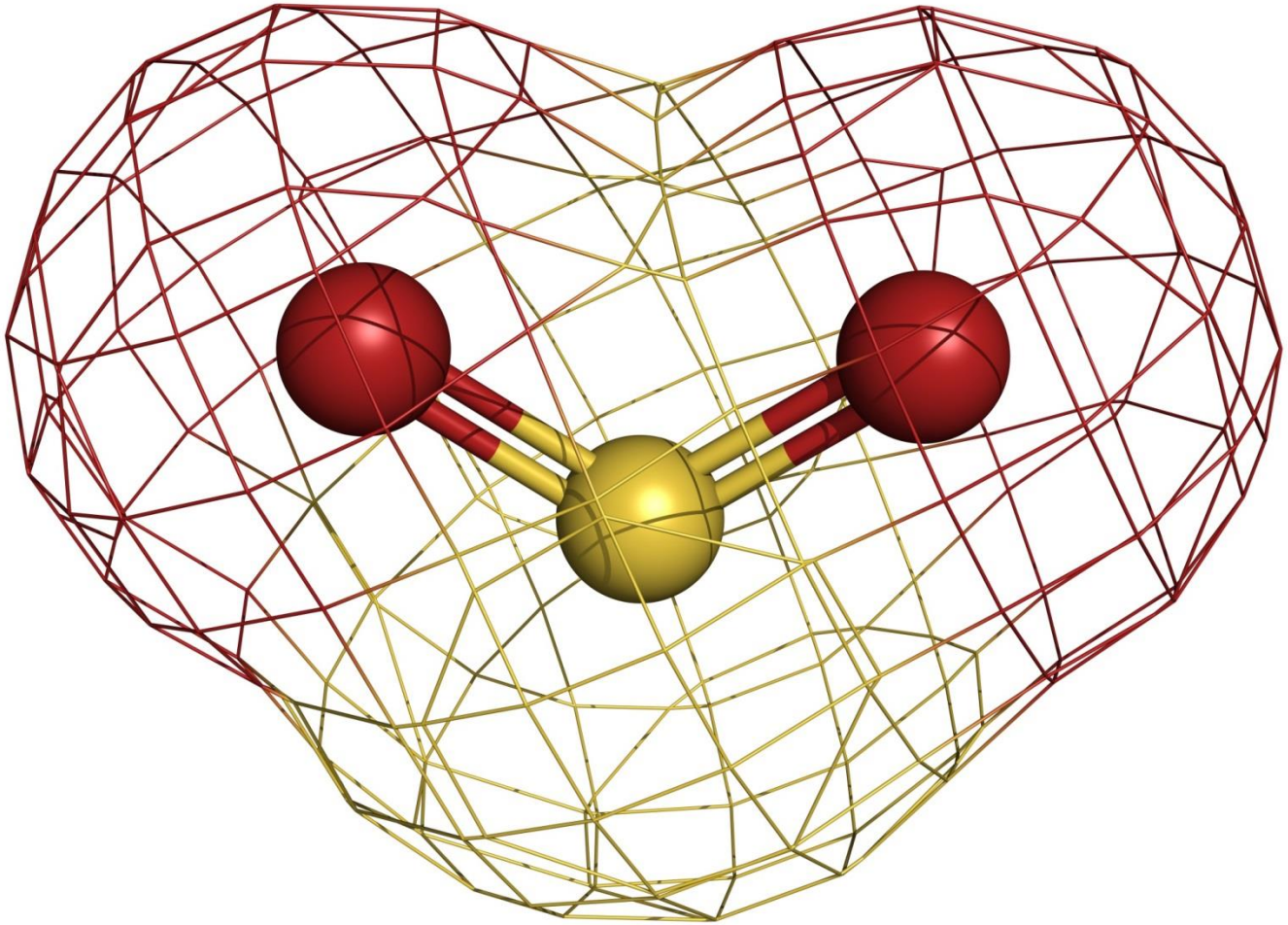
Atmosphere

Part Two

Atmosphere
Sulfur Dioxide, SO_2



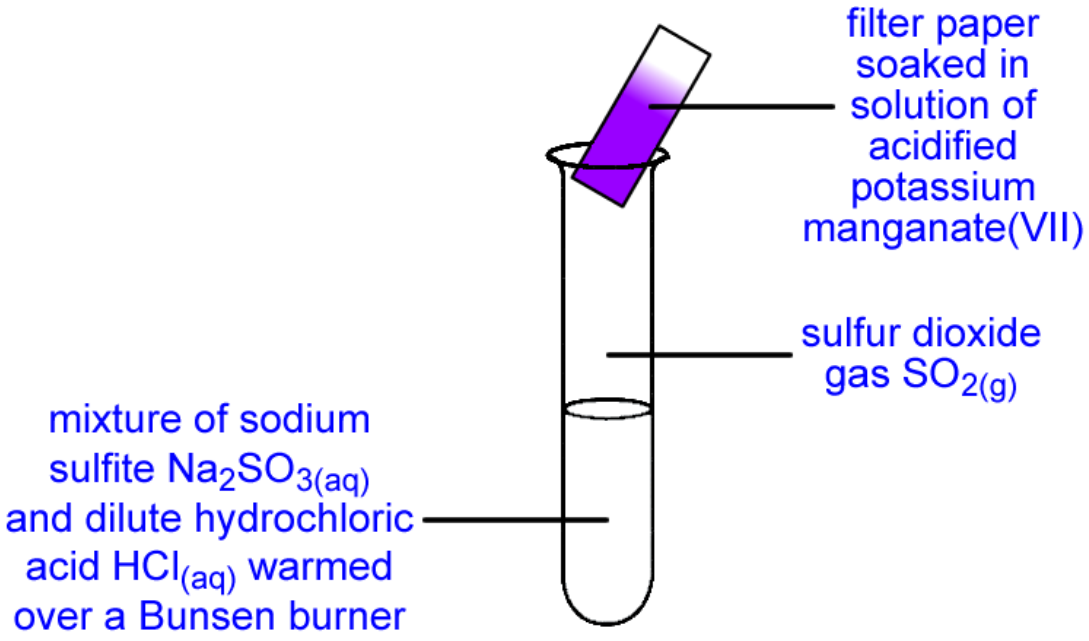
Atmosphere

Sulfur Dioxide, SO_2

Pop quiz! What is the qualitative test for sulfur dioxide gas?

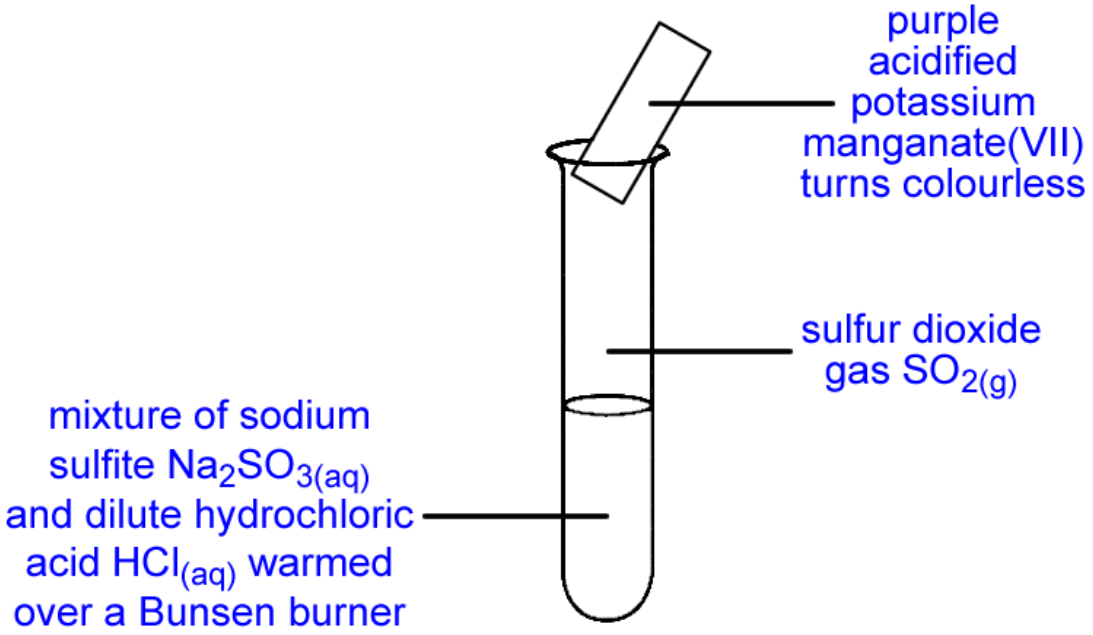
Atmosphere

Sulfur Dioxide, SO_2



Atmosphere

Sulfur Dioxide, SO_2



Sulfur dioxide gas will turn acidified potassium manganate(VII) from **purple** to **colourless**.

