## Cycles in Nature

Bacteria break down complex organic compounds to form small molecules.
Aerobic decomposition requires $O_2$
Anaerobic decomposition only functions in the absence of $O_2$

Products of decomposition for organic matter containing certain elements:

| Element | Aerobic product | Anaerobic product |
|---|---|---|
| Carbon (C) | $CO_2$ (carbon dioxide) | $CH_4$ (methane) |
| Nitrogen (N) | $NO_3^-$ (nitrate) | $NH_3$ (ammonia) |
| Phosphorus (P) | $PO_4^{3-}$ (phosphate) | $PH_3$ (phosphine) |
| Sulphur (S) | $SO_4^{2-}$ (sulfate) | $H_2S$ (hydrogen sulfide) |

Photosynthesis converts carbon dioxide and water into glucose using sunlight for energy and chlorophyll as a catalyst.

$$6CO_{2\,(g)} + 6H_2O_{(l)} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} C_6H_{12}O_{6\,(aq)} + 6O_{2\,(g)}$$

Aerobic respiration obtains energy from glucose and oxygen:

$$C_6H_{12}O_{6\,(aq)} + 6O_{2\,(g)} \rightarrow 6CO_{2\,(g)} + 6H_2O_{(l)} + \text{Energy}$$

## The Nitrogen Cycle

Nitrogen ($N_2$) has a strong triple covalent bond and therefore tends not to react, but it can be converted into compounds containing nitrogen through biological processes or during lightning discharges or high temperatures. This conversion is called *nitrogen fixation*.

Biological fixation of nitrogen occurs when nitrogen-fixing bacteria catalyse the conversion of nitrogen gas into ammonia and ammonium.

$$N_{2\,(g)} \xrightarrow{\text{Nitrogen fixing bacteria}} NH_{3\,(g)} \,/\, NH_4^+{}_{(aq)}$$

High temperature conversion of nitrogen occurs during lightning discharges, during combustion in engines and in furnaces.

1. $2N_{2\,(g)} + O_{2(g)} \xrightarrow{\text{high energy}} 2N_2O_{\,(g)}$
2. $N_{2\,(g)} + O_{2(g)} \xrightarrow{\text{high energy}} 2NO_{\,(g)}$

   This is followed by a spontaneous reaction:

   $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2\,(g)}$

### Nitrogen cycle natural processes

- Atmospheric nitrogen is converted into oxides of nitrogen due to lightning, forest fires and other natural high energy events. Nitrogen reacts with oxygen to form nitric oxide (NO) which then further reacts spontaneously with oxygen to form nitrogen dioxide ($NO_2$). This dissolves in atmospheric water, producing nitrate ions which fall to the ground during rain.
- Other atmospheric nitrogen is converted into ammonia or ammonium compounds ($NH_3$/$NH_4^+$) by nitrogen-fixing bacteria.These bacteria are found in some plants (mostly legumes).
- Proteins from plants and animals decay to form nitrate ions, ammonia and ammonium.
- Ammonia/ammonium can be converted to nitrate ions by *nitrifying* bacteria.
- Nitrate ions in the ground fertilise the soil.
- Some of the nitrate ions undergo denitrification by *denitrifying* bacteria and return to the atmosphere as nitrogen gas.
- Others of the nitrate ions are taken up from the soil by plants. These decay or are eaten by animals which decay, and the cycle continues.

**Nitrogen cycle industrial processes**

- Some industrial processes (such as in combustion engines and furnaces) provide high temperatures which convert atmospheric nitrogen into oxides of nitrogen.
- Other industrial processes produce inorganic nitrogen compounds, the Haber process being an example:

  $$N_{2\,(g)} + 3H_{2\,(g)} \xrightleftharpoons{\text{Iron catalyst}} 2NH_{3\,(g)}$$

  The Haber process is used to produce ammonia which can then be converted into nitrates for fertilisers.

**Fertilisers** contain nutrients required for plant growth (such as nitrogen and phosphorus) in soluble form. Since plants absorb nutrients in solution through their roots, it is important that they be in a water-soluble form (such as nitrate $NO_3^-$ and dihydrogen phosphate $H_2PO_4^-$).

## Greenhouse Effect

The Earth's surface absorbs short-wave radiation (UV and visible light) from the sun and re-emits it as longer-wave radiation (infra-red). *Greenhouse* gases in the atmosphere (such as $CO_2$, $N_2O$, $H_2O$ vapour and $CH_4$) have polar covalent bonds which stretch and bend to absorb the IR, thereby warming the Earth's atmosphere. Of the four mentioned, water vapour traps by far the most energy.

The effect of this energy absorption is that a steady temperature is maintained in the atmosphere, supporting life.

Human activities affect the concentration of certain greenhouse gases and therefore have the potential to disrupt the thermal equilibrium in the atmosphere. An increase of greenhouse gases leads to excess warming and is known as the *Enhanced Greenhouse Effect*.

Possible contributing human activities:

| **Cause** | **Effect** |
|---|---|
| Use (combustion) of carbon-based fuels | Increased $CO_2$ |
| Deforestation | Decreased $CO_2$ removal (by photosynthesis) |
| Rice paddies, natural gas fields, cows/sheep, industrial activities, garbage dumps | Increased $CH_4$ (methane) emissions |
| Fertiliser usage in agriculture | Increased $N_2O$ emissions |

Predicted effects of the Enhanced Greenhouse Effect:

- Increase in global temperature
- Rise in sea levels due to water expansion at higher temperatures
- Climate change and shift in weather patterns
- Melting glaciers and polar ice caps

Possible solutions to the Enhanced Greenhouse Effect:

- Plant more trees
- Burn less carbon-based fuels
- Use alternate energy sources
- Minimise usage of greenhouse gas producers