Atmosphere

Part One

Atmosphere

Which environment would you prefer to live in?

Atmosphere

Atmosphere

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Atmosphere

The Earth's atmosphere is a complex **system** in which pollutants cause undesirable **change**.

- What are some generalisations about the terms *system* and *change*?

Atmosphere

- Some examples of generalisations that can be made:
  - **Systems:**

$\rightarrow$ Systems are made-up of subsystems that interact with each other.

$\rightarrow$ Systems follow rules.

- **Change:**

$\rightarrow$ Change is inevitable (unavoidable).

$\rightarrow$ Change can have positive consequences or negative consequences.

$\rightarrow$ Change can be reversible or irreversible.

$\rightarrow$ Change can be steady, cyclic, random or chaotic.

Atmosphere

- **Enduring Understanding:**

→ In the name of progress, humanity - driven by developments in science and technology - is changing the Earth's environment. Some of these changes are positive while others are negative. Some of these changes are reversible while some are potentially irreversible.

→ Humans have a moral obligation to preserve planet Earth.

Atmosphere

- **Essential Questions:**

→ What causes atmospheric pollution?

→ What are the consequences of atmospheric pollution? How does atmospheric pollution affect the world that we live in?

→ What measures can be taken to reduce atmospheric pollution?

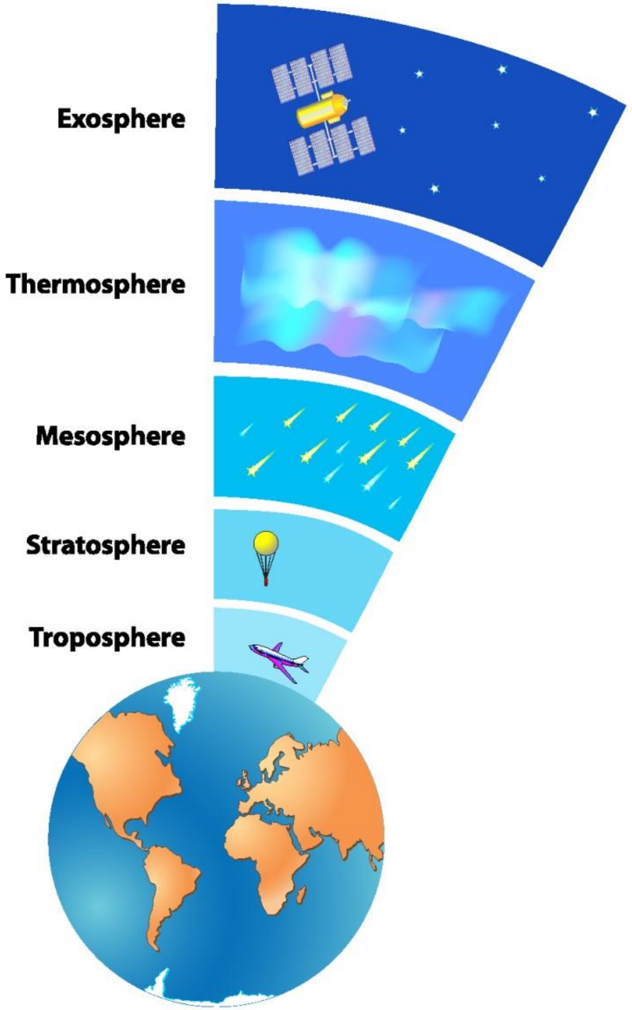
→ What are the possible consequences if humanity fails to reduce atmospheric pollution?

→ To what extent should scientists and engineers be held responsible for atmospheric pollution?

Atmosphere

What is the Earth's Atmosphere?

Atmosphere



- The Earth's atmosphere is a mixture of gases that completely cover the surface of the planet.

- The Earth's atmosphere is an important *natural resource* from which argon (b.p. = –186 °C), nitrogen (b.p. = –196 °C) and oxygen (b.p. = –183°C) are extracted by the *fractional distillation* of liquified air.

- Since the Industrial Revolution (1780 – 1830) the Earth's atmosphere has become increasingly *polluted*.

Atmosphere

What do I need to know about the Earth's atmosphere?

Atmosphere

Learning Outcomes

Candidates should be able to:

a) Describe the volume composition of gases present in dry air as being approximately 78% nitrogen, 21% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide.

b) Name some common atmospheric pollutants, *e.g.* carbon monoxide; methane; nitrogen oxides (NO and NO_2); ozone; sulfur dioxide; unburned hydrocarbons.

c) State the sources of these pollutants as:

i) Carbon monoxide from incomplete combustion of carbon-containing substances.

ii) Nitrogen oxides from lightning activity and internal combustion engines.

iii) Sulfur dioxide from volcanoes and combustion of fossil fuels.

- Singapore Examinations and Assessment
- Board University of Cambridge International Examinations
- Ministry of Education Singapore

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Learning Outcomes

Candidates should be able to:

d) Describe the reactions used in possible solutions to the problems arising from some of the pollutants named in **b)**:

i) The redox reactions in catalytic converters to remove combustion pollutants.

ii) The use of calcium carbonate to reduce the effect of ‘acid rain’ and in flue gas desulfurisation.

e) Discuss some of the effects of these pollutants on health and on the environment:

i) The poisonous nature of carbon monoxide.

ii) The role of nitrogen dioxide and sulfur dioxide in the formation of ‘acid rain’ and its effects on respiration and buildings.

Atmosphere

Learning Outcomes

Candidates should be able to:

f) Discuss the importance of the ozone layer and the problems involved with the depletion of ozone by reaction with chlorine containing compounds, chlorofluorocarbons (CFCs).

g) Describe the carbon cycle in simple terms, to include:
i) The processes of combustion, respiration and photosynthesis.
ii) How the carbon cycle regulates the amount of carbon dioxide in the atmosphere.

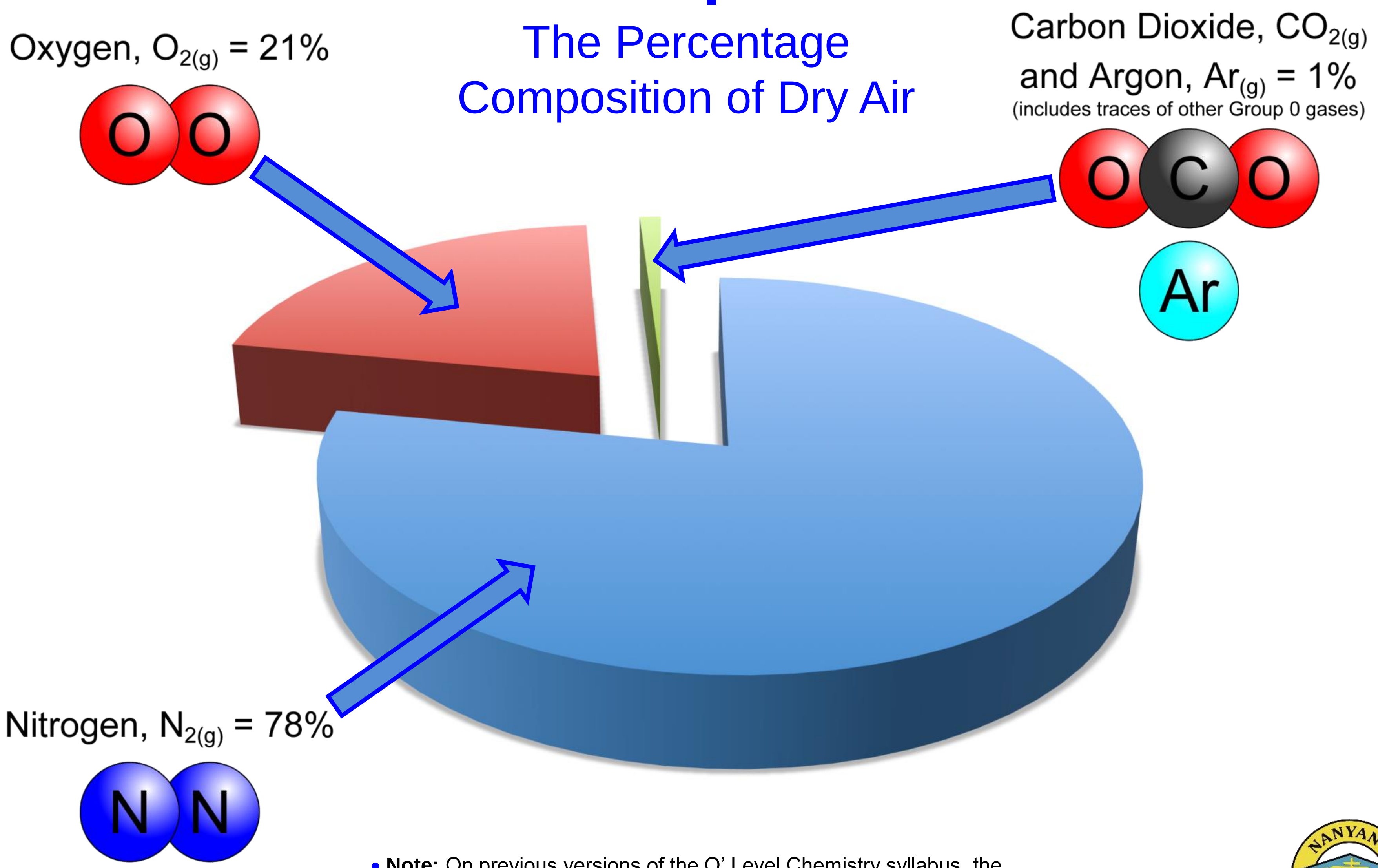
h) State that carbon dioxide and methane are greenhouse gases and may contribute to global warming, give the sources of these gases and discuss the possible consequences of an increase in global warming.

Atmosphere

What is the composition of the Earth's atmosphere?

Atmosphere

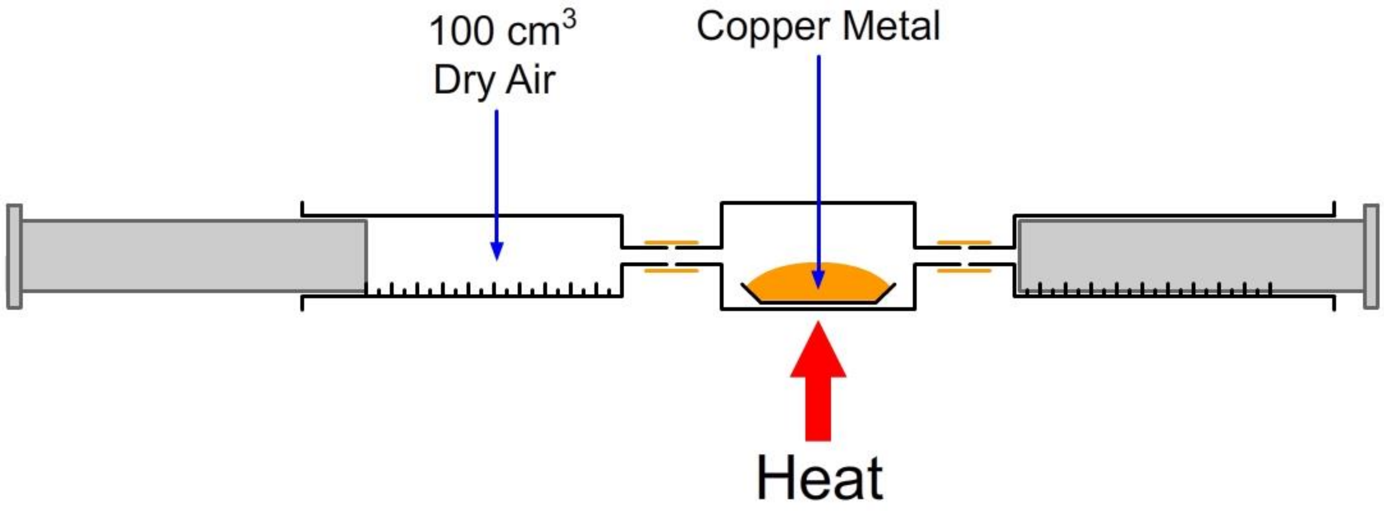
The Percentage Composition of Dry Air



- **Note:** On previous versions of the O' Level Chemistry syllabus, the composition of dry air was given as 79% nitrogen, 20% oxygen and 1% carbon dioxide and argon.