$$2KMnO_{4(aq)} + 5SO_{2(g)} + 2H_2O_{(l)} \rightarrow K_2SO_{4(aq)} + 2MnSO_{4(aq)} + 2H_2SO_{4(aq)}$$

Atmosphere

Sulfur Dioxide, SO_2

Atmosphere

Sulfur Dioxide, SO_2

- The major source of sulfur dioxide in the Earth's atmosphere is the combustion of *fossil fuels* such as coal, crude oil and natural gas. When burnt, the sulfur contained within these fossil fuels reacts with oxygen to form sulfur dioxide:

sulfur + oxygen $\rightarrow$ sulfur dioxide

$$S(s) + O_2(g) \rightarrow SO_2(g)$$


Atmosphere
Sulfur Dioxide, SO_2

Atmosphere

Sulfur Dioxide, SO_2

- The sulfur dioxide in the Earth's atmosphere is not only created by human activities, it is also produced in large quantities during *volcanic eruptions*.

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

Remember, the oxides of non-metallic elements are usually **acidic**.

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- The pH of unpolluted rain water is usually slightly below 7. This is because carbon dioxide in the air dissolves in rainwater to form *carbonic acid* which is a *weak acid*.

carbon dioxide + water → carbonic acid

$$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$$

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- *Acid rain* is formed when acidic air pollutants, such as sulfur dioxide and nitrogen dioxide, dissolve in rainwater. Sulfur dioxide dissolves in rainwater to form *sulfurous acid*:

sulfur dioxide + water → sulfurous acid

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

In the presence of oxygen in the air, sulfurous acid is slowly oxidised to form *sulfuric acid*, H_2SO_4.

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

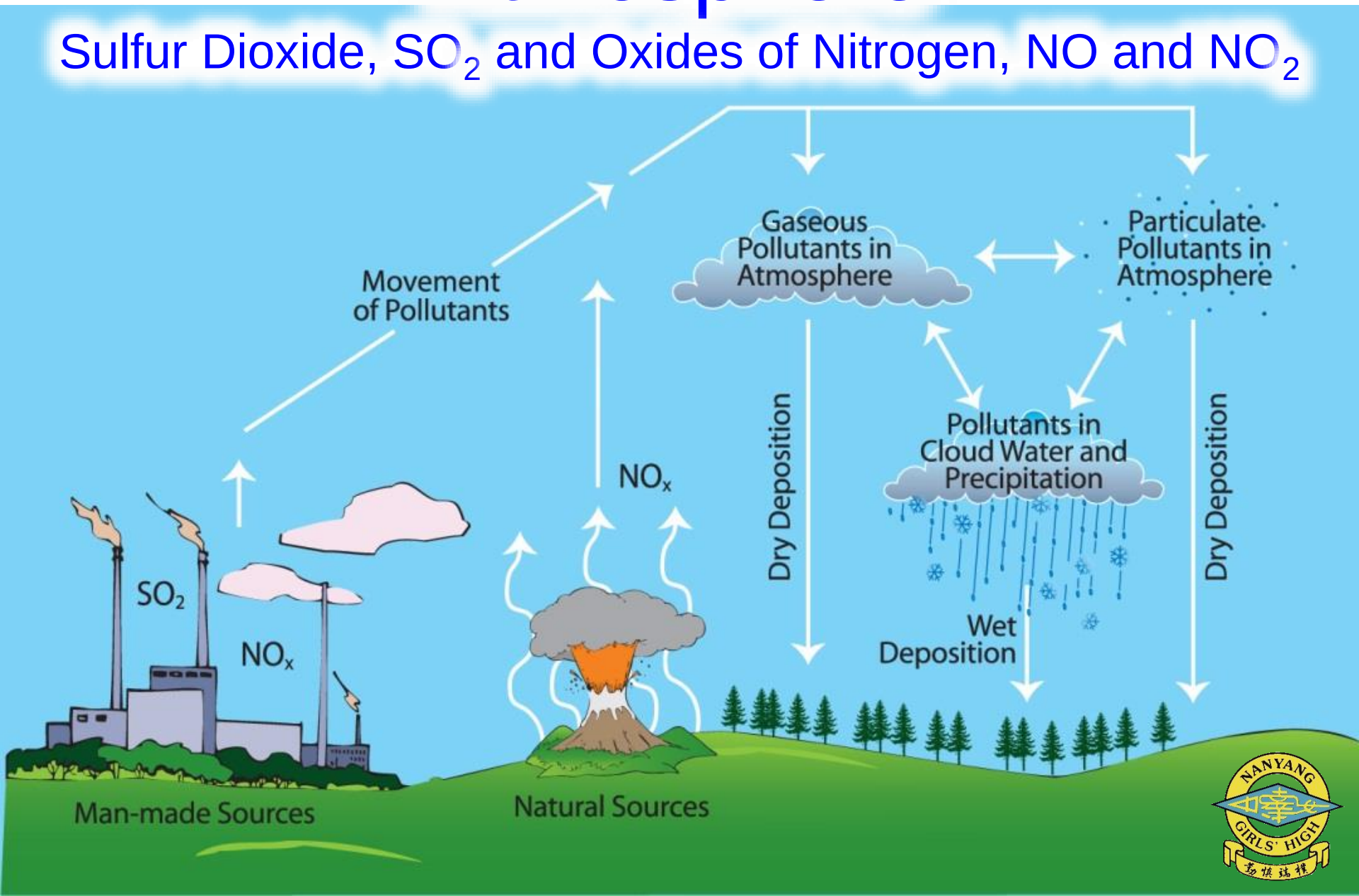
- Oxides of nitrogen also contribute to acid rain. In the presence of oxygen and water, nitrogen dioxide is converted to *nitric acid*:

