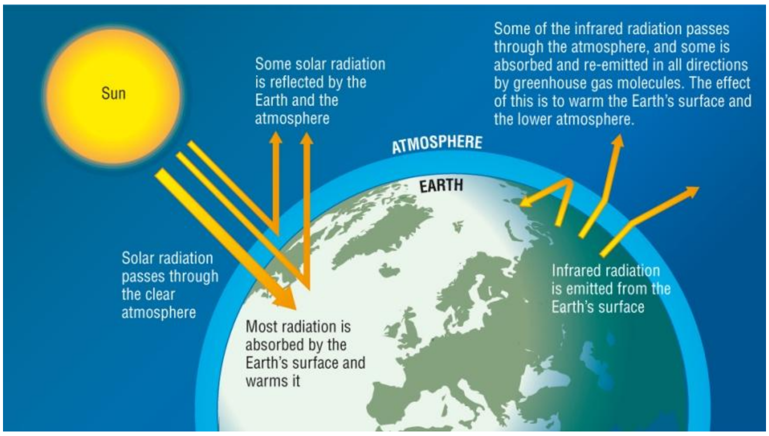
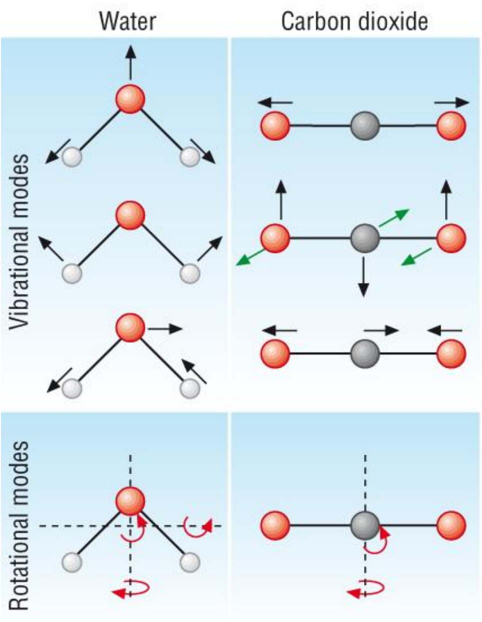
The greenhouse effect - global warming:



- Radiation from the sun reaches the planet.
- The radiation is absorbed by the Earth and re emitted as IR radiation.
- Most of this IR radiation goes back into space but some is absorbed by gases in the atmosphere.
- These gas molecules absorb the IR radiation then re emit it as energy, this energy warms up the atmosphere.
- These gases are: water, methane and carbon dioxide.

How do gases absorb radiation?



- Just like IR spectroscopy, the bonds in these greenhouse gases absorb IR radiation in their bonds.
- The bonds vibrate absorbing the IR radiation.
- Different gases will absorb different amounts of IR radiation.
- 3 factors determine the impact a gas has on Global warming:

1. Its concentration in the atmosphere
2. Its ability to absorb IR radiation
3. Its lifetime in the atmosphere

- These 3 factors make up the GWP (Global Warming Potential)
- The term Climate Change explains that although the average temperature of the planet is rising, different areas around the planet will suffer from extreme weather patterns.

Solutions to the Greenhouse Effect:

- Obviously alternative fuels such as: Wind, tidal, solar, nuclear. But we still need fossil fuels to meet the energy demands of the planet.

Carbon Capture and Storage, CCS:

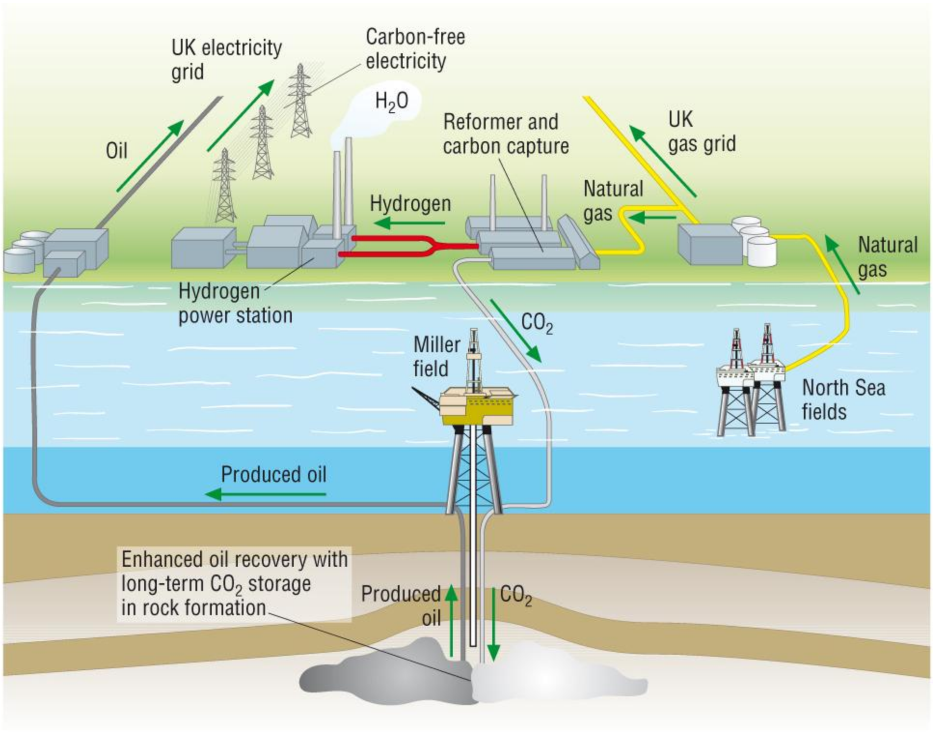
- When methane burns:

$$CH_{4(g)} \quad + \quad 2O_{2(g)} \quad \rightarrow \quad CO_{2(g)} \quad + \quad 2H_2O_{(g)}$$

- Obviously this produces **CO_2** which is emitted into the atmosphere.
- The fuel can be decarbonised:

$$CH_{4(g)} \quad + \quad 2H_2O_{(g)} \quad \rightarrow \quad CO_{2(g)} \quad + \quad 4H_{2(g)}$$

- The **CO_2** can be separated and pumped into oil wells to get the last bit of oil out.
- **H_2** is produced which is a clean fuel as it only produces water vapour.
- The **CO_2** is now trapped in the oil well and not emitted into the atmosphere:



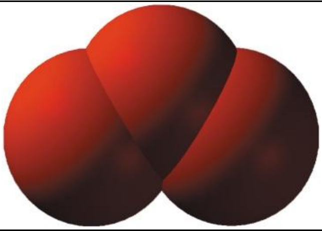
Storage as carbonates:

- Mineral storage aims to store the CO_2 locked up in minerals as carbonates, CO_3:

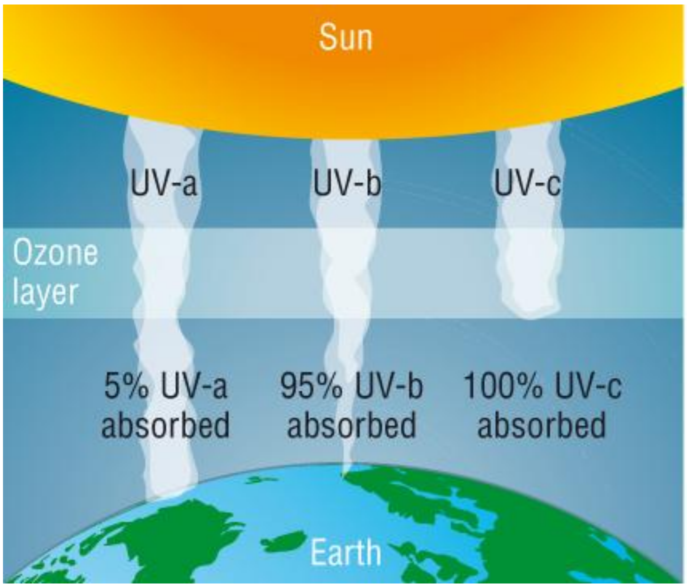
$$CaO_{(s)} \quad + \quad CO_{2(g)} \quad \rightarrow \quad CaCO_{3(s)}$$
$$MgO_{(s)} \quad + \quad CO_{2(g)} \quad \rightarrow \quad MgCO_{3(s)}$$

- This process occurs naturally but is very slow, More research is needed if this is to be a viable storage option.

The ozone layer



- Ozone is 3 oxygen atoms joined together.
- We are producing ozone where we don't want it and destroying it where we do want it.
- Low level ozone in the troposphere causes respiratory problems.
- The destruction of high level ozone allows harmful UV radiation to reach earth.



- Ozone acts like a big pair of sunglasses filtering out most of the harmful UV radiation.
- Prior to the formation of ozone our planet was scorched and no life could survive.
- UV radiation is divided into a, b, and c.
- C is the most harmful and is blocked out completely by ozone.
- A is the weakest and only a small amount is absorbed by ozone. This is the one that gives you a tan and ages your skin prematurely.

