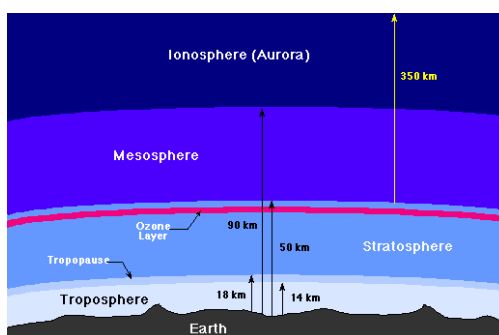


Topic 14 – Environmental Chemistry

Revision Notes

1) Introduction

- The Earth's atmosphere consists of several layers
- The layer nearest the Earth's surface is the troposphere. This is up to 15 km thick and is where the Earth's weather occurs
- The other layer of interest is the stratosphere which goes from about 18 to 50 km above the Earth's surface. The ozone layer is towards the top of the stratosphere. There is no weather in the stratosphere

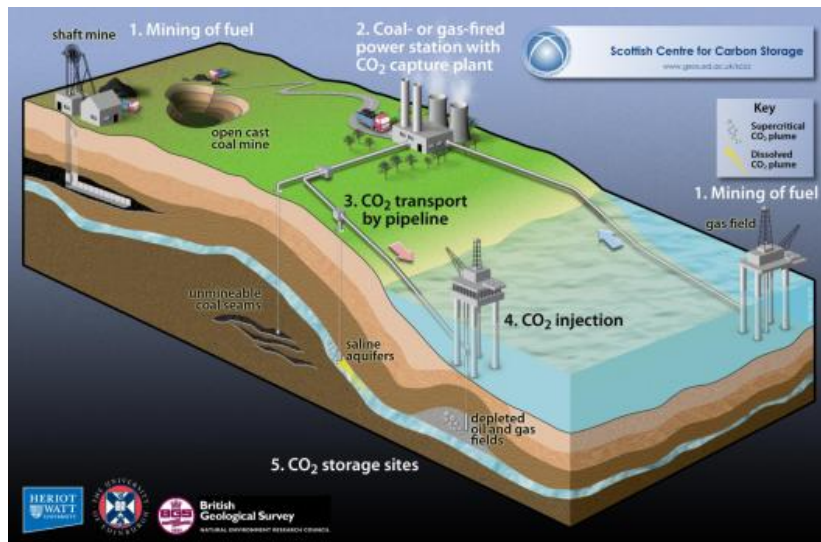


2) The 'Greenhouse Effect'

- In the troposphere, various gases absorb infrared radiation and keep the atmosphere warm
- Infrared radiation is absorbed by C=O bonds in CO₂, O-H bonds in H₂O and C-H bonds in methane. CFCs (chlorofluorocarbons) are also greenhouse gases
- The absorbed energy makes the bonds vibrate
- The warming effect (or 'Greenhouse Effect') of a given gas depends on its concentration in the atmosphere, its ability to absorb infrared radiation and the time taken for it to break down

a) Global Warming

- Increased concentrations of greenhouse gases, like CO₂, contributes global warming because of the increased absorption of IR radiation
- Global warming has undesirable effects such as climate change and the melting of polar ice-caps and consequent rise in sea level which could flood low-lying areas. It is, therefore, important to control global warming resulting from increased concentrations of greenhouse gases
- Chemists are involved in minimising climate change by:
 - Providing scientific evidence to governments to verify that global warming is taking place
 - Investigating solutions to environmental problems (such as CCS described below)
 - Monitoring progress against initiatives such as the Kyoto protocol
- One way of reducing CO₂ emissions is carbon capture and storage, CCS
- CCS involves storing waste CO₂ as a liquid injected deep in the oceans, storing CO₂ in deep geological formations and by reacting CO₂ with metal oxides to form stable carbonate minerals e.g. CaCO₃



Source: <http://www.co2capture.co.uk>

3) The ozone layer

- Ultraviolet radiation is harmful to living things. The ozone layer towards the top of the stratosphere absorbs much of the UV from the sun's radiation
- Life on land would not have evolved without the presence of the ozone layer

a) **Formation of ozone**

- Ozone, O₃, is continuously formed and broken down in the stratosphere by the action of ultraviolet radiation. The equation for the reaction involved is:



- Oxygen atoms for the forward reaction, O, are formed in the stratosphere by the action of ultraviolet radiation on O₂ and O₃
- The backward reaction occurs when ozone breaks down by absorbing harmful ultraviolet radiation
- These reactions keep the concentration of ozone in the stratosphere steady

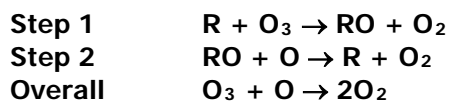
b) **Depletion of the ozone layer**

- In recent years the ozone layer has been depleted by chemicals produced by human activity
- The depletion of the ozone layer over Antarctica has led to increased rates of skin cancer in the Southern hemisphere
- The chemical species responsible for depleting the ozone layer are Cl and NO radicals
- These radicals are produced by the action of UV light on CFCs and oxides of nitrogen, respectively (this is sometimes called photolysis)
- The oxides of nitrogen (NO_x) are produced by aircraft engines (and thunderstorms)





- Cl and NO radicals, R, catalyse the breakdown of stratospheric ozone



- R does not appear in the overall equation because it is a catalyst (it is used up in step 1 and reformed in step 2)
- One radical can catalyse the decomposition of many ozone molecules
- RO is the intermediate in this reaction

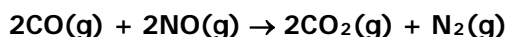
c) More on CFCs

- CFCs had many uses such as refrigerants, for blowing polystyrene and in aerosols. Their damaging effect on ozone only became apparent after they had been in use for a considerable period
- CFCs have now been banned but they are stable compounds and will persist in the troposphere and stratosphere for some time. They will therefore continue to break ozone down during this time
- Replacements for CFCs have been developed. However, some of these also deplete the ozone layer although to a much smaller extent than CFCs

4) Controlling air pollution

a) Catalytic converters

- The pollutants produced by car engines include carbon monoxide, CO, oxides of nitrogen, NO_x and unburnt hydrocarbons
- Carbon monoxide comes from the incomplete combustion of the hydrocarbons in petrol and is toxic
- Oxides of nitrogen are produced when oxygen and nitrogen from the air react together due to the very high temperatures reached inside car engines
- Small amounts of hydrocarbons pass straight through a car engine without being burnt
- These pollutants are toxic and contribute to the production of ozone in the lower levels of the atmosphere and the creation of photochemical smog
- Catalytic converters reduce the emission of CO and NO by allowing them to react together to make harmless products



- Catalytic conversion involves three steps
 - Adsorption of the reactants (CO and NO) onto the surface of the catalyst.
 - Chemical reaction
 - Desorption of products (CO₂ and N₂) from the surface of the catalyst
- In adsorption, the reactants are bonded to the catalyst. This weakens bonds inside the reactants and allows a chemical reaction to take place
- The adsorption must be strong enough to weaken bonds in the reactants but weak enough to allow desorption of products
- Tungsten, W, adsorbs too strongly so products are not desorbed. Silver, Ag, adsorbs too weakly so reactants are not held long enough for reaction to take place or bonds to be weakened

- The best catalysts are found in the centre of the d-block i.e. Ni, Pt, Rh, Pd (nickel, platinum, rhodium, palladium)

b) Monitoring pollution

- Infrared spectroscopy can be used to monitor the level of pollutants such as carbon monoxide, CO
- Infrared radiation of a certain frequency is passed through the test sample
- Some of the radiation will be absorbed by carbon monoxide in the sample
- Absorption by sample is compared with absorption by a control e.g. nitrogen, N₂
- The difference in infrared absorption measures the amount of CO present in the test sample
- The method can be adapted to test for other gases, such as NO, but different frequencies of IR will be needed

5) Sustainability

- There are five principles of chemical sustainability:
 - Using industrial processes that involve fewer chemicals and reduce or eliminate the use of hazardous chemicals
 - Designing processes with a high atom economy that minimise the production of waste materials
 - Using renewable resources such as plant-based substances (e.g. making ethanol by fermentation of sugar rather than hydration of ethene)
 - Using alternative energy sources, such as solar energy, rather than consuming finite resources, such as fossil fuels i.e. using renewable rather than non-renewable resources
 - Ensuring that any waste products are non-toxic and can be recycled or biodegraded into harmless substances
- The apparent benefits of sustainable processes may be offset by unexpected and detrimental side-effects e.g. production of biodiesel uses grain and land needed for food, with poorer countries being worse affected
- Pollution can cross national boundaries so it is important to establish international co-operation to promote the reduction of pollution levels