nitrogen dioxide + water + oxygen $\rightarrow$ nitric acid

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

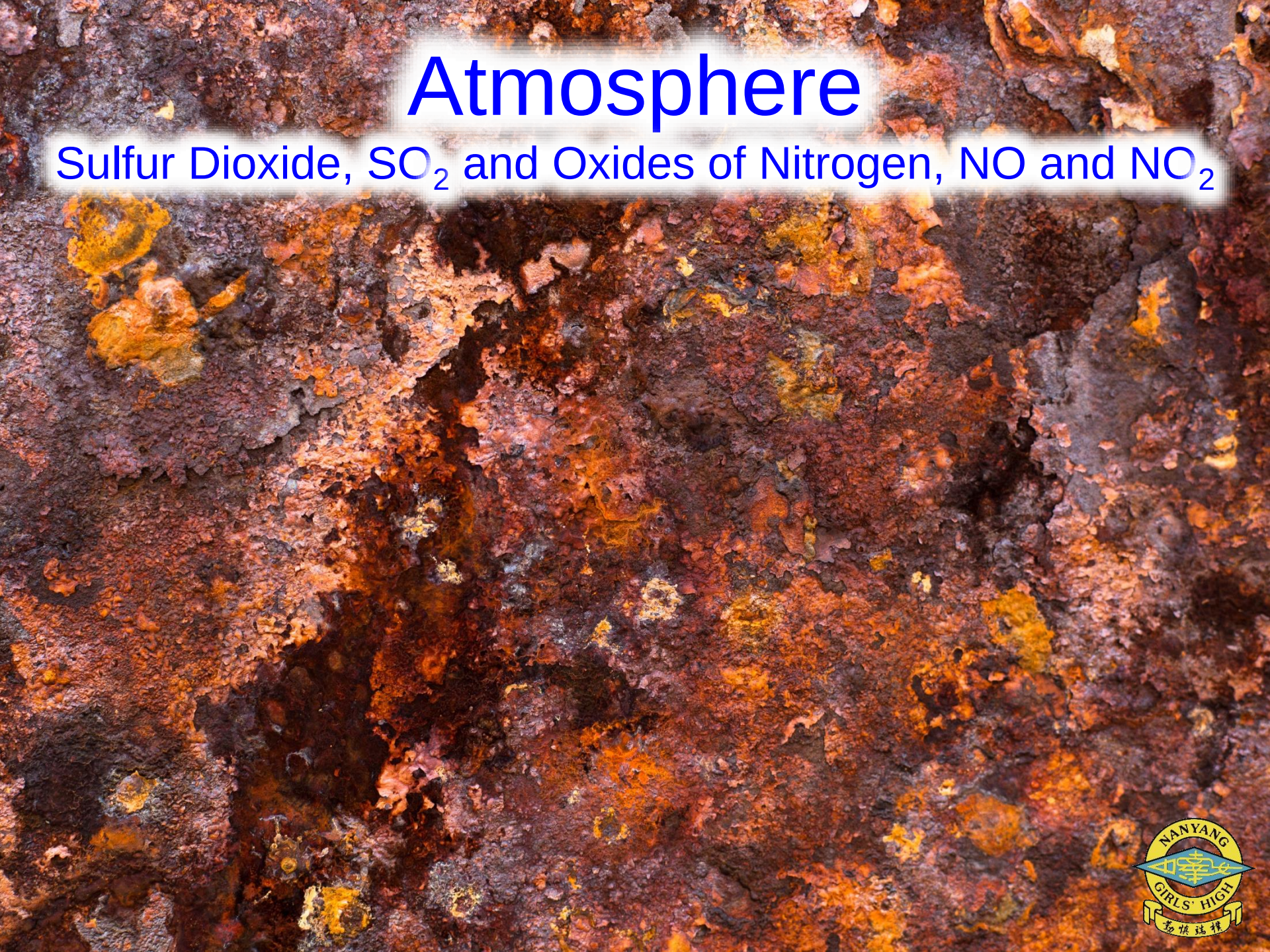
Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2



Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2



Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- Acid rain, with a pH value of 4, is much more acidic than unpolluted rainwater with a pH value of slightly less than 7.

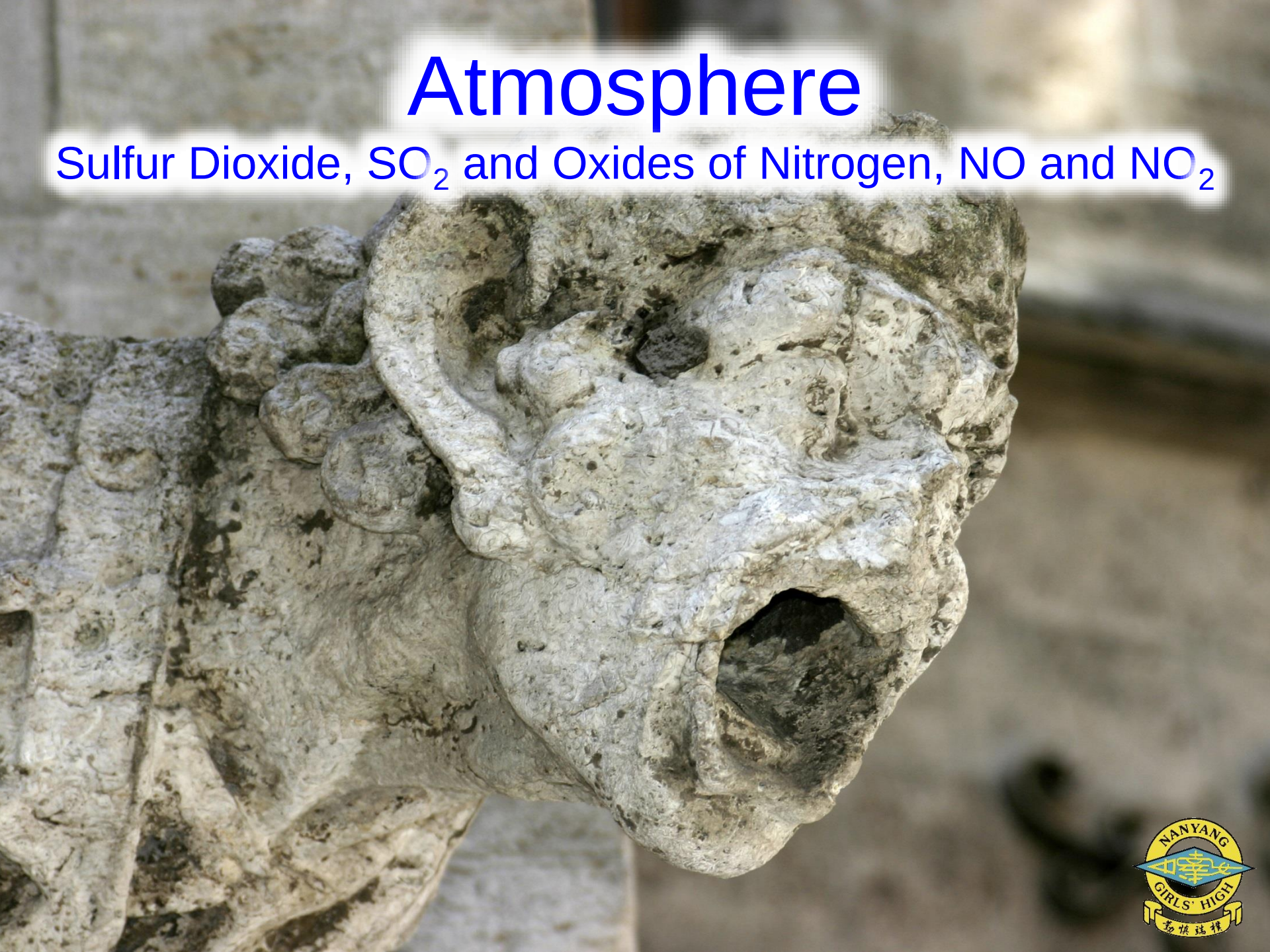
- Acid rain reacts with metals. When this happens, metal structures are corroded and damaged. For example:

iron + sulfuric acid $\rightarrow$ iron(II) sulfate + hydrogen

$$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$$

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2



Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- Acid rain reacts with calcium carbonate in marble and limestone. When this happens, stone buildings are damaged. For example:

calcium carbonate + nitric acid → calcium nitrate + water + carbon dioxide

$$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

Atmosphere

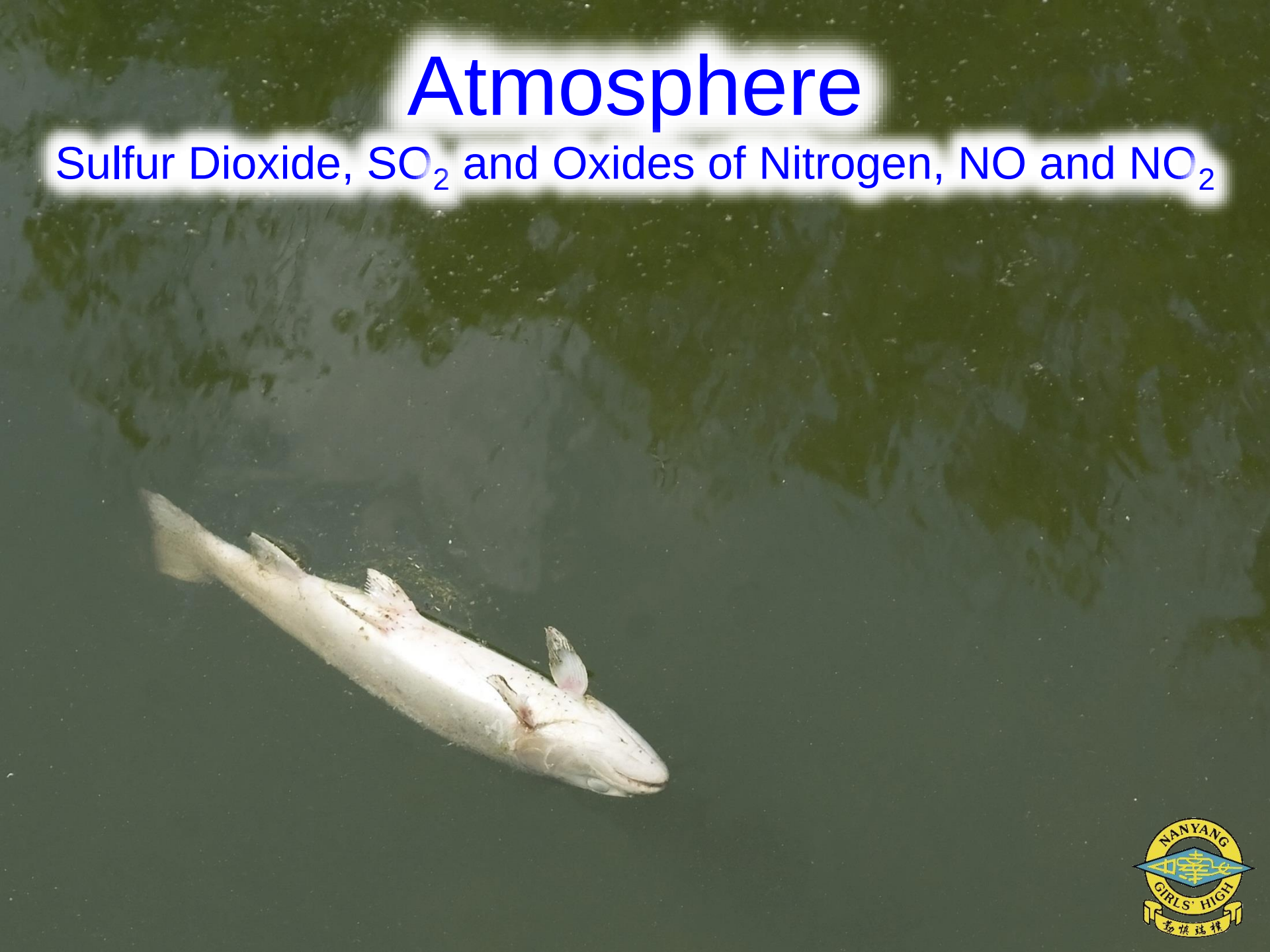
Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- Acid rain leaches essential nutrients form the soil, killing plants. Without these nutrients, plant growth is stunted.

- In some cases, acid rain dissolves aluminium hydroxide, $Al(OH)_3$, in the soil to produce $Al^{3+}(aq)$ ions which are toxic to plants.

Atmosphere

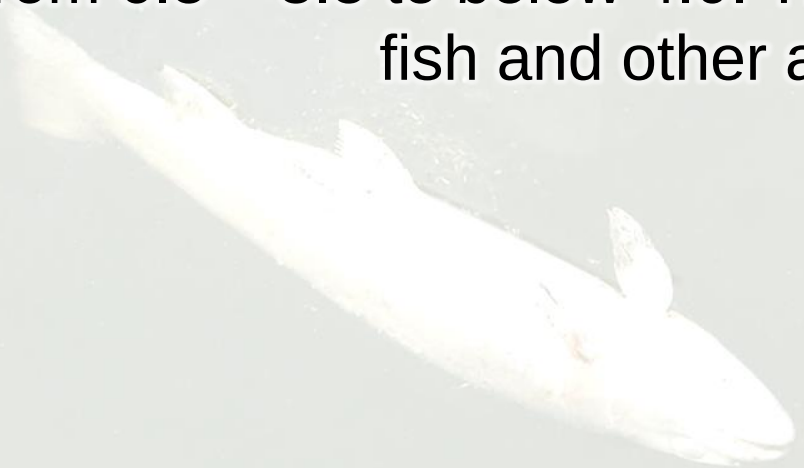
Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2



Atmosphere

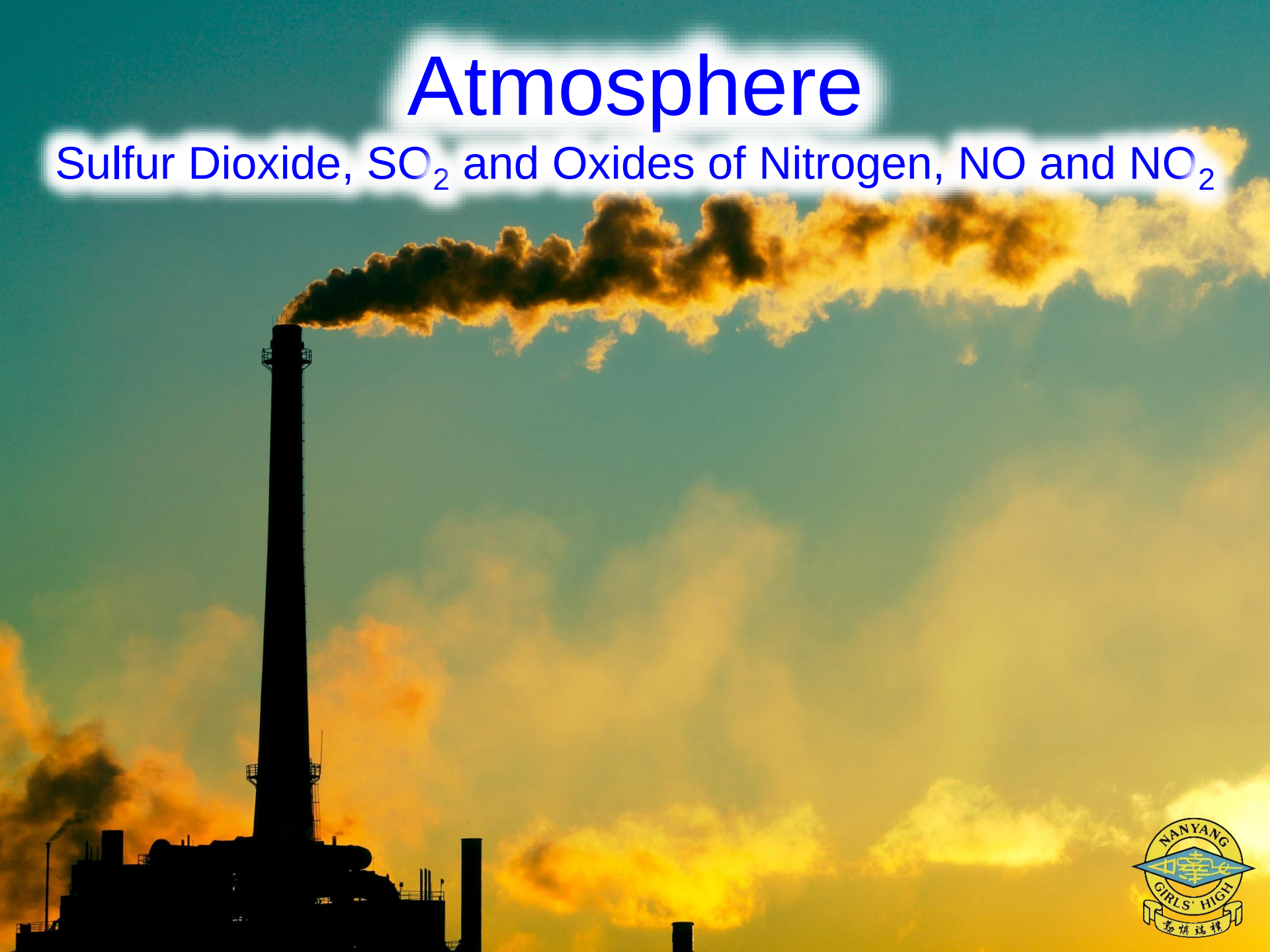
Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- Acid rain can reduce the pH of natural bodies of water from 6.5 – 8.5 to below 4.0. This results in the death of fish and other aquatic life.



Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2



Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- There are two different ways of reducing the effects of pollution caused by sulfur dioxide.

1) Remove sulfur from the fossil fuel before it is burnt. This approach, although very direct, is expensive and technologically difficult to achieve.

2) A cheaper way is to remove sulfur dioxide from the waste gases formed when fossil fuels undergo combustion. The waste gases are called *flue gases*. The process of removing sulfur dioxide from flue gases is called *desulfurisation*.

Atmosphere

Sulfur Dioxide, SO_2 and Oxides of Nitrogen, NO and NO_2

- Calcium carbonate can be used to remove sulfur dioxide from the flue gases:

calcium carbonate + sulfur dioxide → calcium sulfite + carbon dioxide

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

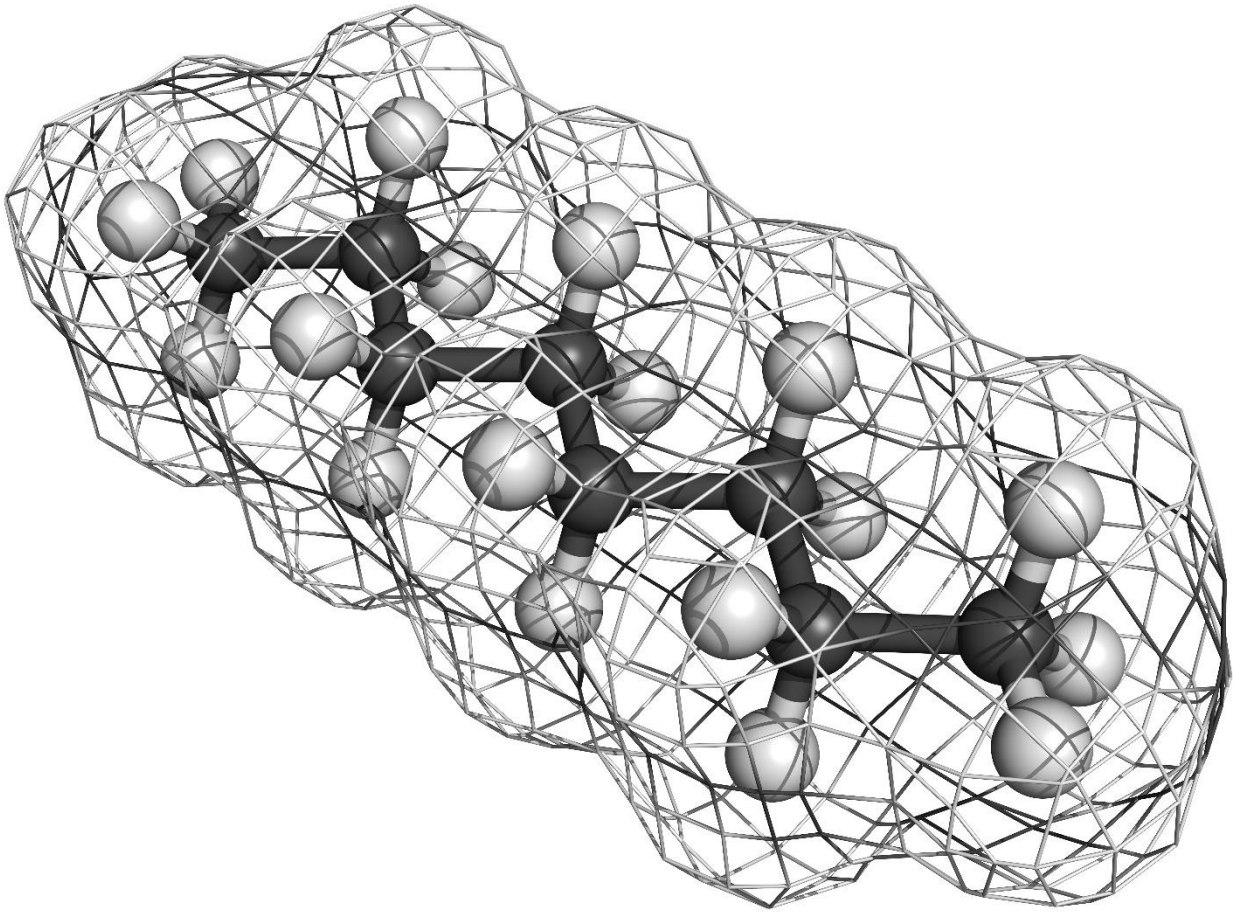
- In addition to calcium carbonate, calcium oxide can also be used for desulfurisation:

calcium oxide + sulfur dioxide → calcium sulfite

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

Atmosphere

Unburned Hydrocarbons, *e.g.* C_8H_{18}



Atmosphere

Unburned Hydrocarbons, *e.g.* C_8H_{18}

Atmosphere

Unburned Hydrocarbons, *e.g.* C_8H_{18}

- Hydrocarbons are compounds that are composed of the chemical elements hydrogen and carbon only.
- Unburned hydrocarbons enter the Earth's atmosphere through motor vehicle exhaust fumes.
- Motor vehicles produce unburned hydrocarbons due to the *incomplete combustion* of petrol. Incomplete combustion occurs when the supply of oxygen is limited.
- Unburned hydrocarbons are removed from motor vehicle exhaust fumes by *catalytic converters*:

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

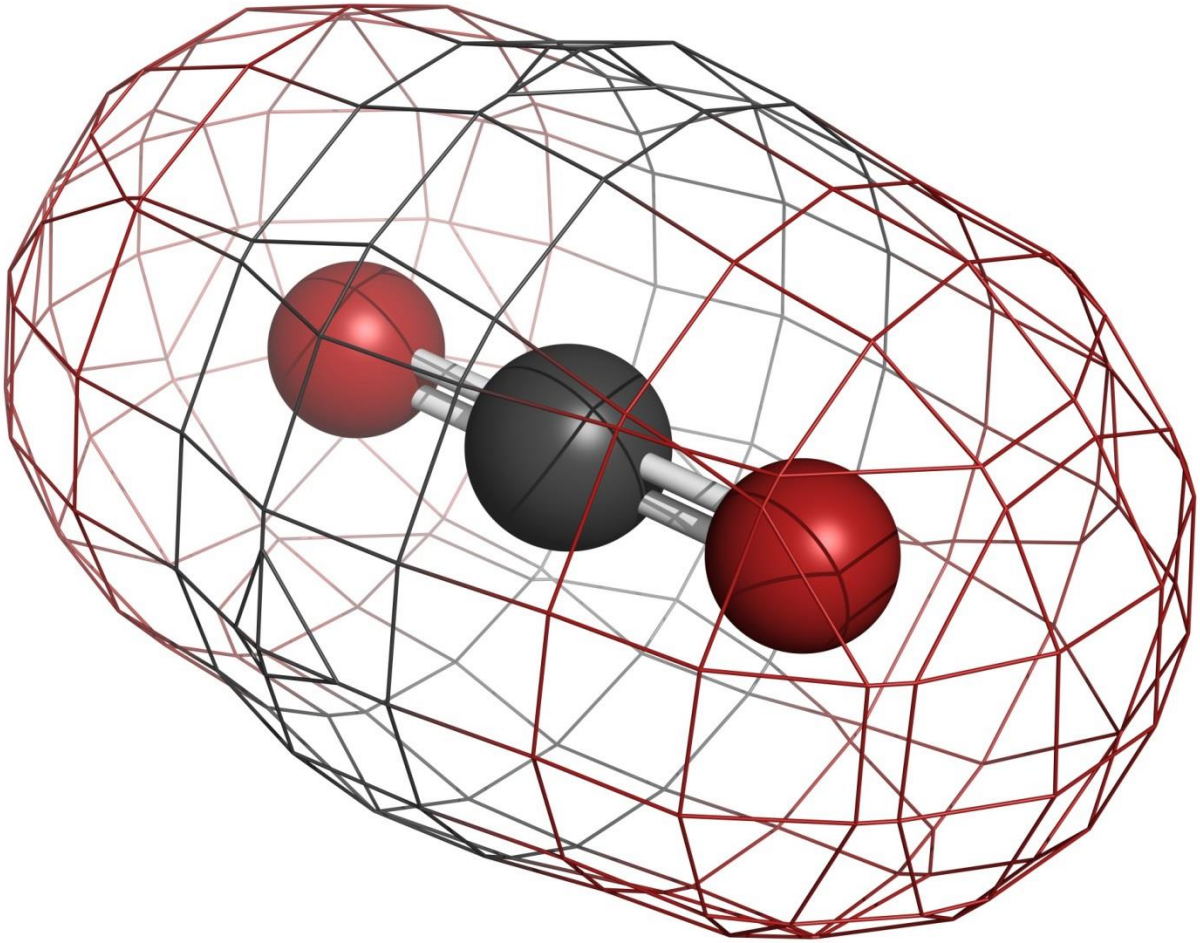
Atmosphere

Unburned Hydrocarbons, *e.g.* C_8H_{18}

- Unburned hydrocarbons are *carcinogenic*, meaning that they can cause *cancer*.

- In sunlight, unburned hydrocarbons react with nitrogen oxides to form *ozone*.

Atmosphere
The Carbon Cycle



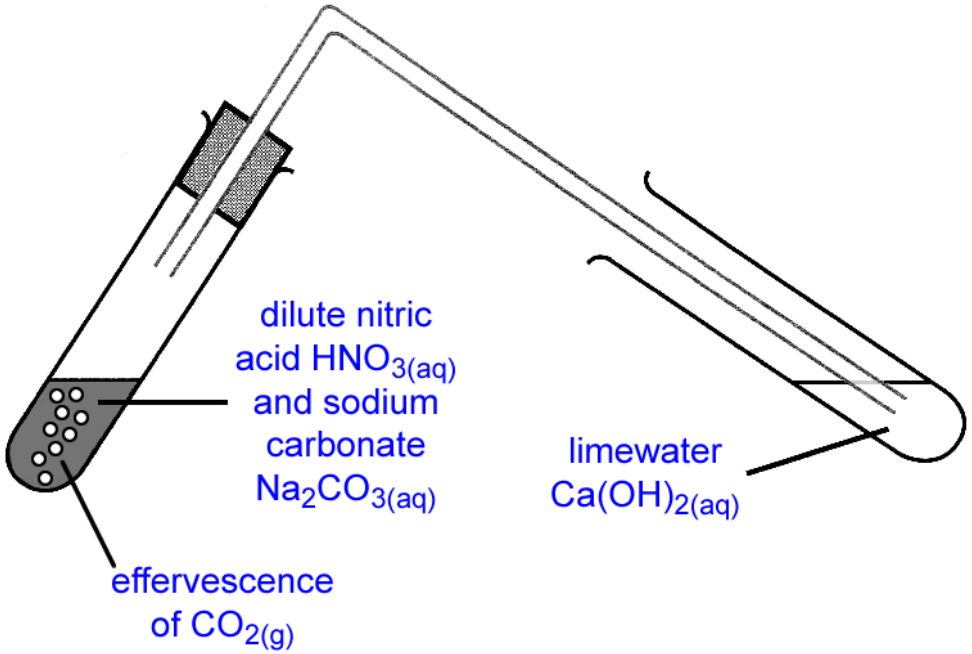
Atmosphere

The Carbon Cycle

Pop quiz! What is the qualitative test for carbon dioxide gas?

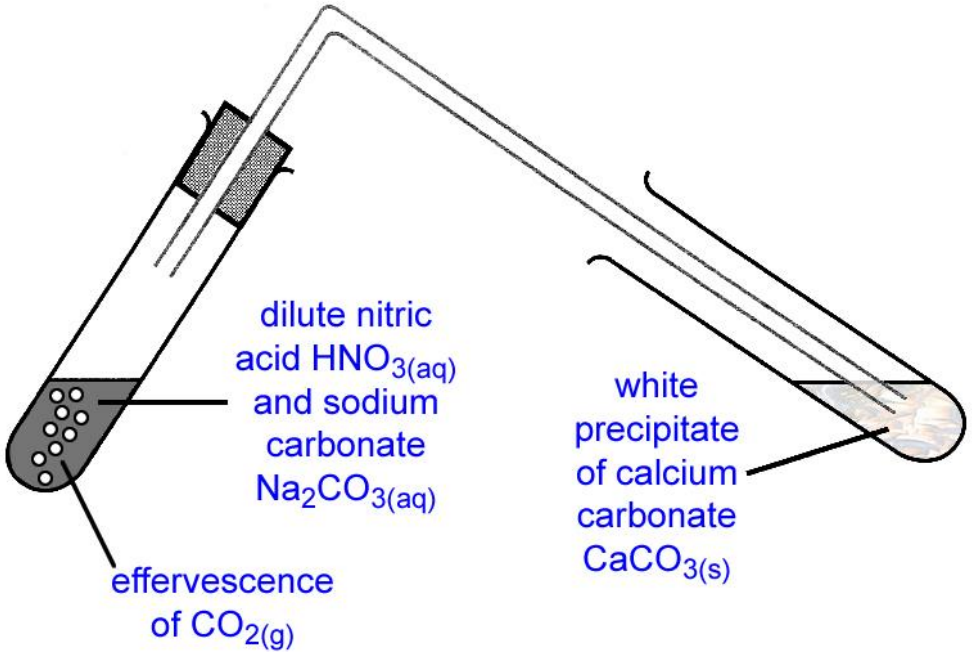
Atmosphere

The Carbon Cycle



Atmosphere

The Carbon Cycle



Calcium Hydroxide + Carbon Dioxide → Calcium Carbonate + Water

$$Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$$

$$Ca^{2+}_{(aq)} + 2OH^-_{(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$$