Atmosphere

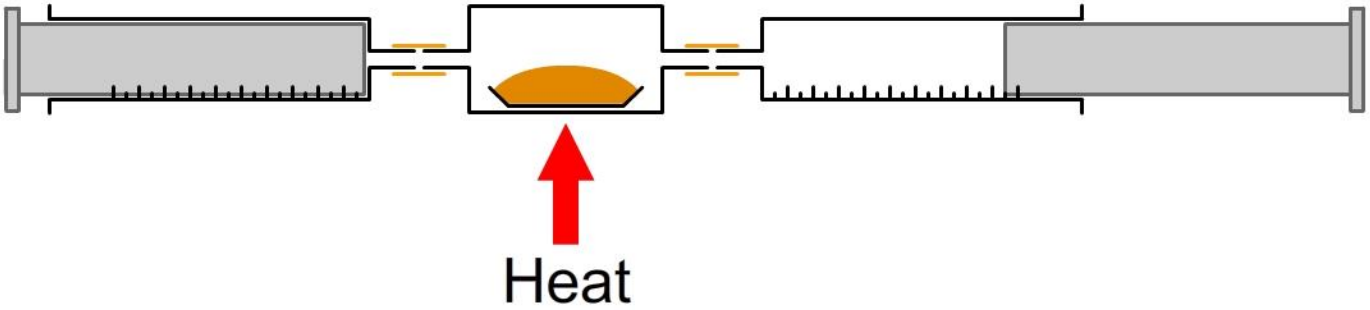
- In a simple experiment to determine the percentage oxygen in dry air, 100 cm^3 of dry air (measured at room temperature and pressure) is passed over the surface of hot copper.



$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

Atmosphere

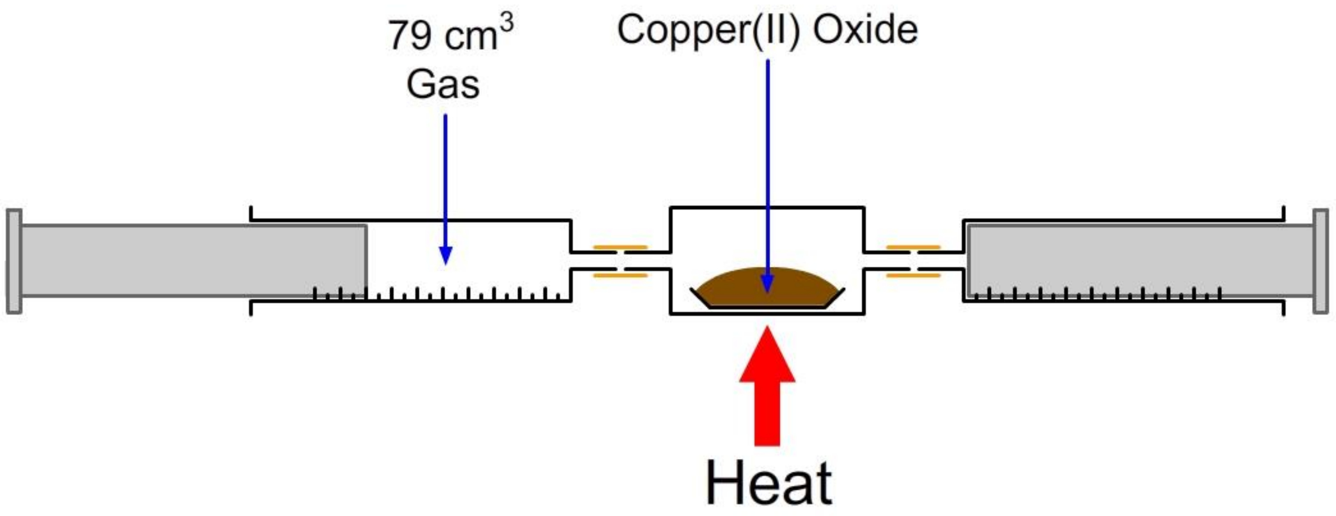
- Only the oxygen in the dry air reacts with the hot copper to form solid copper(II) oxide. The argon, carbon dioxide and nitrogen remain in their gaseous states.



$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

Atmosphere

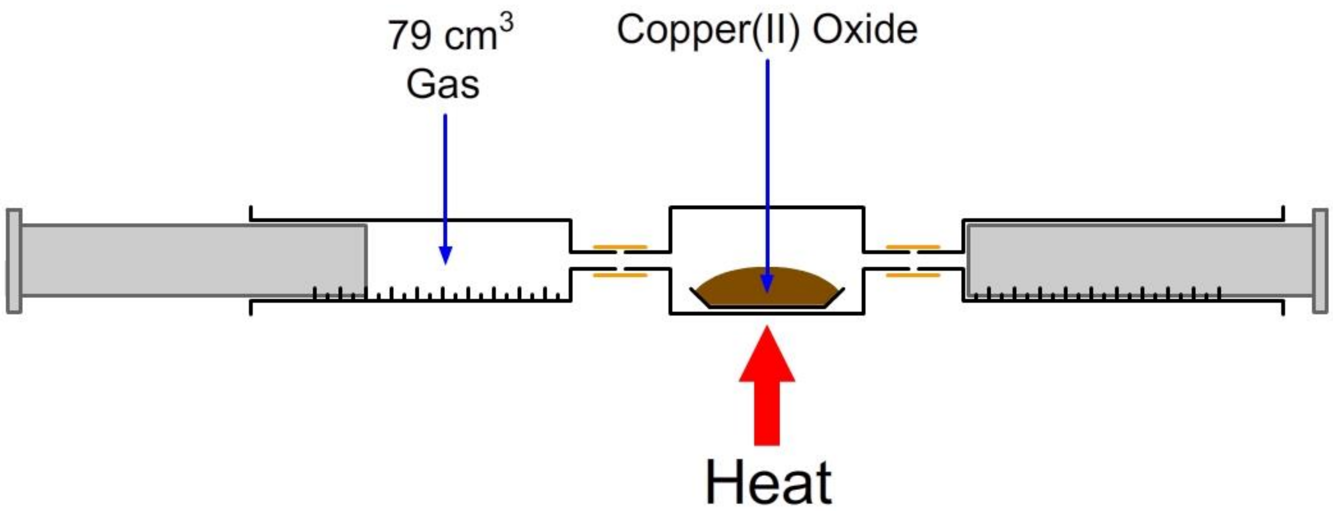
- The air is heated until it reaches a constant volume. At the end of the experiment the apparatus is allowed to cool to room temperature once again.



$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

Atmosphere

- At the end of the experiment 79 cm^3 of gas is found to remain in the gas syringe. This indicates that 100 – 79 = *21 cm^3* of *oxygen* was present in the dry air.

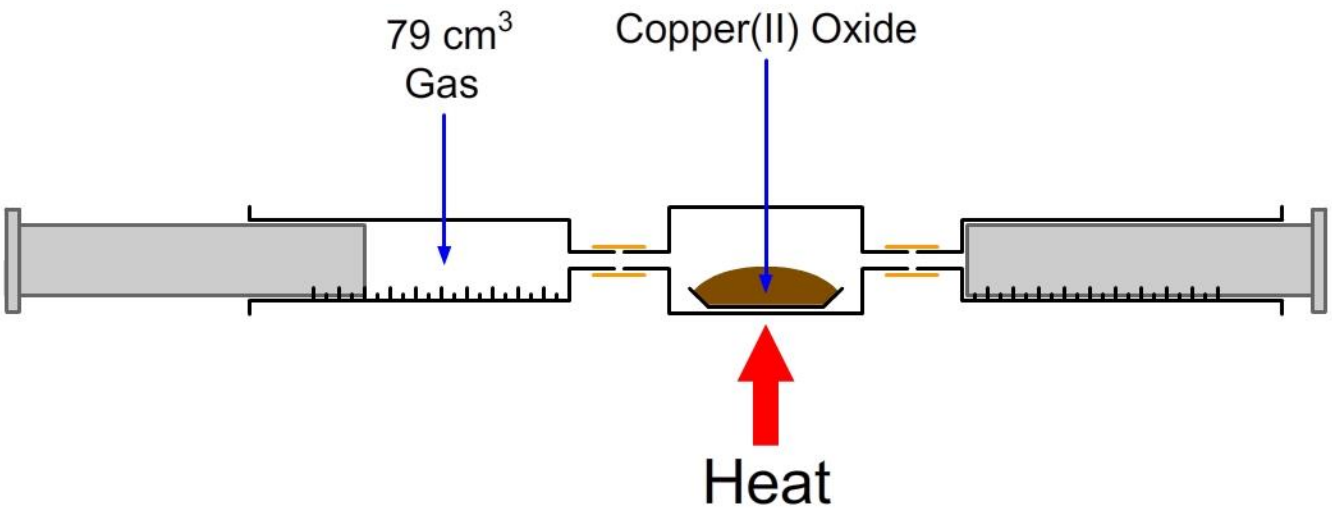


$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

Atmosphere

- Dry air is therefore ($21\ cm^3 \div 100\ cm^3$) $\times$ 100 = *21 % oxygen*.

Note: the volume occupied by the solid copper(II) oxide is considered to be insignificant, and does not affect the results.



$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

Atmosphere

Why is copper used in the experiment, as opposed to elements such as carbon or magnesium?

Atmosphere

- When copper reacts with oxygen, the only product is *solid* copper(II) oxide, which is black in appearance:

$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

The volume occupied by the solid copper(II) oxide is *negligible* and does not affect the results of the experiment.

Atmosphere

- When carbon reacts with oxygen, the only product is *gaseous* carbon dioxide:

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

For every mole of oxygen gas removed from the dry air by the reaction, one mole of carbon dioxide gas is produced. As a consequence, there is no overall change in the volume of the gas in the experiment, making it impossible to determine the volume of oxygen gas present in the sample of dry air.

Atmosphere

- Magnesium is a very reactive metal. When magnesium burns in air, it reacts with both oxygen and *nitrogen* to form a white solid mixture of magnesium oxide and magnesium nitride:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

$$3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$$

Because magnesium reacts with both oxygen and nitrogen in the air sample, it is impossible to determine the volume of oxygen gas alone.

Atmosphere

Why must the apparatus be allowed to cool down at the end of the experiment before taking any readings?