Ozone formation:

- The first step is the homolytic fission of an oxygen molecule by UV light:

$$O_{2(g)} \quad + \quad UV \quad \rightarrow \quad 2O_{(g)}$$

- This is an oxygen atom which contains 2 unpaired electrons, sometimes called a **di - radical**.
- The oxygen atoms reacts with oxygen molecules forming ozone. This gives out heat - exothermic:

$$O_{(g)} \quad + \quad O_{2(g)} \quad \rightarrow \quad O_{3(g)} \quad + \quad \text{Heat}$$

How the ozone layer works:

- Ozone absorbs UV radiation breaking the molecule into oxygen molecules and atoms:

$$O_{3(g)} \quad + \quad UV \quad \rightarrow \quad O_{2(g)} \quad + \quad O_{(g)}$$

- The oxygen atom then react with an oxygen molecule:

$$O_{(g)} \quad + \quad O_{2(g)} \quad \rightarrow \quad O_{3(g)} \quad + \quad \text{Heat}$$

- Overall, UV is converted to heat energy and this process continues until the 2 reactions reach an equilibrium:

$$O_{(g)} \quad + \quad O_{2(g)} \quad \leftrightarrows \quad O_{3(g)}$$

Removal of ozone:

$$O_{(g)} \quad + \quad O_{3(g)} \quad \rightarrow \quad 2O_{2(g)}$$

- Oxygen atoms remove ozone. This is a slow reaction but the balance can be affected easily (later).

<u>Ozone depletion</u>

1) CFC's:

- UV light breaks the C – Cl bond releasing chlorine radical

$$CF_2Cl_2 \rightarrow CF_2Cl^{\cdot} + Cl^{\cdot}$$

- This chlorine radical catalyses the decomposition of ozone with the chlorine radical coming out unchanged (and available for more ozone decomposition).

$$Cl^{\cdot} + O_3 \rightarrow ClO^{\cdot} + O_2 \text{ Step 1}$$

$$ClO^{\cdot} + O \rightarrow Cl^{\cdot} + O_2 \text{ Step 2}$$

Overall

$$O_{(g)} \quad + \quad O_{3(g)} \quad \rightarrow \quad 2O_{2(g)}$$

- Free radicals react fast and the chlorine radical could decompose as many as 100000 ozone molecules.
- The oxygen radical in step 2 is produced from UV dissociation of oxygen and ozone in the stratosphere.

2) Nitrogen oxide:

- Nitrogen oxides are formed by lightening strikes and aircraft engines:

$$^{\cdot}NO + O_3 \rightarrow {}^{\cdot}NO_2 + O_2 \text{ Step 1}$$

$$^{\cdot}NO_2 + O \rightarrow {}^{\cdot}NO + O_2 \text{ Step 2}$$

Overall

$$O_{(g)} \quad + \quad O_{3(g)} \quad \rightarrow \quad 2O_{2(g)}$$

Controlling air pollution

The internal combustion engine:

- The high pressures and temperatures causes many atmospheric pollutants:

1) Carbon monoxide:

- Is poisonous, combines with haemoglobin in place of oxygen.
- Reduces the ability to perform complex tasks, dexterity,vision

2) Nitrogen oxides (NO_x):

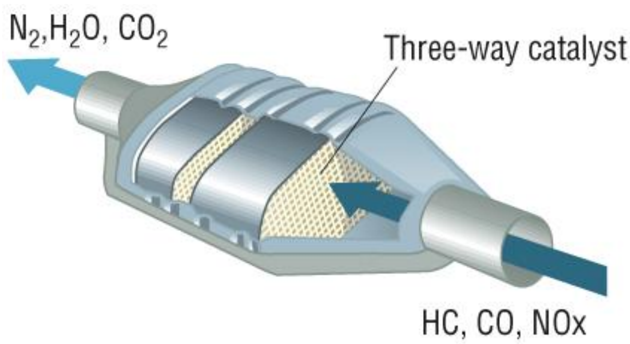
- The high temperatures in a car engine will break the triple bond in nitrogen, N_2 allowing them to react with oxygen forming nitrogen oxides.
- 2 main oxides are nitrogen monoxide, NO and nitrogen dioxide, NO_2.
- Produces low level ozone and nitric acid (acid rain)
- NO_x irritate the respiratory system (asthmatics).

3) Unburnt hydrocarbons:

- Volatile organic compounds (VOC's) are unburnt fuels released in exhaust gases.
- Benzene compounds are carcinogenic and of particular concern.
- These benzene compounds will react with NO_2 causing low level ozone.
- Low level ozone irritates the respiratory system.