Atmosphere

The Carbon Cycle

Atmosphere

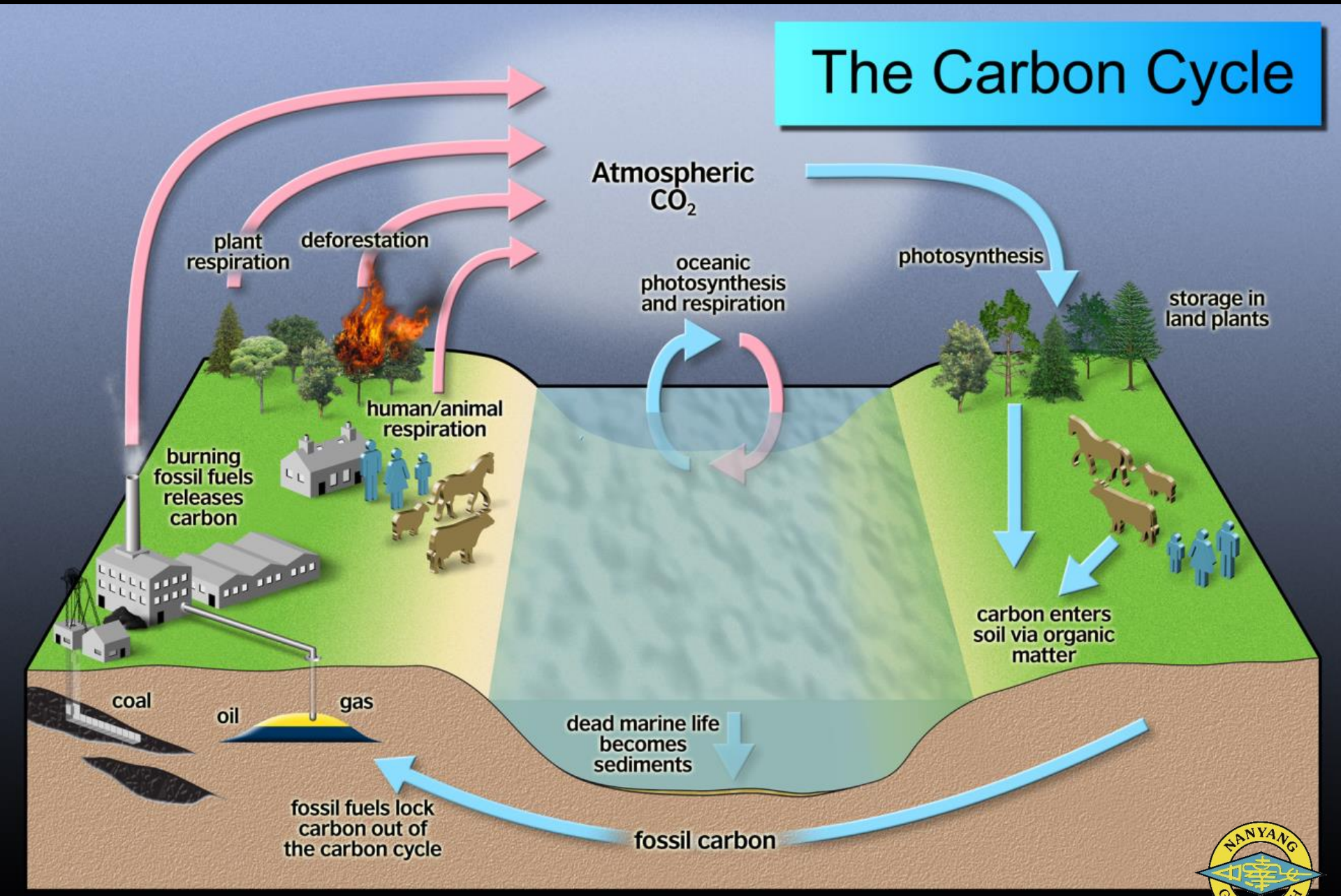
The Carbon Cycle

- The Earth's atmosphere contains approximately 0.03% carbon dioxide by volume.

- Carbon dioxide is continuously removed and returned to the atmosphere by a variety of processes.

- If the amount of carbon dioxide in the atmosphere is to remain constant, then the rate at which carbon dioxide is removed from the atmosphere must equal the rate at which it is returned to the atmosphere.

- The *carbon cycle* is the mechanism that maintains the level of carbon dioxide in the atmosphere.


The Carbon Cycle
Atmospheric CO_2
plant respiration
deforestation
oceanic photosynthesis and respiration
photosynthesis
storage in land plants
human/animal respiration
burning fossil fuels releases carbon
carbon enters soil via organic matter
coal
oil
gas
dead marine life becomes sediments
fossil fuels lock carbon out of the carbon cycle
fossil carbon
NANYANG GIRLS' HIGH

Atmosphere

The Carbon Cycle

- Carbon dioxide is added to the Earth's atmosphere by three main processes.

1) Respiration: All living things respire. Respiration is described as an *exothermic* process because it *releases energy*:

glucose + oxygen $\rightarrow$ carbon dioxide + water

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

Atmosphere

The Carbon Cycle

- Carbon dioxide is added to the Earth's atmosphere by three main processes.

2) Combustion of Fuels: Most fuels, such as coal, petroleum and natural gas, are *hydrocarbons*. This means that they are composed of hydrogen and carbon. When these fuels undergo complete combustion, they produce carbon dioxide and water as the reaction products:

methane + oxygen $\rightarrow$ carbon dioxide + water

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

Atmosphere

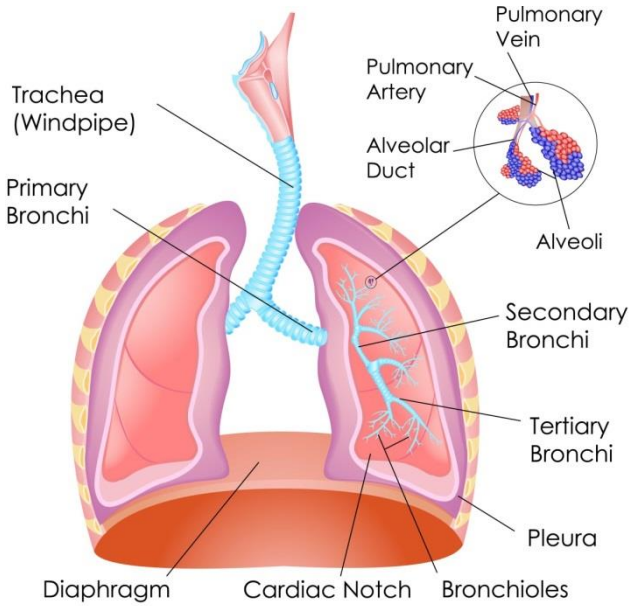
The Carbon Cycle

- Carbon dioxide is added to the Earth's atmosphere by three main processes.

3) Decay and Bacterial Decomposition: Bacteria break down the carbon based compounds inside dead plants and animals to produce carbon dioxide as one of the reaction products.

Atmosphere

The Carbon Cycle – Respiration



glucose + oxygen $\rightarrow$ carbon dioxide + water

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

Atmosphere

The Carbon Cycle

- Carbon dioxide is removed from the Earth's atmosphere by two main processes.

1) Photosynthesis: During photosynthesis, green plants convert carbon dioxide and water into glucose and oxygen in the presence of sunlight. Photosynthesis is described as an *endothermic* process because *absorbs energy*:

carbon dioxide + water $\rightarrow$ glucose + oxygen

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

Atmosphere

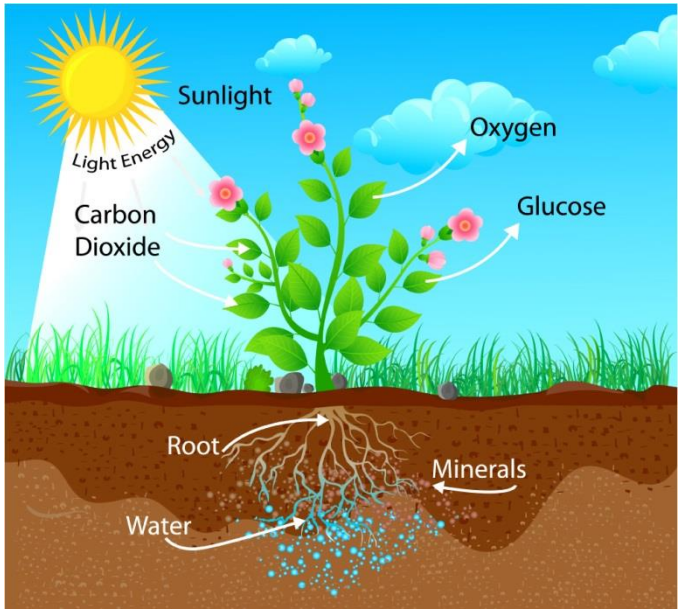
The Carbon Cycle

- Carbon dioxide is removed from the Earth's atmosphere by two main processes.