Atmosphere

- The volume occupied by a gas depends upon its temperature and pressure.
- An increase in temperature causes a gas to expand and occupy a larger volume, while a decrease in temperature causes a gas to contract an occupy a smaller volume.
- **Note:** It is assumed that pressure remains constant throughout this experiment.

Atmosphere

- The apparatus must be allowed to cool so that the temperature of the gas at the end of the experiment is the same as the temperature of the gas at the start of the experiment.
- This is to ensure that any change in the volume of the gas sample is only due to the removal of oxygen and not due to the expansion / contraction of the gas due to changes in temperature.
- A change in the volume of the gas sample caused by a change in temperature would lead to incorrect observations and conclusions.

Atmosphere

What is atmospheric pollution?

Atmosphere

- Pollution occurs when chemicals that can harm living organisms or damage non-living things are released into the environment.

- Air pollution is caused by harmful gases (referred to as *pollutants*) such as carbon dioxide, sulfur dioxide and oxides of nitrogen. In the 21st Century, air pollution has become a great threat to human life.

Atmosphere

What are some common examples of atmospheric pollutants?

- Carbon monoxide, CO.
- Methane, CH_4.
- Oxides of nitrogen, NO and NO_2.
- Ozone, O_3.
- Sulfur dioxide, SO_2.
- Unburned hydrocarbons, *e.g.* C_8H_{18}.

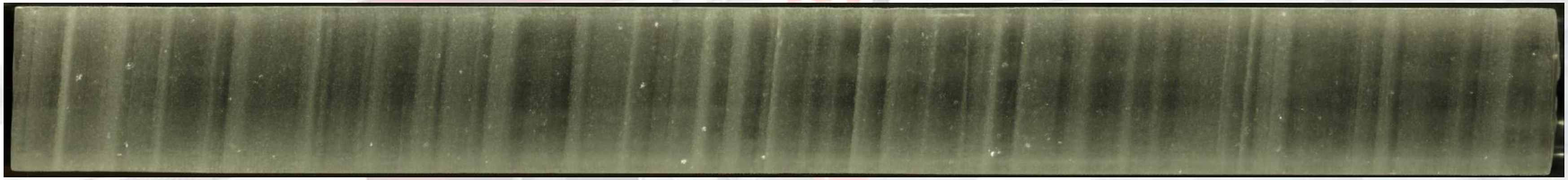
Atmosphere

How do scientists know how the levels of pollutants in the Earth's atmosphere have changed over time?

Atmosphere

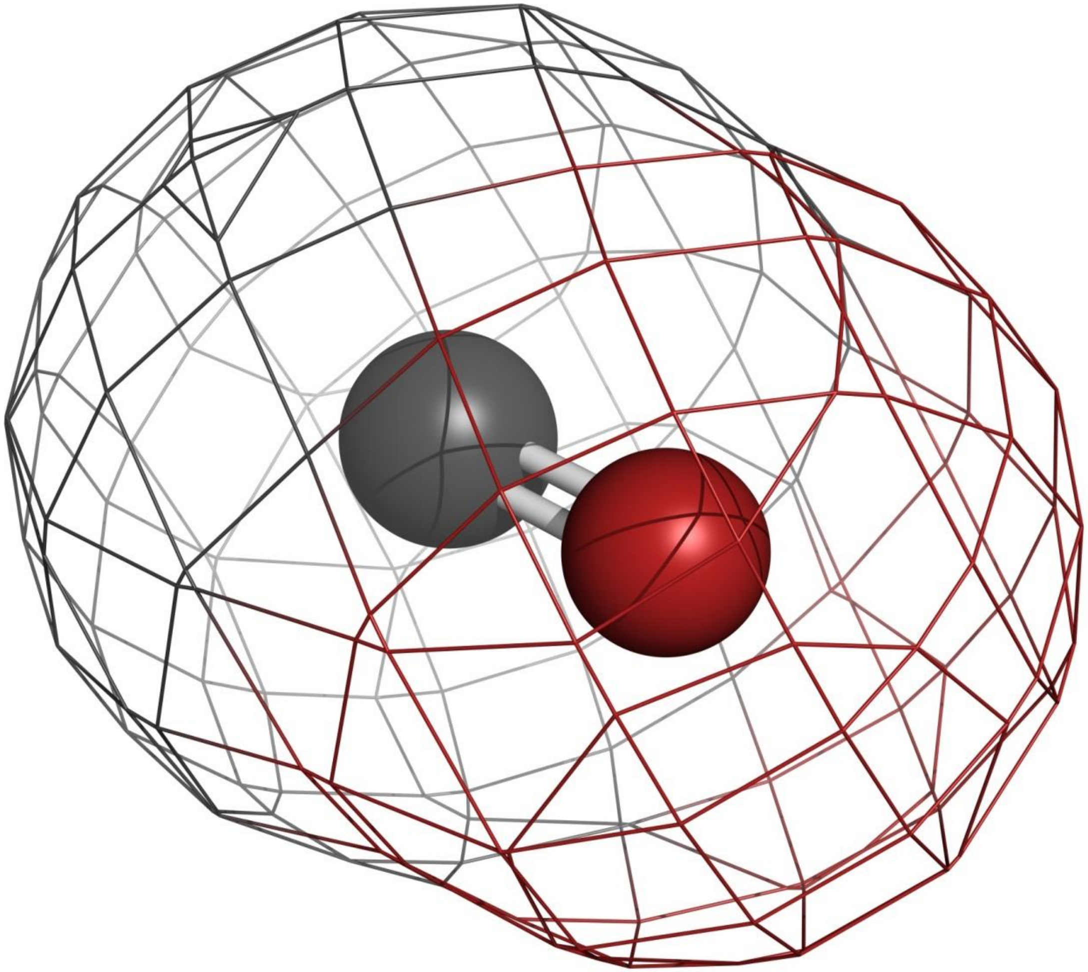
Atmosphere

- Holes drilled into ice fields in the Artic and Antarctic allow scientists to extract *ice cores*.
- Because the ice forms from the incremental build-up of annual layers of snow, the lower layers of the ice core are older than the upper layers of the ice core.
- Analysis of the ice core's chemical composition allows scientists to reconstruct a model of the Earth's atmosphere over time.



- This ice core, extracted from a depth of 1837 - 1838 m, allows scientists to study what the Earth's atmosphere was like 16250 years ago.

Atmosphere
Carbon Monoxide, CO



Atmosphere

Carbon Monoxide, CO

Atmosphere

Carbon Monoxide, CO

- Carbon monoxide (formula, CO) is a poisonous gas that is colourless and odourless.

- Carbon monoxide is produced by the *incomplete combustion* of carbon containing fuels. Incomplete combustion occurs when fuel is burned in a limited supply of oxygen, *i.e.* oxygen is the *limiting reagent* for the reaction.

- Example, the incomplete combustion of methane:

methane + oxygen → carbon monoxide + water

$$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l)$$

Atmosphere

Carbon Monoxide, CO

NANYANG GIRLS' HIGH

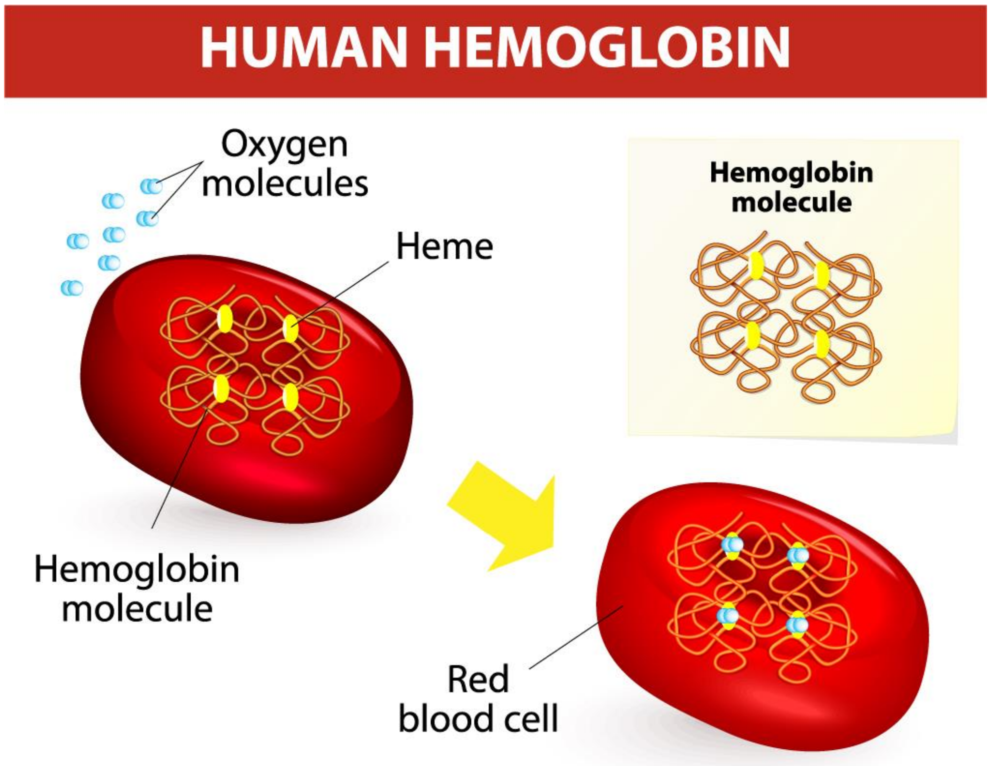
Atmosphere

Carbon Monoxide, CO

- A large proportion of the carbon monoxide in the Earth's atmosphere comes from the *incomplete combustion* of petrol in motor car engines.

Atmosphere

Carbon Monoxide, CO



- Carbon monoxide is a poisonous gas because it reacts with *haemoglobin* in the blood to form *carboxyhaemoglobin*. As a result, the haemoglobin is unable to transport oxygen around the body.

