The Atmosphere and Environment

The Atmosphere

Clean, dry air

may contains

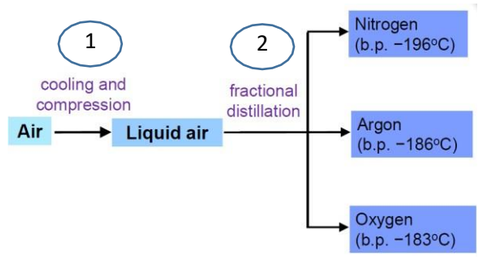
Carbon cycle (Box A)

Carbon cycle is the mechanism that maintains the level of carbon dioxide in the atmosphere.

Composition of clean dry air (dry means no water or water vapour)

Gas	Composition by volume / %
Nitrogen (N_2)	78
Oxygen (O_2)	21
Other gases • Noble gas (mostly argon) • Carbon dioxide	1 0.97 0.03

How is air separated into its constituent gases?



Air pollutants (refer to table)

Air pollution is the condition in which air contains a high concentration of chemicals that may harm living things or damage non-living things.

Pollutants	Sources (how they are produced)	Harmful effects	How to reduce the effect?
Carbon monoxide (CO)	Incomplete combustion of fossil fuels in power plants, factories or combustion engines of vehicles due to **lack of oxygen**	• Reacts irreversibly with haemoglobin in blood to form carboxyhaemoglobin which reduces the ability of haemoglobin to transport oxygen to rest of the body • Results in breathing difficulties, fatigue and even death.	• Catalytic converters **(Box E)**
Sulfur dioxide (SO_2)	• Combustion of fossil fuels which contain sulfur impurities in motor vehicles, power stations and factories • $S(s) + O_2(g) \rightarrow SO_2(g)$ • Volcanic eruptions	• Irritate the eyes and lungs and cause breathing difficulties • Reacts with water in atmosphere to form acid rain (**Box B**) which corrodes metal and limestone structures and harms aquatic life and plants.	• Liming (adding calcium carbonate to neutralise and hence restore lakes and rivers polluted by acid rain) – expensive and effects are temporary. • Flue gas desulfurisation **(Box F)**
Oxides of nitrogen (NO and NO_2)	• Internal combustion of engines • Lightning activity *__temperature must be high__ for oxides of nitrogen to be formed. $N_2(g) + O_2(g) \rightarrow 2NO(g)$ $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$	• Irritate the eyes and lungs and cause breathing difficulties • Reacts with water in atmosphere to form acid rain (**Box B**) which corrodes metal and limestone structures and harms aquatic life and plants. • Leaches nutrients from the soil and causes plants to wither and die.	• Liming (adding calcium carbonate to neutralise and hence restore lakes and rivers polluted by acid rain) – expensive and effects are temporary. • Catalytic converters **(Box E)**
Unburnt hydrocarbons	Released in vehicle exhaust fumes and chemical plants	• Health: cause cancer • Environment: react with nitrogen oxides to form ozone which can damage crops	• Catalytic converters **(Box E)**
Methane Colourless and odourless gas	Decay of plant and animal matter	• It is a greenhouse gas which causes global warming **(Box C)** and thus cause melting of large quantities of ice in north and south poles, resulting in floods that destroys crops and buildings.	
Ozone (O_3) Pale blue pungent gas		• Health: forms photochemical smog which irritates the eyes and lungs and causes breathing difficulties • Environment: damages crops, reduce visibility for traffic	
Chlorofluorocarbons (CFCs) – compound that contains carbon, fluorine and chlorine.	Propellants in aerosols, as well as coolants in refrigerators and air conditioners, release CFCs into the atmosphere	• Cause ozone depletion **(Box D)** which results in increases UV radiation on earth. This causes skin cancer, genetic mutations, eye damage and death to marine life.	• Ban the use of CFCs. Note: Even if the use of CFCs is totally stopped at once, the depletion of ozone layer will continue for many years due to the CFCs already present in the atmosphere. • Use alternative materials such as HFCs HFCs (hydrofluorocarbons) do not have C-Cl bonds which can be broken easily by UV, so HFCs do not release Cl atoms to break down ozone in atmosphere.

Carbon cycle (Box A)

Green plants convert CO_2 and H_2O into glucose and oxygen **in sunlight**.

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

Carbon cycle is the mechanism that maintains the level of carbon dioxide in the atmosphere. (rate of removal of CO_2 is balanced by the rate of CO_2 production)

Removal of carbon dioxide --- photosynthesis and ocean uptake (ocean uptakes serves as massive sinks that trap CO_2 which is later used by marine plants.)

Production of carbon dioxide --- respiration, combustion and decay and bacterial decomposition

Respiration converts glucose in the food we eat into CO_2 and water and energy.

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

Combustion of fuel like methane releases CO_2.