The catalytic converter:

- These are made from **Pt Rh Pd** metals in a honeycombed structure to increase surface area forming the catalyst.



- There are 2 types of catalytic converters:

1) Oxidation catalytic converters - diesel engines:

- Convert CO to CO_2 and oxidise VOC's:

$$2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$$

$$C_{12}H_{26(l)} + 18.5O_{2(g)} \rightarrow 12CO_{2(g)} + 13H_2O_{(g)}$$

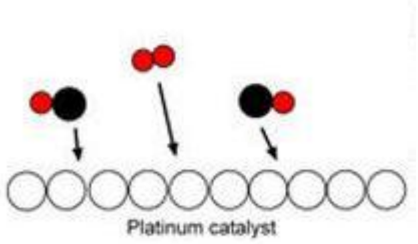
- A complex filter also removes any particulate matter.

2) 3-way catalyst - petrol engines:

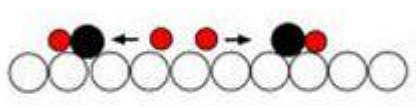
- As above but also converts removes NO:

$$2NO_{(g)} + 2CO_{(g)} \rightarrow N_{2(g)} + 2CO_{2(g)}$$

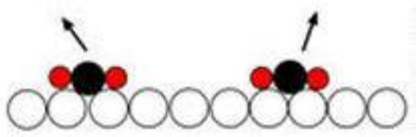
How the catalyst functions:



Adsorption: As the molecules diffuse over the surface of the catalyst some of the molecules are held on the metal surface.



Reaction: Temporary bonds are formed between the molecules and the surface of the catalyst. This weakens the bonds in the molecules. The molecules can now react.



Desorption: After the reaction the products are desorbed from the catalyst and diffuse away.

Green chemistry

Sustainability and the green chemist

The 12 principles:

1) Prevention

2) Atom economy

3) Less hazardous chemical synthesis

4) Design safer chemicals

5) Safer solvents and auxiliaries

6) Design for energy efficiency

7) Use of renewable feedstocks

8) Reduce derivatives

9) Catalysts

10) Design for degradation

11) Real time analysis for pollution prevention

12) Inherently safer chemistry for accident prevention

CO_2 - villain to saviour

Using CO_2

- CO_2 can be used instead of allowed to pollute the atmosphere.
- It can be collected from fermentation or the decarbonisation of methane

1) In foam:

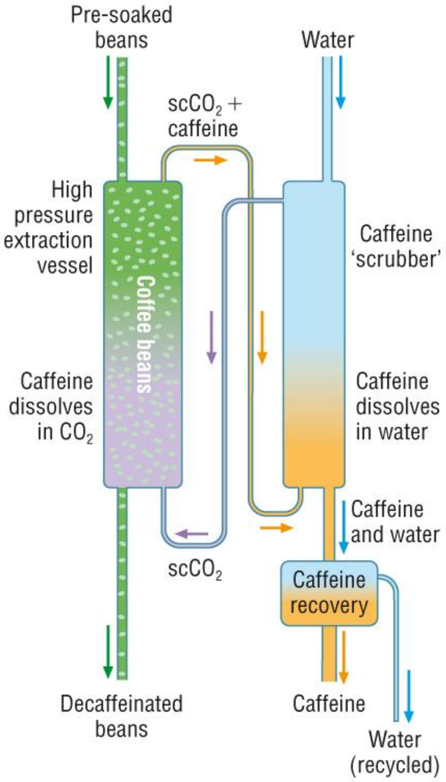
- It can be used in expanded foam instead of CFC's

2) As a solvent:

- By altering temperature and pressure CO_2 can be converted to a liquid (known as a super critical fluid, $scCO_2$)
- An advantage is that it is not flammable or toxic.

a) Decaffeinating coffee:

- It has the advantage that it removes 97 - 99% without affecting the taste:



b) Extracting beer flavour:

- As with decaffeinating coffee, $scCO_2$ can remove the beer flavour from hops without losing flavour or increasing toxicity risks.

c) Dry cleaning:

- $scCO_2$ has now replaced C_2Cl_4 and CCl_4, known carcinogens.
- It has the same properties for dissolving greases and oils but without the risks.

d) Toxic waste treatment:

- $scCO_2$ can remove dissolved organic compounds (toxic waste) from waste mixtures.

e) For chemical synthesis:

- $scCO_2$ ability as a solvent can be controlled by varying temperature and pressure.
- This allows you to produce the desired product with fewer co products.
- It also makes separation much easier.