Atmosphere

Carbon Monoxide, CO

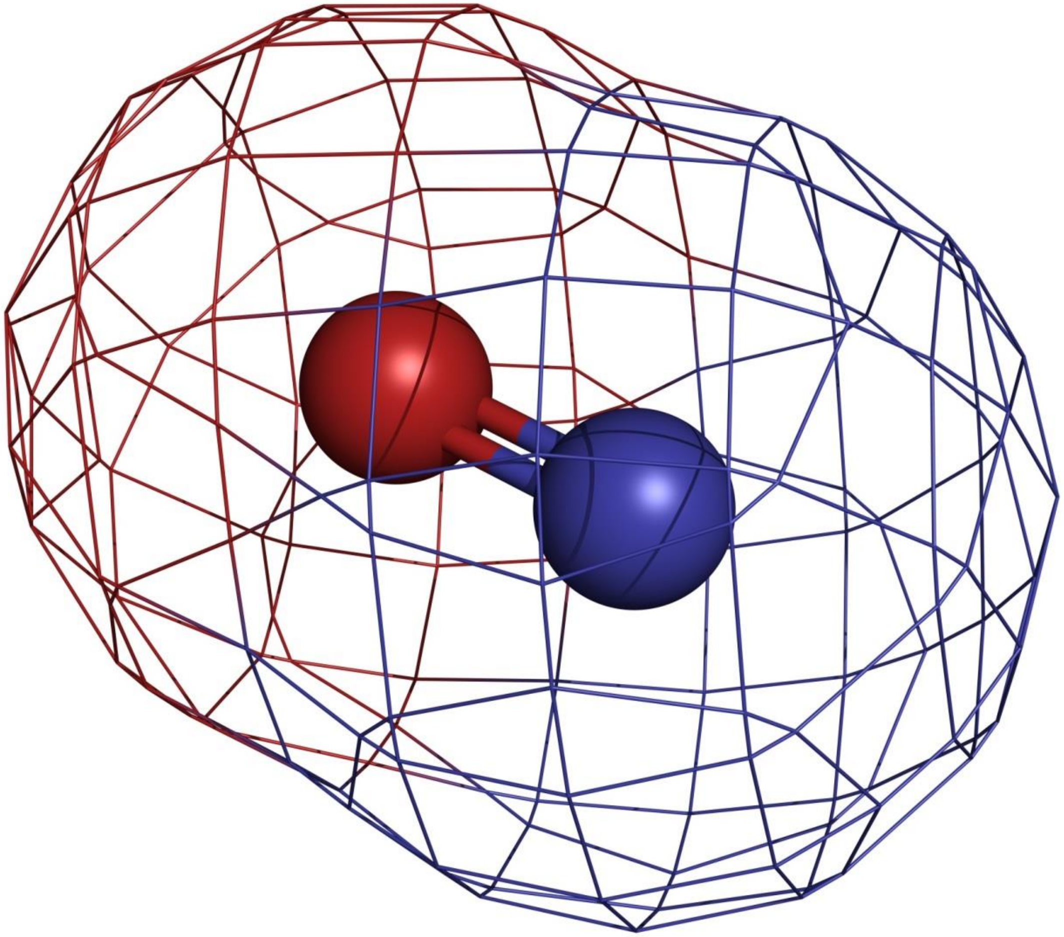
Atmosphere
Carbon Monoxide, CO

- When carbon monoxide prevents the transport of oxygen around the body, the consequences are very serious, including sever *headaches*, *fatigue* and even *death*.

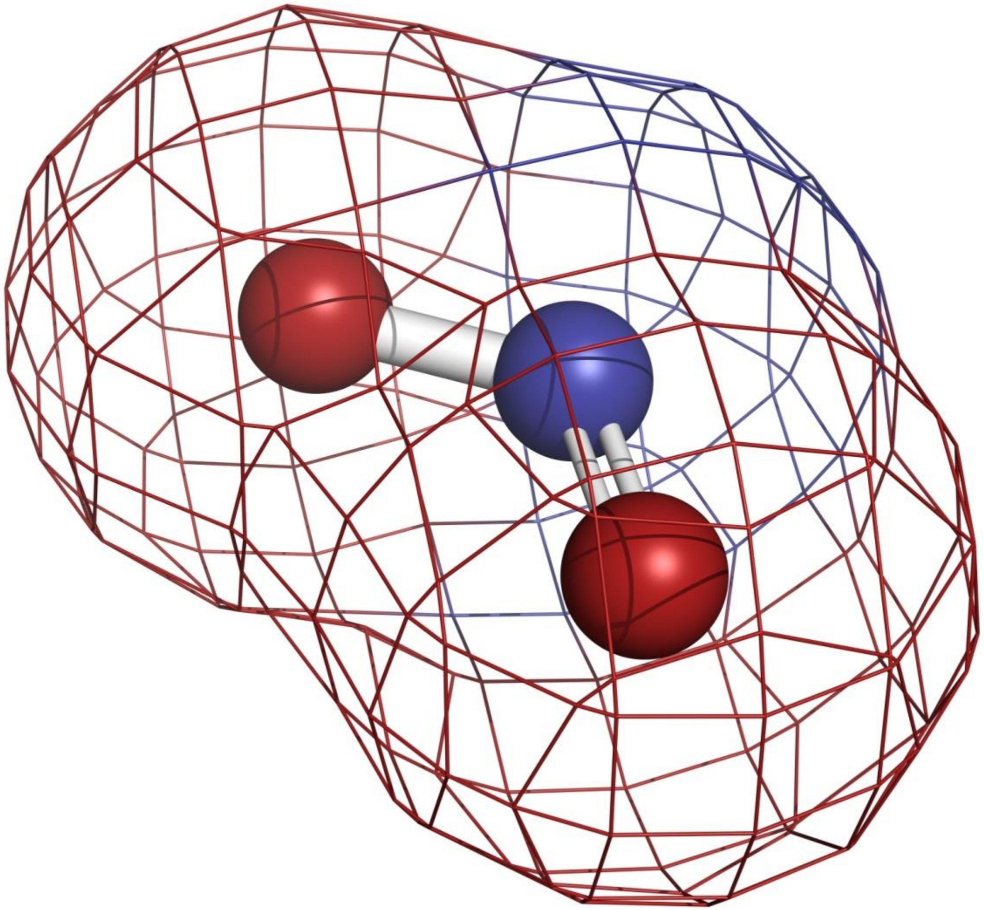
- Because carbon monoxide is a colourless and odourless gas, it is very difficult to detect. This, coupled with the fact that it is poisonous, have led to carbon monoxide being referred to as a “*silent killer*”.

- Levels of carbon monoxide in the Earth’s atmosphere can be reduced by fitting motor cars with *catalytic converters* (discussed under oxides of nitrogen).

Atmosphere
Nitrogen Monoxide, NO



Atmosphere
Nitrogen Dioxide, NO_2



Atmosphere

Oxides of Nitrogen, NO and NO_2

Atmosphere

Oxides of Nitrogen, NO and NO_2

- In Internal combustion engines and jet engines, where temperature and pressure are both very high, nitrogen and oxygen from the air react to form nitrogen monoxide:

nitrogen + oxygen → nitrogen monoxide

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

- Nitrogen monoxide can react with oxygen to form a brown gas, nitrogen dioxide:

nitrogen monoxide + oxygen → nitrogen dioxide

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Atmosphere

Oxides of Nitrogen, NO and NO_2

Atmosphere

Oxides of Nitrogen, NO and NO_2

- The brown colour of nitrogen dioxide gas can be seen in this photograph of sever atmospheric pollution taken in Beijing, China, on 9th May 2012.

Atmosphere

Oxides of Nitrogen, NO and NO_2

Atmosphere

Oxides of Nitrogen, NO and NO_2

- The nitrogen monoxide and nitrogen dioxide in the Earth's atmosphere are not only created by human activities, they are also produced by natural phenomena.
- During an electrical storm, the temperature in the core of a lightning strike can exceed 50 000 °C. At such high temperatures, nitrogen and oxygen in the Earth's atmosphere react together to form nitrogen monoxide and nitrogen dioxide:

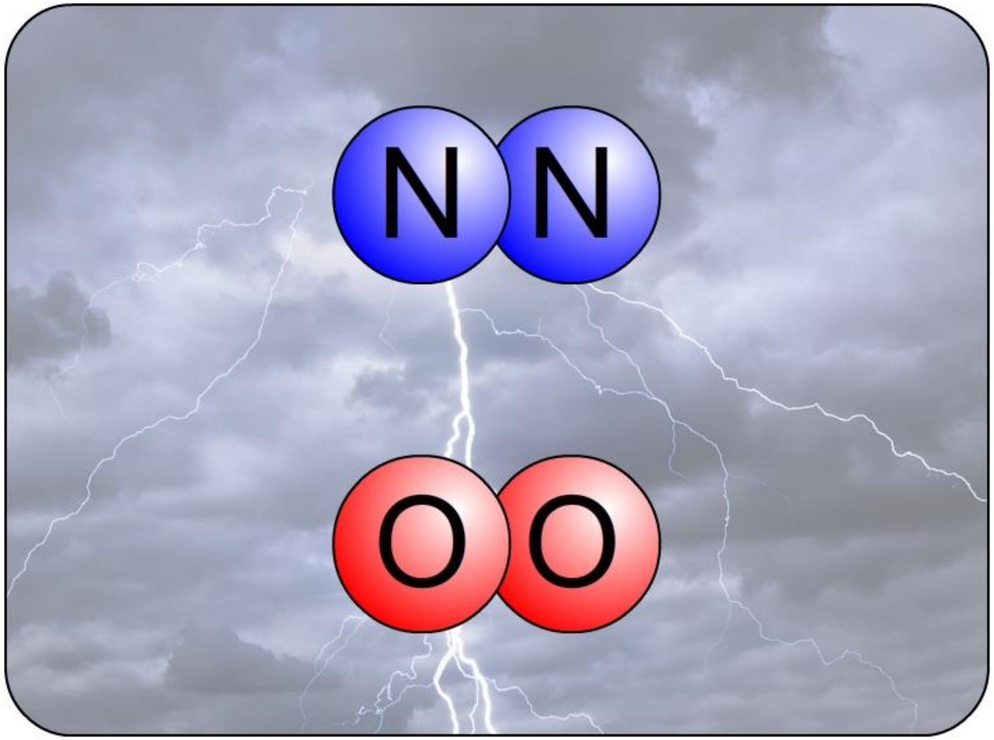
$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Atmosphere

Oxides of Nitrogen, NO and NO_2

- Bond breaking requires energy. This energy is provided by the lightning.
- Bond breaking is an *endothermic* process.



- Once covalent bonds have been broken, new covalent bonds can form.
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nitrogen + oxygen → nitrogen monoxide

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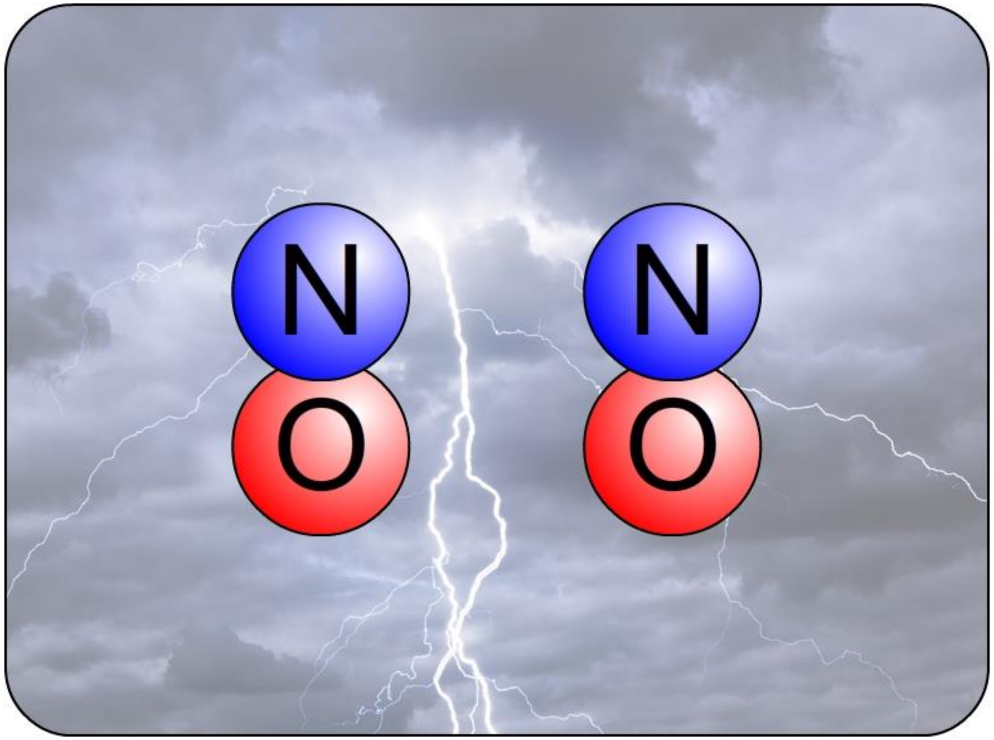

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Atmosphere

Oxides of Nitrogen, NO and NO_2

Atmosphere

Oxides of Nitrogen, NO and NO_2

- Nitrogen monoxide and nitrogen dioxide irritate the eyes and lungs and cause breathing difficulties.

