10000-25000</td><td>0.004</td></tr>
</table>

- Some consequences of an enhanced greenhouse effect (rising temperatures) are:

  - expansion of sea water leading to rising sea levels and increased flooding;

  - animals and plants that cannot adapt to the changing climates will die out and finally <u>decreasing crop yields</u>;

  - **changing weather patterns** leading to severe droughts in some areas and greatly increased rainfall in other areas and

  - possible long-term melting of polar ice caps producing a very dramatic rise in sea levels and large-scale flooding of major land areas.

- Some ways to decrease the amount of carbon dioxide being released into atmosphere are as follows:

  - Use sources of energy that so not involve the combustion of fossil fuels, e.g. ***renewable sources of energy*** such as solar, wind, wave, tidal and geothermal energy.

  - Conserve energy so that less fossil fuel is burned.

  - Many countries have set targets for switching to clean ways to get electricity, such as windpower and solar power.

  - Capture and store carbon dioxide (CCS – **carbon capture** and storage) released from power stations or large-scale industrial processes, and burying it deep underground.

DATA SHEET
The Periodic Table of the Elements

Group

I	II											III	IV	V	VI	VII	0
							1 **H** Hydrogen 1										4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	**Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57 *	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	**Po** Polonium 84	**At** Astatine 85	**Rn** Radon 86
Fr Francium 87	226 **Ra** Radium 88	227 **Ac** Actinium 89 †															

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	**Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	162 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70	175 **Lu** Lutetium 71
232 **Th** Thorium 90	**Pa** Protactinium 91	238 **U** Uranium 92	**Np** Neptunium 93	**Pu** Plutonium 94	**Am** Americium 95	**Cm** Curium 96	**Bk** Berkelium 97	**Cf** Californium 98	**Es** Einsteinium 99	**Fm** Fermium 100	**Md** Mendelevium 101	**No** Nobelium 102	**Lr** Lawrencium 103

*58-71 Lanthanoid series
†90-103 Actinoid series

Key

a **X** b	a = relative atomic mass X = atomic symbol b = proton (atomic) number

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).