$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (l) + heat\ energy$

Acid rain (Box B)

Acid rain is formed when acidic air pollutants such as SO_2 and NO_2 react with water in the atmosphere.

pH of acid rain is **pH 4 or less.**

$SO_2\ (g) + H_2O\ (l) \rightarrow H_2SO_3\ (aq)$ (sulfurous acid)

In the presence of O_2 in air, sulfurous acid is oxidised to sulfuric acid (H_2SO_4).

Oxides of nitrogen also cause acid rain. In the presence of oxygen and water, NO_2 is converted to nitric acid.

$4NO_2\ (g) + 2H_2O(l) + O_2\ (g) \rightarrow 4HNO_3\ (aq)$

These acids cause the acid rain.

Note that pH of unpolluted rainwater is about 5.7. This is because CO_2 (an acidic oxide) in the air dissolves in rainwater to form carbonic acid (H_2CO_3) which is a weak acid.

Global warming (Box C)

What is greenhouse effect?

Greenhouse gases such as CO_2, CH_4 and water vapour trap some of the **infrared radiation** on earth, thus **heat energy is retained** in the atmosphere. This produces a **warming effect called the greenhouse effect**.

It is crucial for maintaining the proper temperature needed to sustain life on Earth. Without these greenhouse gases, Earth's surface will be around -40°C and be permanently covered with ice.

However, activities such as burning of fossil fuels are causing more CO_2 (greenhouse gas) to be produced. The excess CO_2 is added to the atmosphere at a **higher rate** than photosynthesis can remove (refer to carbon cycle). This then lead to global warming. (**Global warming is the increase in the Earth's average temperature due to the build-up of greenhouse gases in the atmosphere**).

Depletion of ozone (Box D)

Ozone layer is important to us. It acts as a giant sunscreen that filters some of the harmful UV radiation from the sun.

However, the use of chlorofluorocarbons (CFCs) found in propellants in aerosols, as well as coolants in refrigerators and air conditioners, causes the depletion of ozone layer. This will cause an increase in amount of UV radiation that can cause skin cancer, eye damage or death to marine life.

In the presence of UV light, CFCs decompose to form chlorine atoms.

CFC $\xrightarrow[\text{UV}]{}$ chlorine atoms

Chlorine atoms react with ozone molecules to form chlorine oxide and oxygen.

$Cl + O_3 \rightarrow ClO + O_2$

Catalytic converters (Box E)

- A catalytic converter helps to remove air pollutants in vehicle exhaust gases.
- When the hot exhaust gases pass over the **platinum and rhodium** catalysts, the harmful pollutants undergo redox reactions and are converted into harmless substances.

  Carbon monoxide is oxidised to carbon dioxide while nitric oxide is reduced to nitrogen:

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

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

  Unburnt hydrocarbons are oxidised to carbon dioxide and water:

  Example: **$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$**

Note:

Other ways to reduce air pollution caused by motor vehicles.

- Use lightweight alloys to make car bodies to improve fuel efficiency.
- Switch to electric or hybrid electric vehicles to reduce exhaust gas emissions.
- Use alternative fuels such as hydrogen fuel, where products of combustion are harmless.

Flue gas desulfurisation (Box F)

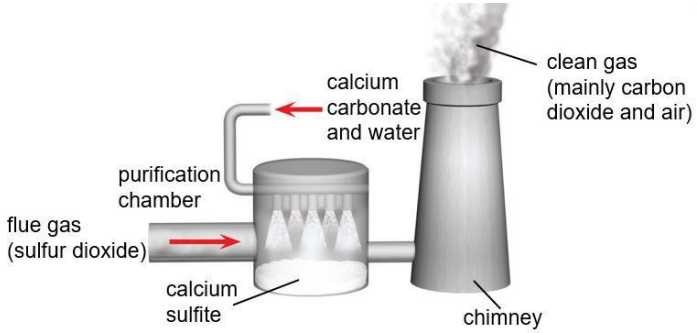
Two ways to minimise the effects of sulfur dioxide pollution:

Way 1:

- Remove sulfur from fossil fuels before burning.
  - However, this method is too expensive and difficult.

Way 2:

- Remove sulfur dioxide from the waste gases (flue gases) formed when the fossil fuels undergo combustion (cheaper).
- The process of removing sulfur dioxide from flue gases is called **desulfurisation**.



SO_2 reacts with calcium carbonate to form calcium sulfite ($CaCO_3$) and CO_2.

$CaCO_3(s) + SO_2(g) \rightarrow CaSO_3(s) + CO_2(g)$

The calcium sulfite than oxidized to $CaSO_4$ by O_2 in the air.

$2CaSO_3(s) + O_2(g) \rightarrow 2CaSO_4(s)$

Alternatively, we can also use calcium oxide for desulfurisation.

$CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$