- Exposure to high levels of nitrogen monoxide and nitrogen dioxide can cause inflammation of the lungs, a condition that is called *bronchitis*.

- Nitrogen dioxide reacts with oxygen and water to form nitric acid, which can fall onto the Earth's surface as *acid rain*:

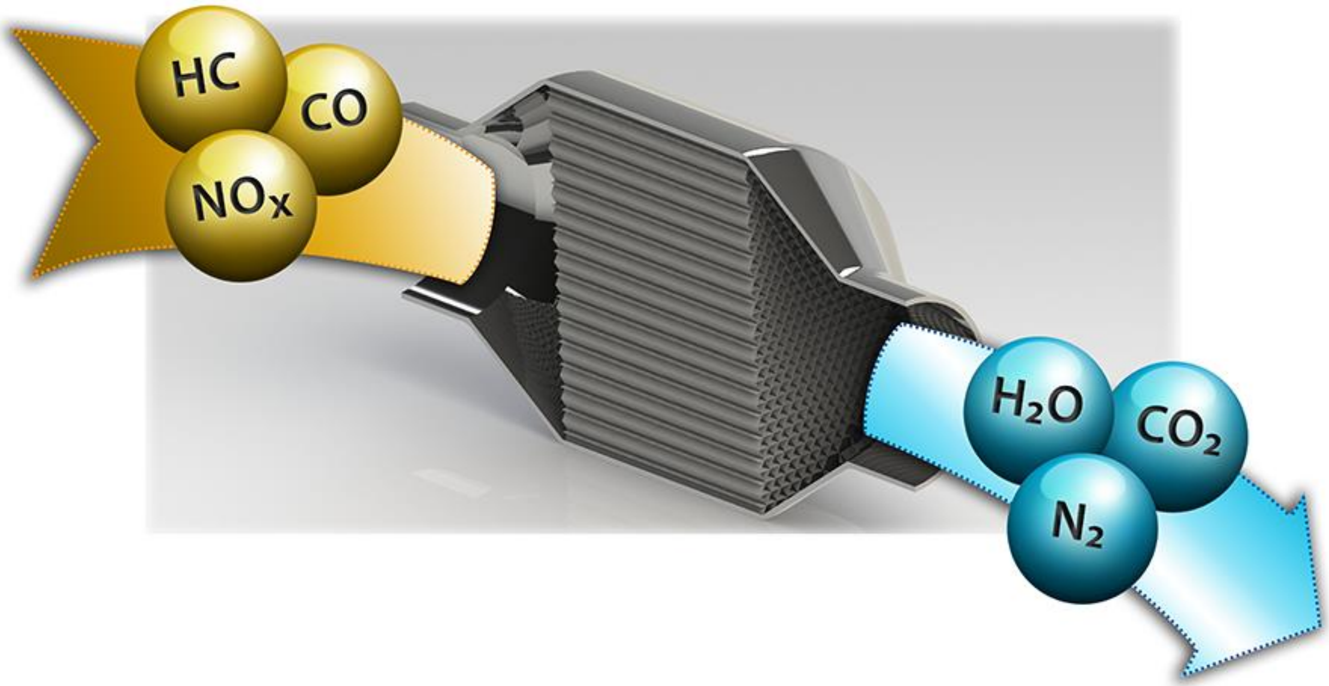
nitrogen dioxide + water + oxygen → nitric acid

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

Acid rain can corrode buildings and harm aquatic life and plants (discussed under sulfur dioxide).

Atmosphere

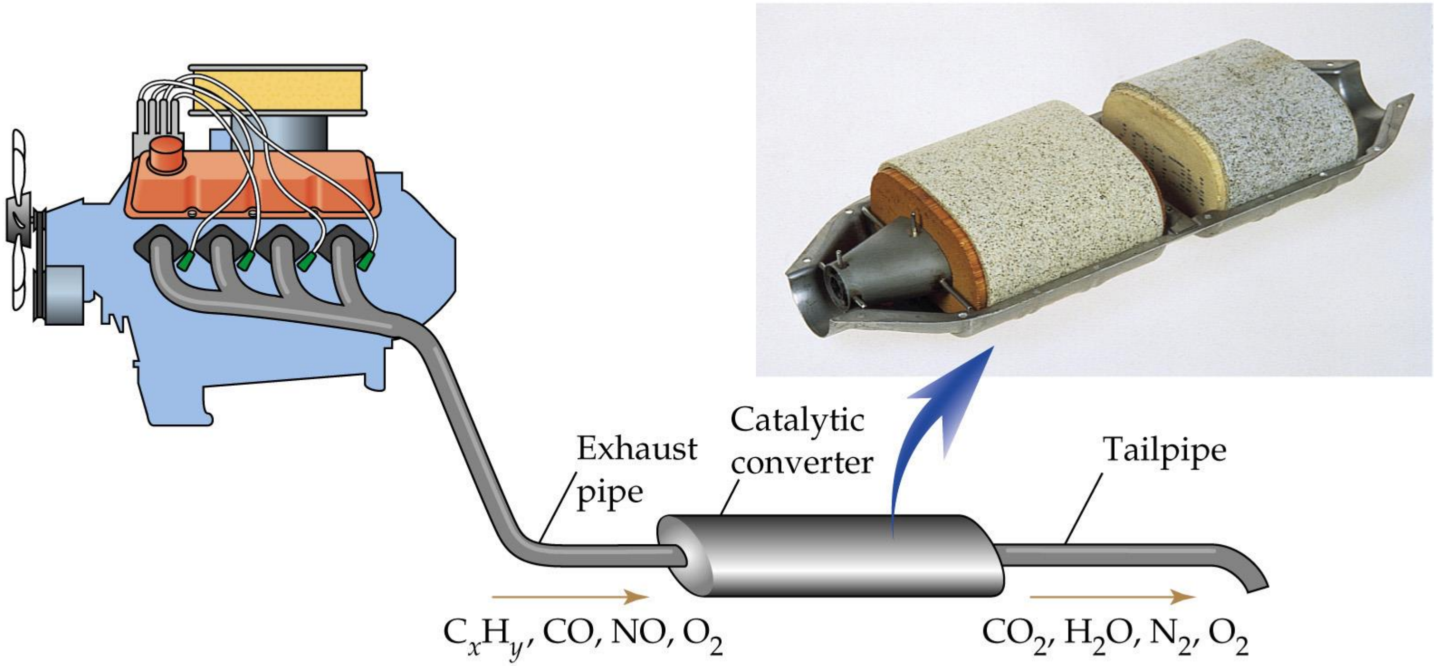
Oxides of Nitrogen, NO and NO_2



- Carbon monoxide, oxides of nitrogen and unburned hydrocarbons can be removed from motor car exhaust fumes by a *catalytic converter*.

Atmosphere

Oxides of Nitrogen, NO and NO_2



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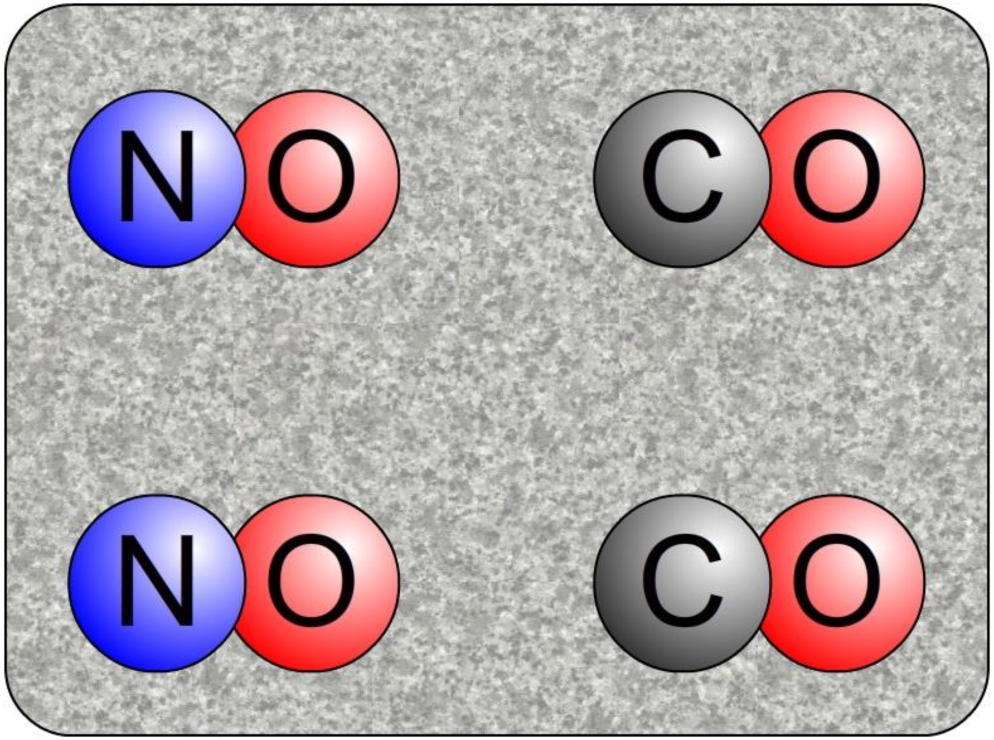
Atmosphere

Oxides of Nitrogen, NO and NO_2



- The catalytic converter is made of finely divided *platinum* and *rhodium*.

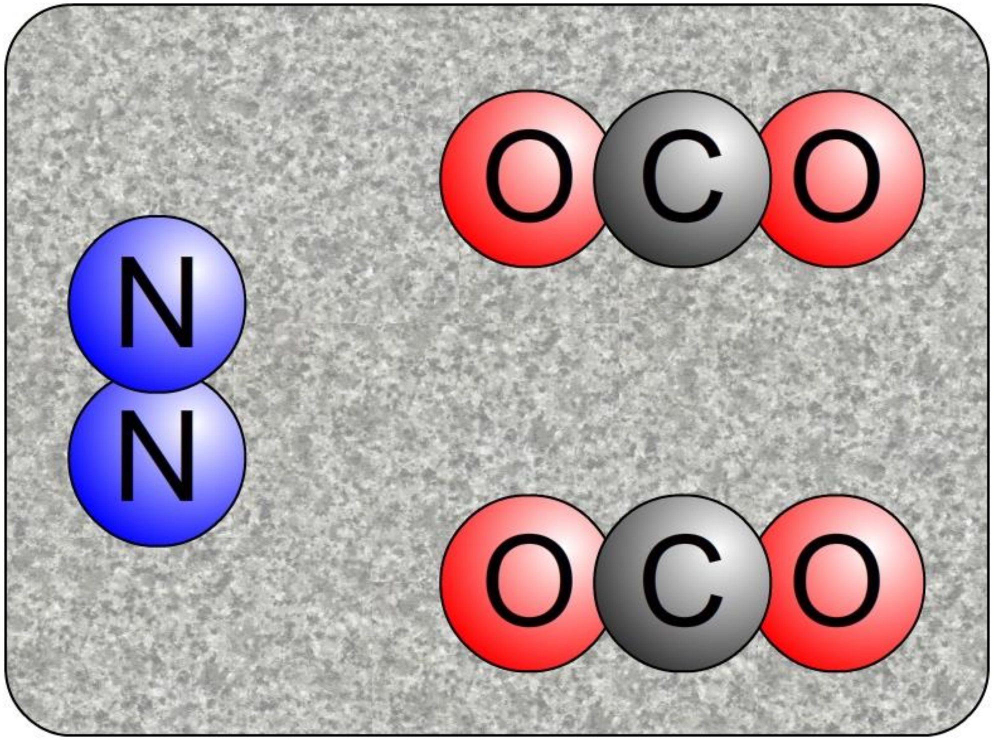
carbon monoxide + nitrogen monoxide → carbon dioxide + nitrogen

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

Atmosphere

Oxides of Nitrogen, NO and NO_2

- The catalytic converter is made of finely divided *platinum* and *rhodium*.



