NEUB CHE 101 Lecture 10: Environmental Chemistry

Effects of greenhouse gases:

1. Infrared radiation IR from the sun has a short wavelength and most of it passes through the atmosphere and is absorbed by the earth's surface.
2. The earth heats up, and re-emits longer wavelength IR. Any greenhouse gases in the atmosphere effectively reflect the longer wavelength IR which warms the atmosphere.
3. The relative greenhouse effect of a gas varies because molecules absorb IR differently.
4. The global warming potential of a gas combines it ability to absorb IR with its lifetime in the atmosphere. The concentration of a gas in the atmosphere also affects GWP. E.g. CO_2 has a low global warming potential, but the concentrations of it are increasing. CFCs have a much higher GWP but the overall concentrations are very low.

Anthropogenic and natural climate change:

Anthropogenic: results from human activities, e.g. burning fossil fuels and deforestation. These increase levels of CO_2, methane and other gases over relatively short timescales.

Natural climate change: natural processes such as dissolving of CO_2 in sea water or formation of carbonates in rocks over hundreds of years. Volcanic eruptions can also cause climate change.

Carbon neutrality and carbon footprint:

- A carbon neutral fuel is one for which the release of CO_2 in its manufacture and burning equals the absorption of CO_2 as the raw material is grown or the fuel formed. Only certain biofuels can be considered carbon neutral
- A carbon neutral process occurs when there is no overall carbon emission into the atmosphere.
- A carbon footprint in general is a measure of the amount of carbon dioxide emitted through the use of fossil fuels. It is often measured in tonnes of carbon dioxide, and can be calculated for an individual, a household, an organisation or over a product lifecycle for manufactured goods.
- The fuel petrol is definitely not carbon neutral - releases CO2 into atmosphere which was trapped in the earth millions of years ago.
- Bioethanol is more or less carbon neutral- produced by fermentation of sugar from crops. It's thought of as being carbon neutral as the CO2 released when burnt was removed by the crop as it grew. However, there are still carbon emissions when considering the whole process.
- Hydrogen gas can be carbon neutral. But heat involved in production of hydrogen can be an issue.

The ozone layer and CFCs

The atmosphere is composed of several layers. Most pollutant molecules are broken down before they reach the upper atmosphere. However it is possible for some particularly stable molecules to enter the upper atmosphere. One such type of molecule are the chlorofluorocarbons, CFCs, which are stable because of the strength of the C-F bond. These were used in aerosols and refrigerants. When they enter the upper atmosphere, the CFCs can damage the —ozone layer .

The ozone layer is formed by the energy from the sun's ultra violet radiation being able to split an oxygen molecule into two oxygen atoms.

$$O_2 \rightarrow 2O\cdot$$

The oxygen atom formed can then combine with an oxygen molecule to form ozone, O_3

$$O2 + O\cdot \rightarrow O3$$

The ozone formed is able to absorb harmful ultra violet radiation from the Sun, so protecting the Earth's surface from these rays. When this happens the reaction above is reversed.

$$O_3 \rightarrow O_2 + O\cdot$$

In the 1980s it was discovered that this protective ozone layer was diminishing during the summer over the Antarctic and that the —hole was increasing in size. Chemists tracked the cause down to the CFCs. The stability of CFCs means that they are not broken down in the lower atmosphere, but when they reach the upper atmosphere the UV radiation causes the C-Cl bond to be broken forming Cl· radicals. These radicals then react with ozone as follows:

$$O_3 + Cl\cdot \rightarrow O_2 + ClO\cdot$$

The radical then proceeds to react with the oxygen atoms present in the stratosphere:

PREPARED BY
SHAHADAT HUSSAIN PARVEZ

$$O\cdot + ClO\cdot \rightarrow O_2 + Cl\cdot$$

This reaction removes oxygen atoms that could otherwise generate more ozone, but it also regenerates the Cl· radical, allowing a series of reaction to take place similar to the propagation stages of the chlorination of methane. It is estimated that one Cl· radical can breakdown a million ozone molecules.

As a result scientists recommended the phasing out of CFCs. In 1987 a United Nations conference was held in Montreal to tackle the problem and an agreement was established in which there would be a phased reduction in the use of CFCs leading to an eventual ban. This agreement was called the Montreal Protocol.

Five ways in which the Chemical industry can become Greener

- Change to renewable resources.
- Find alternatives to very hazardous chemicals.
- Discover catalysts for reactions with high atom economies, e.g. the development of methods used to produce ethanoic acid based on catalysts of cobalt, rhodium and iridium
- Make more efficient use of energy, e.g. the use of microwave energy to heat reactions in the pharmaceutical industry
- Reduce waste and prevent pollution of the environment.

Processes in the chemical industry are being reinvented to make them more sustainable or 'greener' by:

1. Changing to renewable resources: e.g. plastics made from crude oil can be made from plant products
2. Making more efficient use of energy. E.g. in the pharmaceutical industry microwave radiation is used to heat the reacting mixture directly rather than using conventional eating systems which heat the reaction vessel which passes on heat to the reaction mixture – less efficient.
3. Finding alternatives to very hazardous chemicals e.g. some chemicals can harm humans, other living organisms or the environment.
4. Discovering catalysts for reactions with higher atom economies. This is important because a high atom economy means less waste is produced and this makes the best use of resources.
5. Reducing waste and preventing pollution of the environment. E.g. creating recyclable or using products to conserve raw materials and where possible waste should be recycled or biodegradable.

Alternative fuels

Use of fossil fuels as energy sources for vehicles, power generation plants or domesticheating is one of the key activities which places carbon dioxide into the atmosphere. Ifthese can be made carbon neutral or have their carbon footprint reduced, it isadvantageous to the environment.

One way of reducing the carbon footprint is to use biofuels. The principle of a biofuel isthat they are formed by plants that take up carbon dioxide from the air to make the plantmaterial which is then converted into fuel, and when the fuel is burnt, it simply puts backinto the air the carbon dioxide it originally removed, so overall it does not add to thecarbon dioxide level, and can therefore be described as carbon-neutral.

This simple view of biofuels does not however provide the full picture. Bioethanol forexample is produced from sugar cane in Brazil and from maize in the USA. Theproduction of ethanol in the USA uses fertilizers and pesticides which have taken energy(form oil) to make. The ethanol then needs to be separated by distillation, a processagain which uses energy from oil. Biodiesel is more effective in reducing the carbonfootprint because it does not require distillation.

Hydrogen is a much better alternative fuel as it only produces water when it is burnt. Thekey point about hydrogen is how it is produced. If it is made by electrolysis using mainselectrical supply, it can still have a large carbon footprint if the electrical generationinvolves the combustion of fossil fuels. In the same way hydrogen generated by thereaction of methane with steam, the final products being hydrogen and carbon dioxide,has a significant carbon footprint. Hydrogen produced by