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Atmosphere

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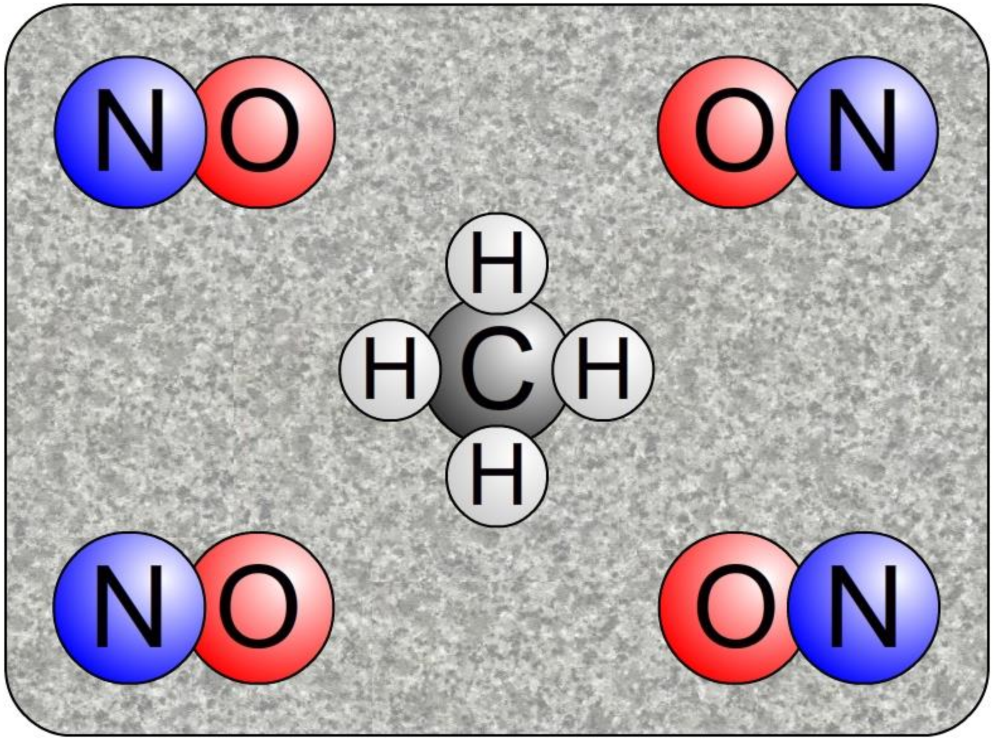

methane + nitrogen monoxide → carbon dioxide + water + nitrogen

$$CH_4(g) + 4NO(g) \rightarrow CO_2(g) + 2H_2O(g) + 2N_2(g)$$

Atmosphere

Oxides of Nitrogen, NO and NO_2

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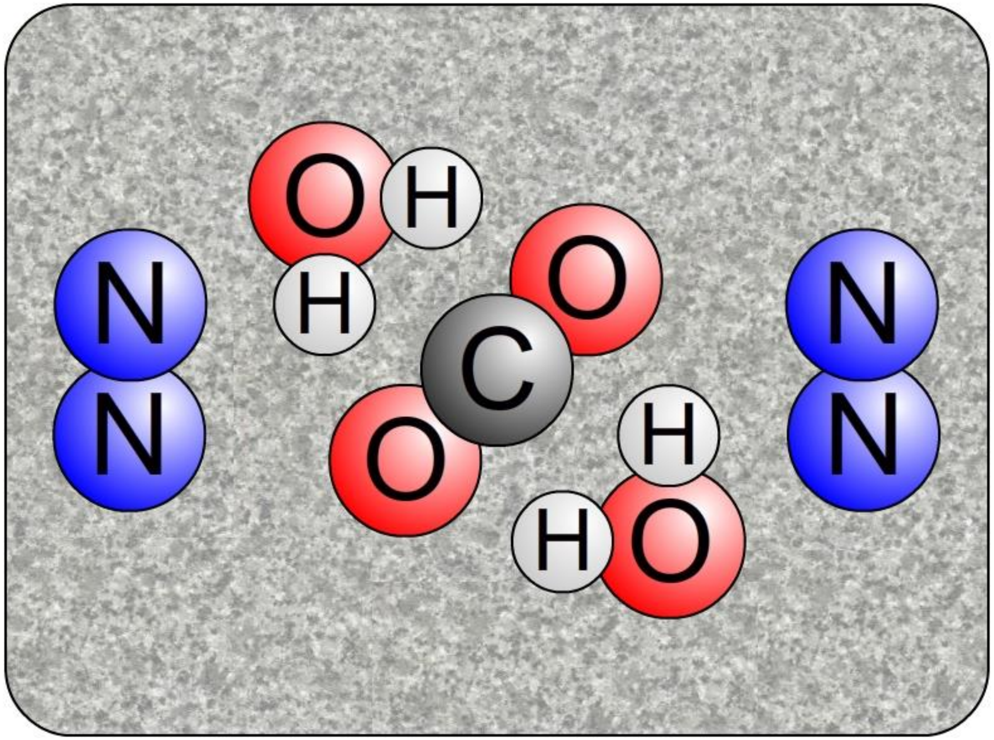


methane + nitrogen monoxide → carbon dioxide + water + nitrogen

$$CH_4(g) + 4NO(g) \rightarrow CO_2(g) + 2H_2O(g) + 2N_2(g)$$

Atmosphere

Oxides of Nitrogen, NO and NO_2

Does a catalytic converter remove all of the pollutants from a car's exhaust fumes?

Atmosphere

Oxides of Nitrogen, NO and NO_2

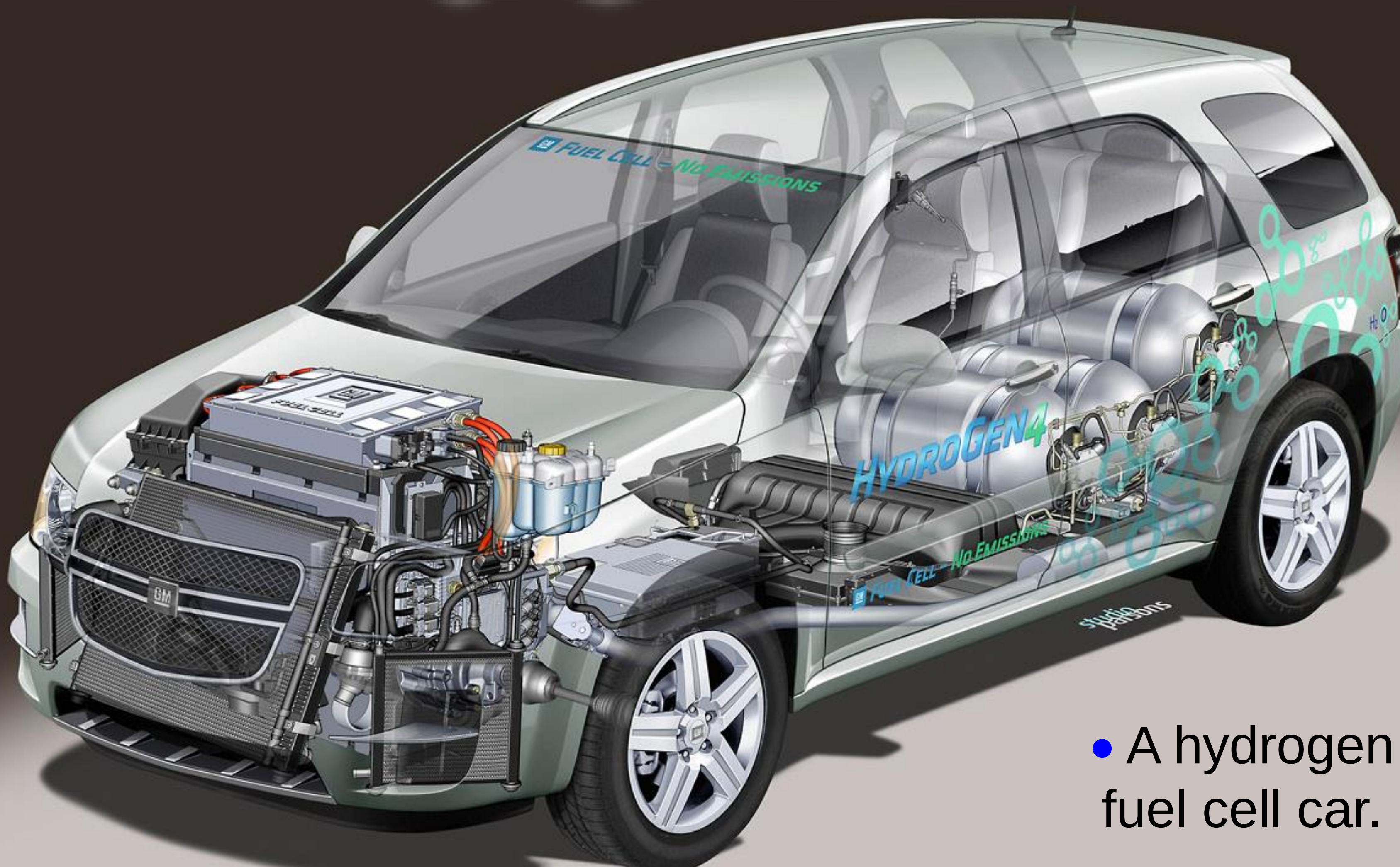
- Although harmful pollutants such as carbon monoxide and nitrogen monoxide are removed from the exhaust fumes of motor cars by the catalytic converter, *carbon dioxide* gas is still released into the Earth's atmosphere.
- Technically, carbon dioxide is not a pollutant, but it is one of the *greenhouse gases* that are responsible for *global warming*.

Atmosphere

Oxides of Nitrogen, NO and NO_2

Are there any alternatives to the internal combustion engine?

Hydrogen Fuel Cells



- A hydrogen fuel cell car.

Hydrogen Fuel Cells

- In a hydrogen fuel cell, hydrogen reacts with oxygen to produce water and electricity.
- Because water is not a pollutant (it is not harmful to the environment) hydrogen fuel cells are described as being a source of "clean energy".

Hydrogen Fuel Cells

- In the hydrogen fuel cell, a catalyst causes molecular hydrogen to break-down into hydrogen ions and electrons.

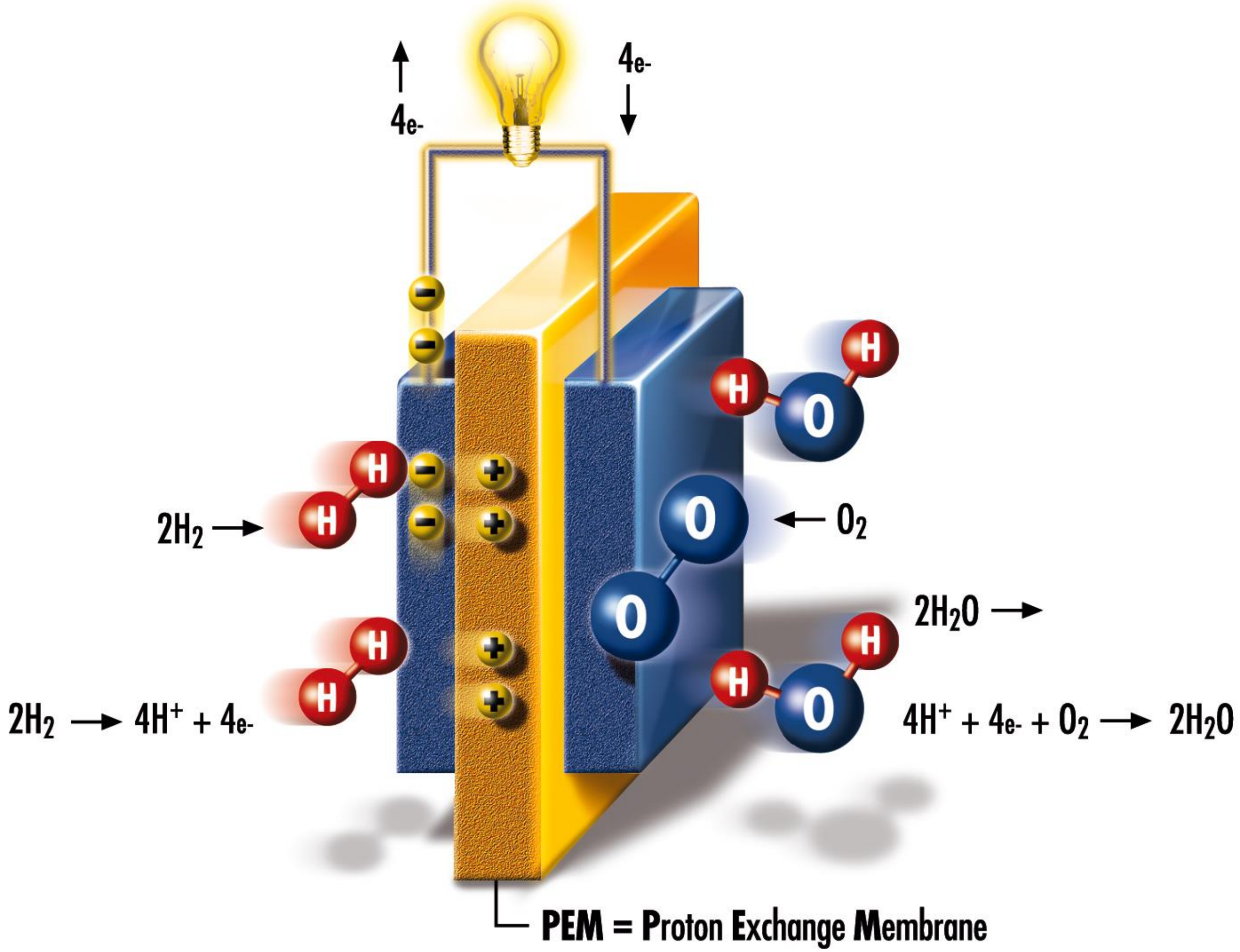
$$H_2(g) \rightarrow 2H^+(aq) + 2e^-$$

- The electrons pass through metal wires in an external circuit where they are made to do useful work, such as drive an electric motor. The hydrogen ions pass through a special membrane.

- On the other side of the membrane, the hydrogen ions, electrons and oxygen combine together to form water.

$$4H^+(aq) + 4e^- + O_2(g) \rightarrow 2H_2O(l)$$

Hydrogen Fuel Cells



Hydrogen Fuel Cells

- Hydrogen required for the hydrogen fuel cell is obtained by *cracking* long-chain hydrocarbons from crude oil, *e.g.*

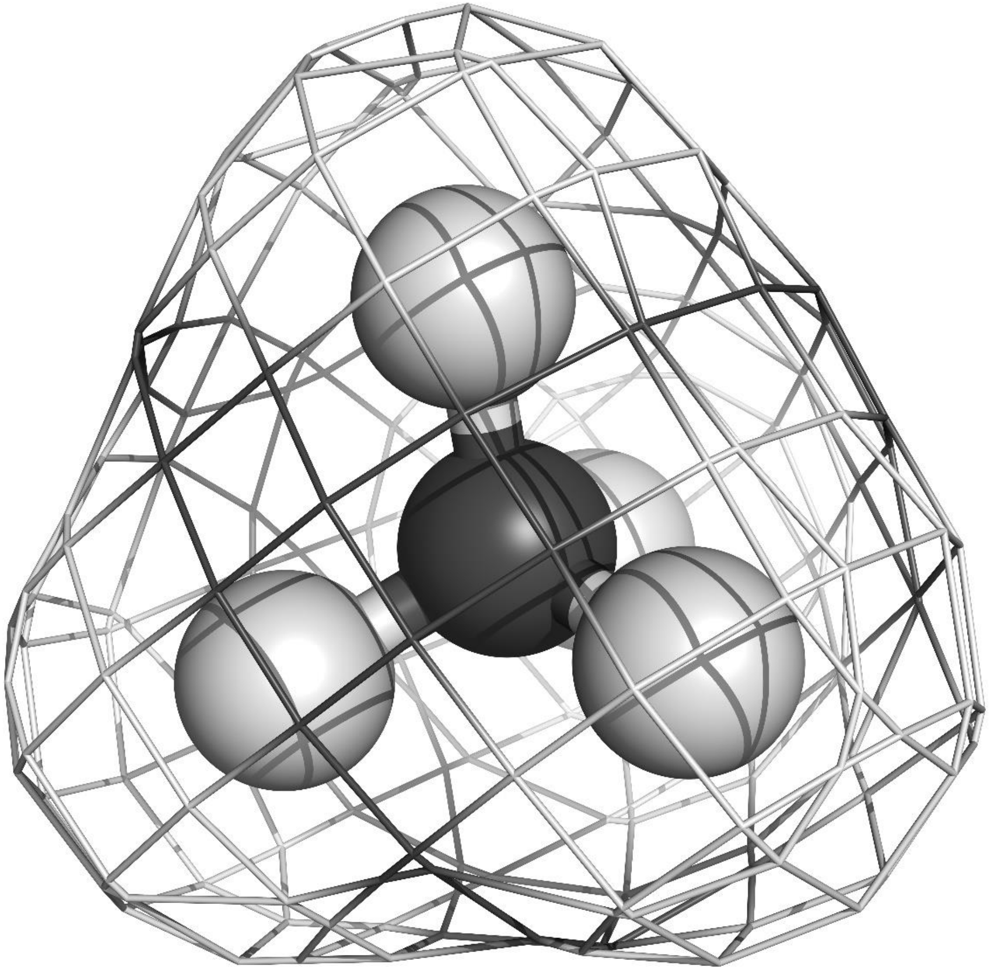
$$C_{20}H_{42}(s) \rightarrow C_8H_{16}(l) + C_{12}H_{24}(l) + H_2(g)$$

- The hydrogen must be stored with the hydrogen fuel cell. The large scale storage of hydrogen is hazardous because it is a highly flammable gas.

- Remember, the hydrogen that is produced by cracking long-chain hydrocarbons is also used in the manufacture of ammonia – NH_3.

- Oxygen required for the hydrogen fuel cell is taken directly from the Earth's atmosphere, which is 21% oxygen.

Atmosphere
Methane, CH_4



Atmosphere

Methane, CH_4

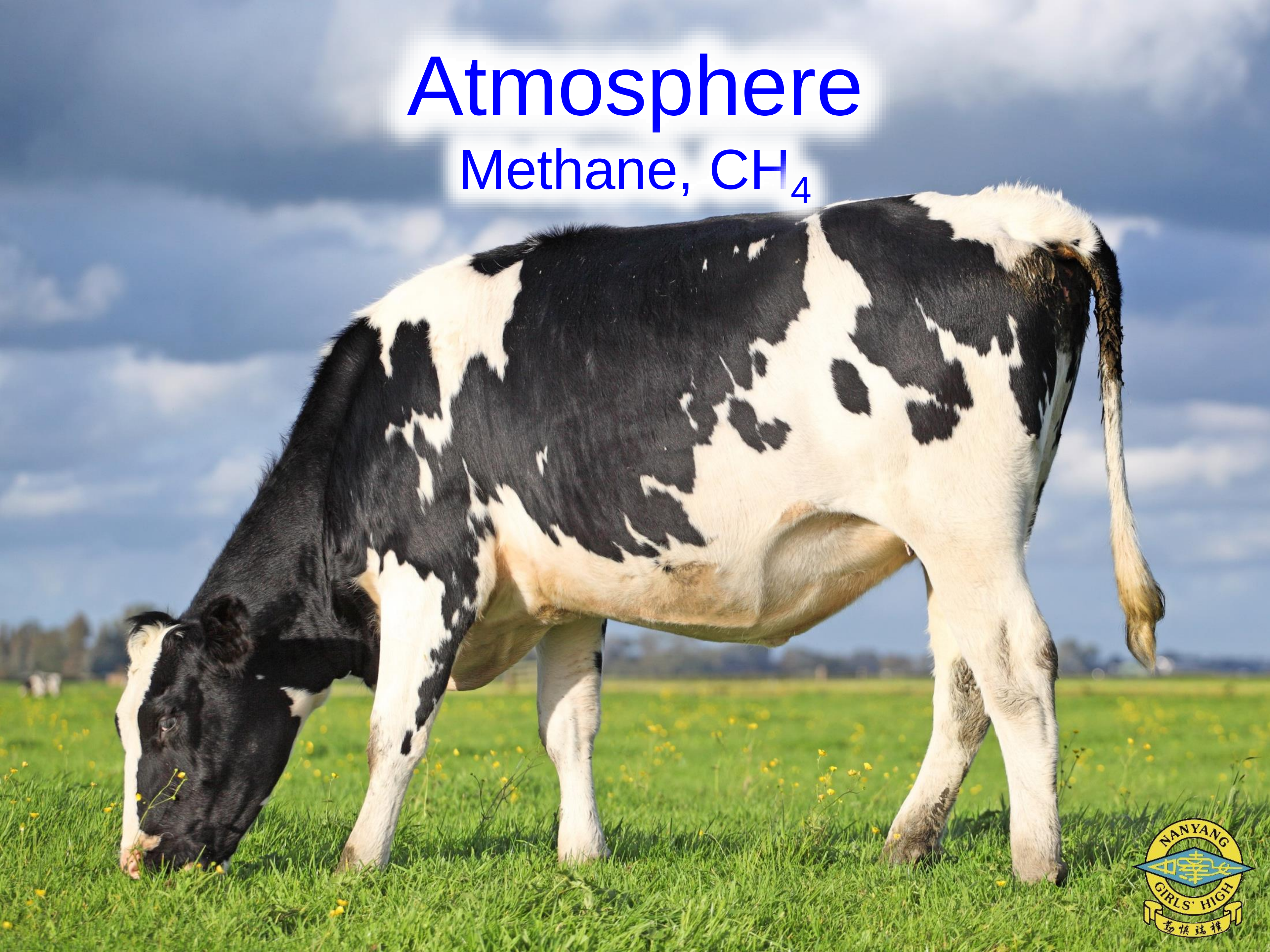
Atmosphere

Methane, CH_4

- Methane is a colourless and odourless gas which is produced when animal and plant matter decay.
- Methane is also produced by the decay of organic waste, *e.g.* discarded food, in landfills.

Atmosphere

Methane, CH_4



Atmosphere

Methane, CH_4

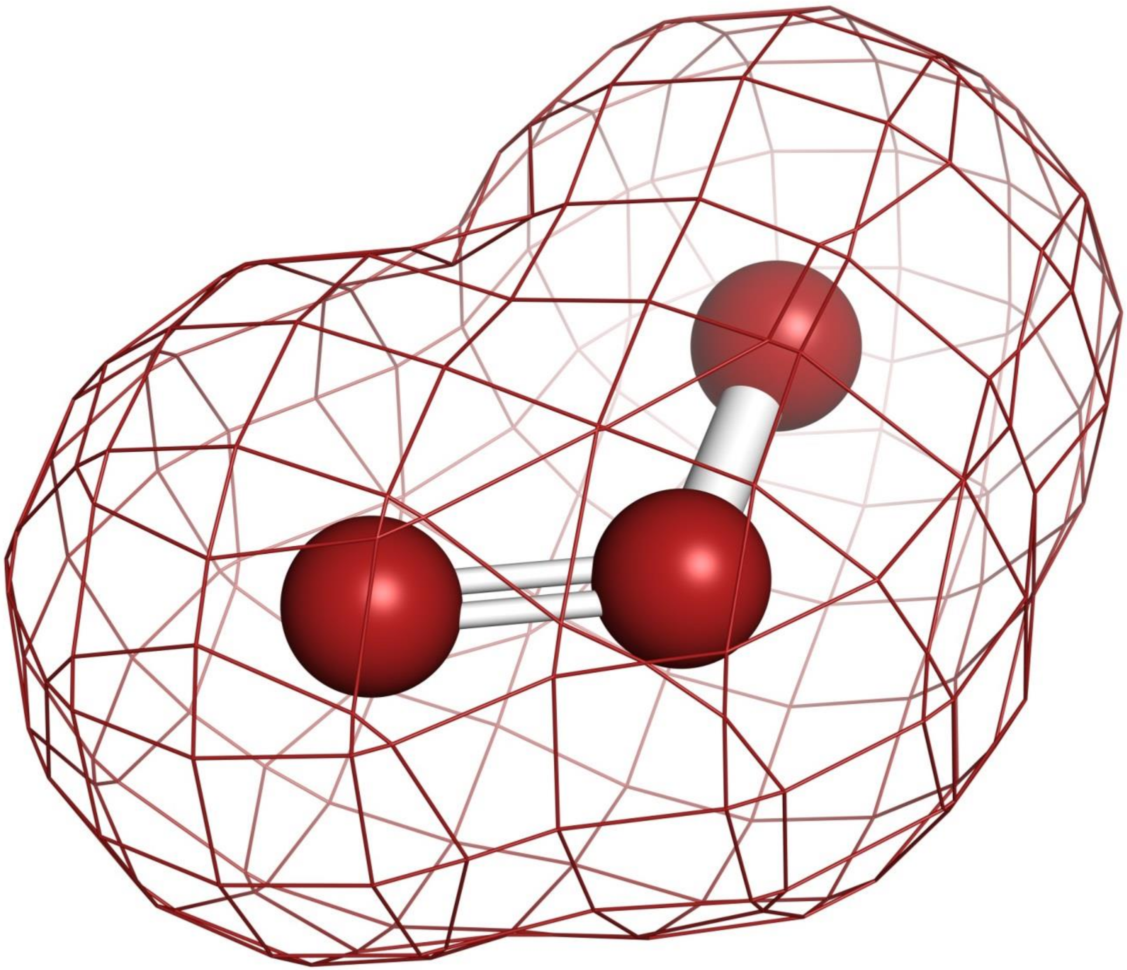
- Cows and sheep also produce methane gas due to the digestion of the plant material that they eat.
- Similar to carbon dioxide, methane is a *greenhouse gas* which causes *global warming*.

Atmosphere

Methane, CH_4

- One way of reducing the production of methane is to *reduce*, *reuse* or *recycle* the organic waste that goes into landfill and decays to produce methane.
- For example, converting waste cooking oil into *biofuel* and using other organic waste to make fertilizer to grow crops.

Atmosphere
Ozone, O_3



Atmosphere

Ozone, O_3

Atmosphere

Ozone, O_3

- During an electrical storm, the temperature in the core of a lightning strike can exceed 50 000 °C. At such high temperatures, molecules of atmospheric oxygen react to produce ozone:

oxygen → ozone

$$3O_2(g) \rightarrow 2O_3(g)$$

Atmosphere

Ozone, O_3

- Ozone is an *allotrope* of oxygen. It is considered a pollutant when it occurs in the lower regions of the Earth's atmosphere. However, ozone is an essential component of the stratosphere, where it absorbs harmful ultraviolet radiation from the sun.

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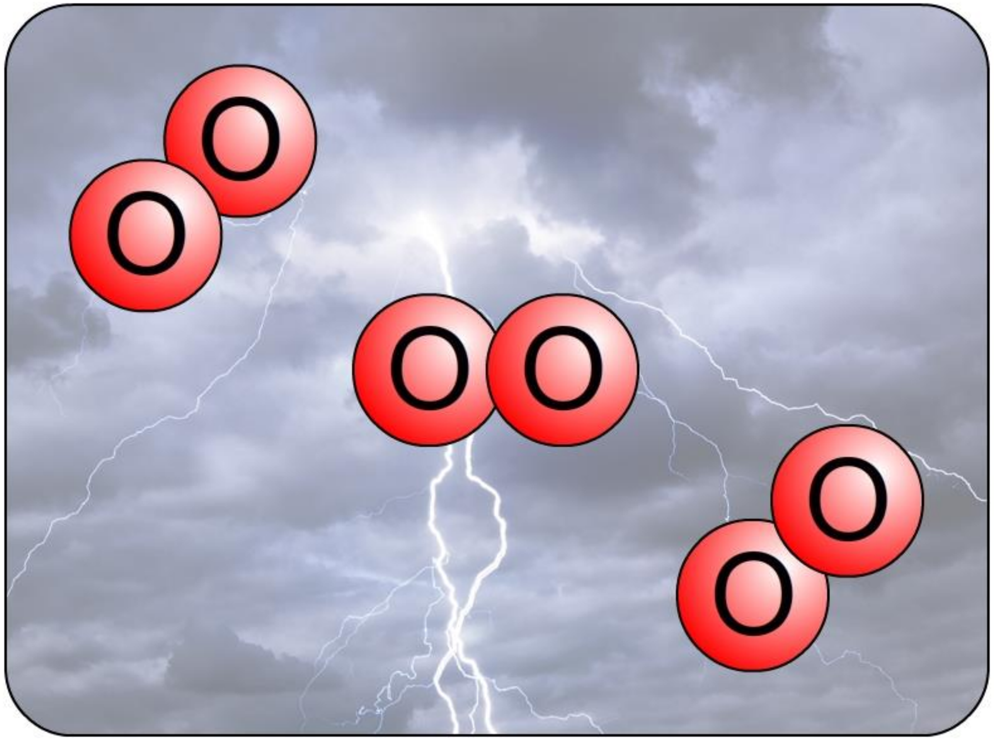
Atmosphere

Ozone, O_3

- Bond breaking requires energy. This energy is provided by the lightning.
- Bond breaking is an *endothermic* process.



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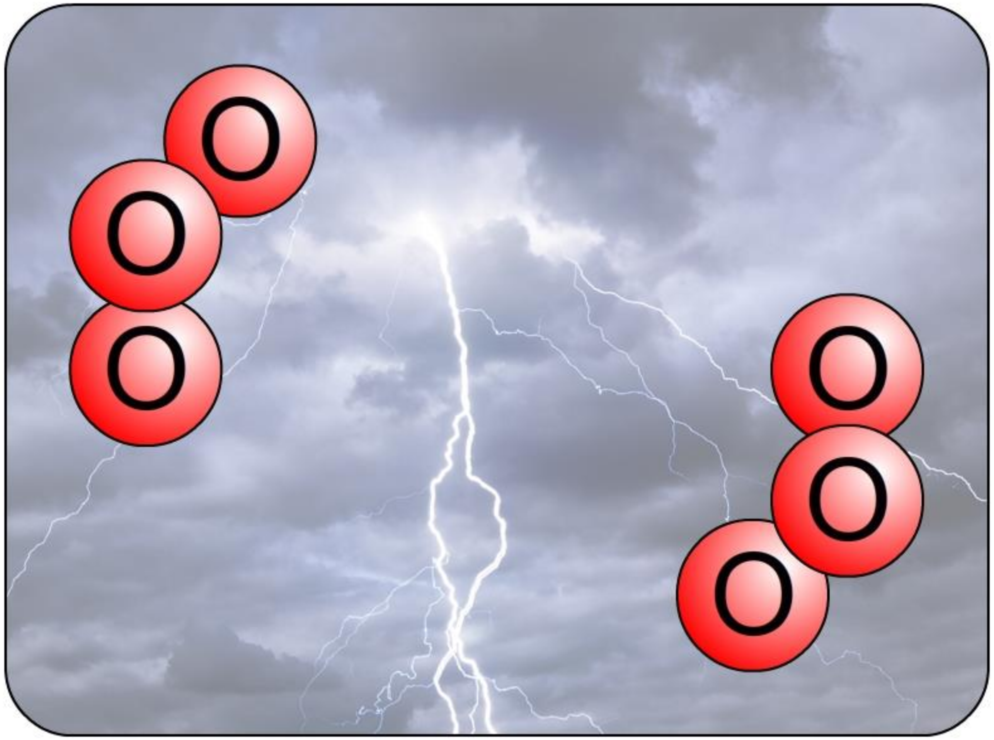

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Atmosphere

Ozone, O_3

Atmosphere

Ozone, O_3

- Ozone is also produced by complex reactions that take place between nitrogen oxides and unburned hydrocarbons in the presence of sunlight. These complex reactions are referred to as *photochemical reactions*.
- Ozone is a component of *photochemical smog* which irritates the eyes and lungs and causes breathing difficulties.
- Ozone in the lower regions of the Earth's atmosphere can be reduced by limiting the amount of unburned hydrocarbons released into the environment. This can be achieved through the use of catalytic converters.

Atmosphere

Presentation on

Atmosphere Part One

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