2) Ocean Uptake: The world's oceans serve as a massive sink that traps carbon dioxide. Much of the dissolved carbon dioxide in the oceans is used by plants and marine organisms. For example, plants use it during photosynthesis. Most of the carbon dioxide is eventually converted into calcium carbonate in the form of shells and skeletons of marine organisms. Over time, these shells and skeletons of dead organisms settle to the seabed to form limestone.

Atmosphere

The Carbon Cycle – Photosynthesis

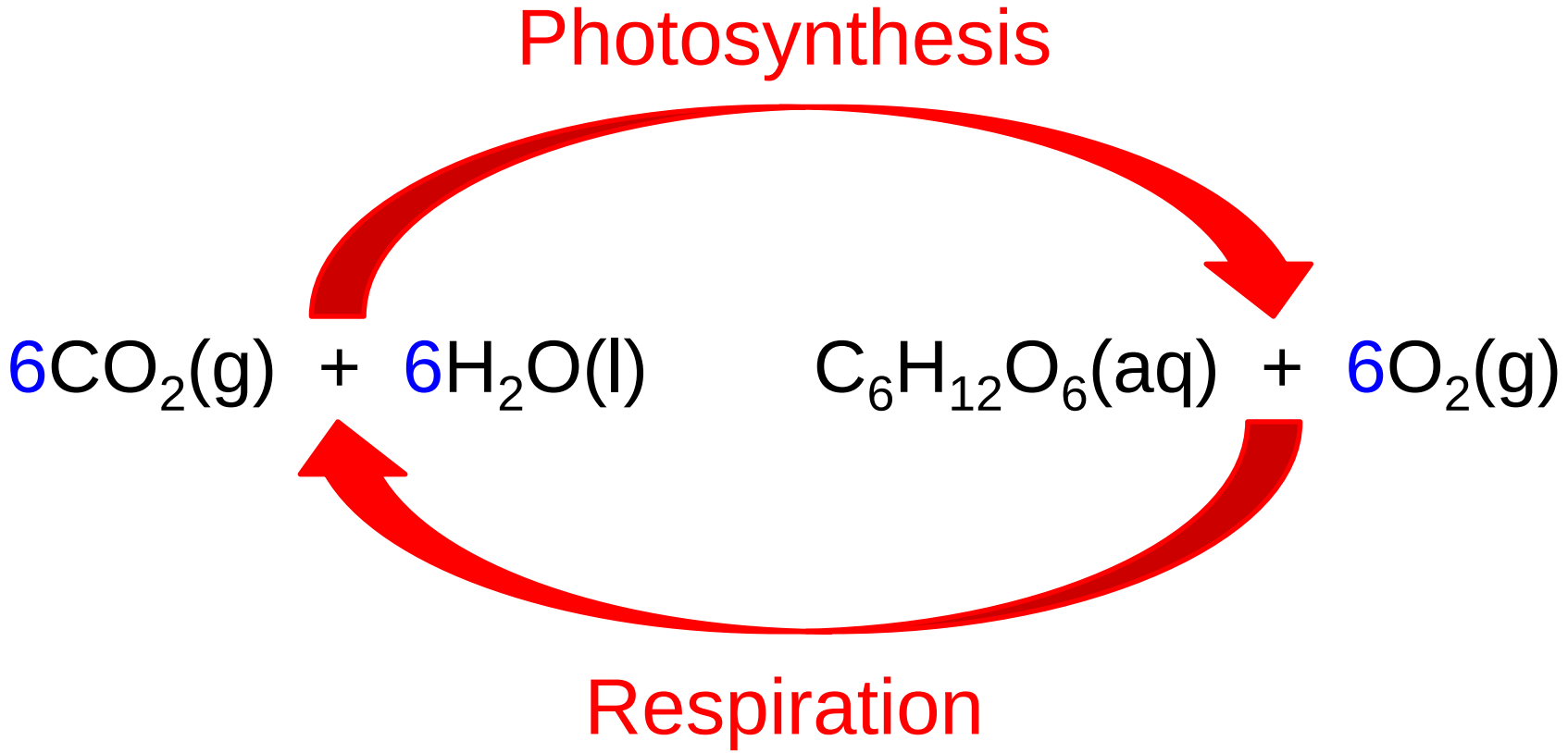


carbon dioxide + water → glucose + oxygen

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

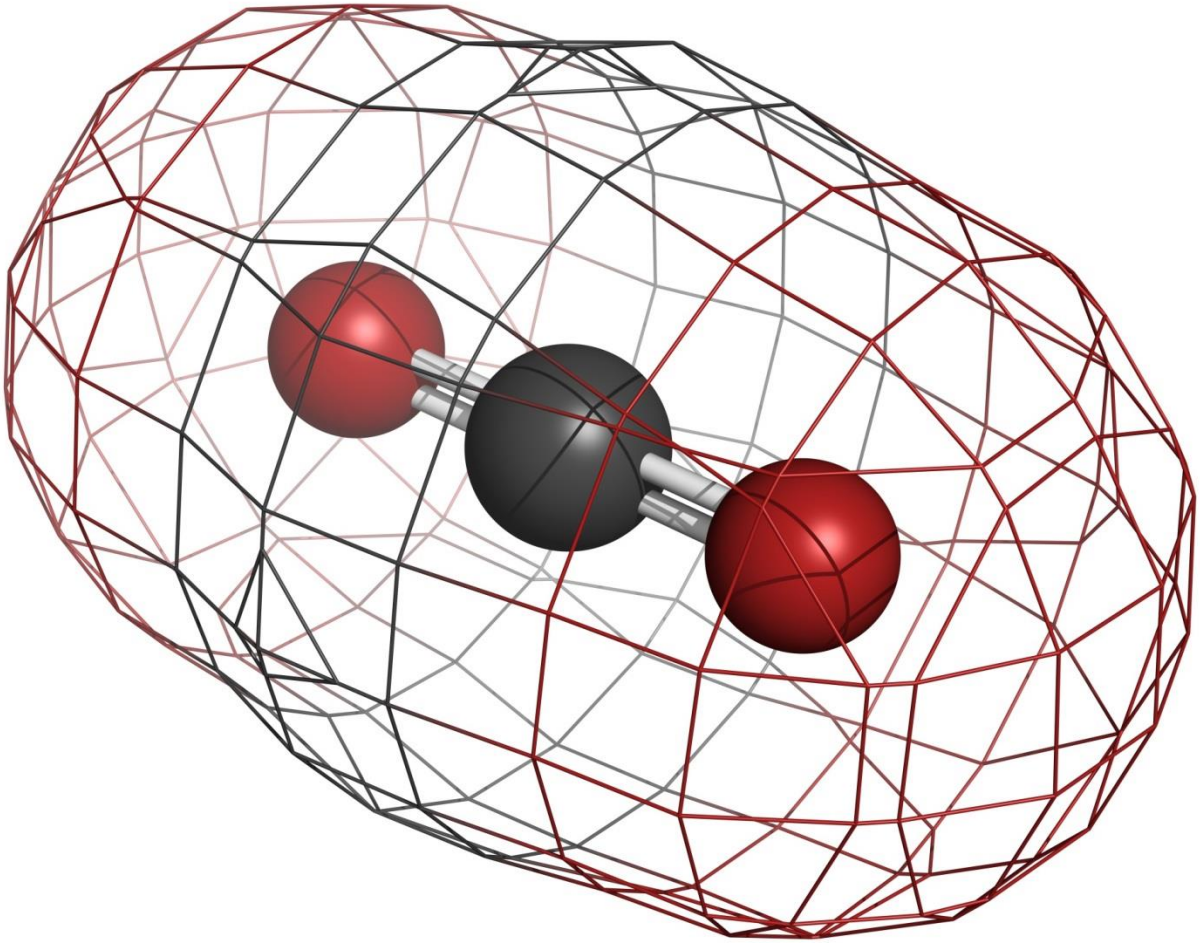
Atmosphere

The Carbon Cycle



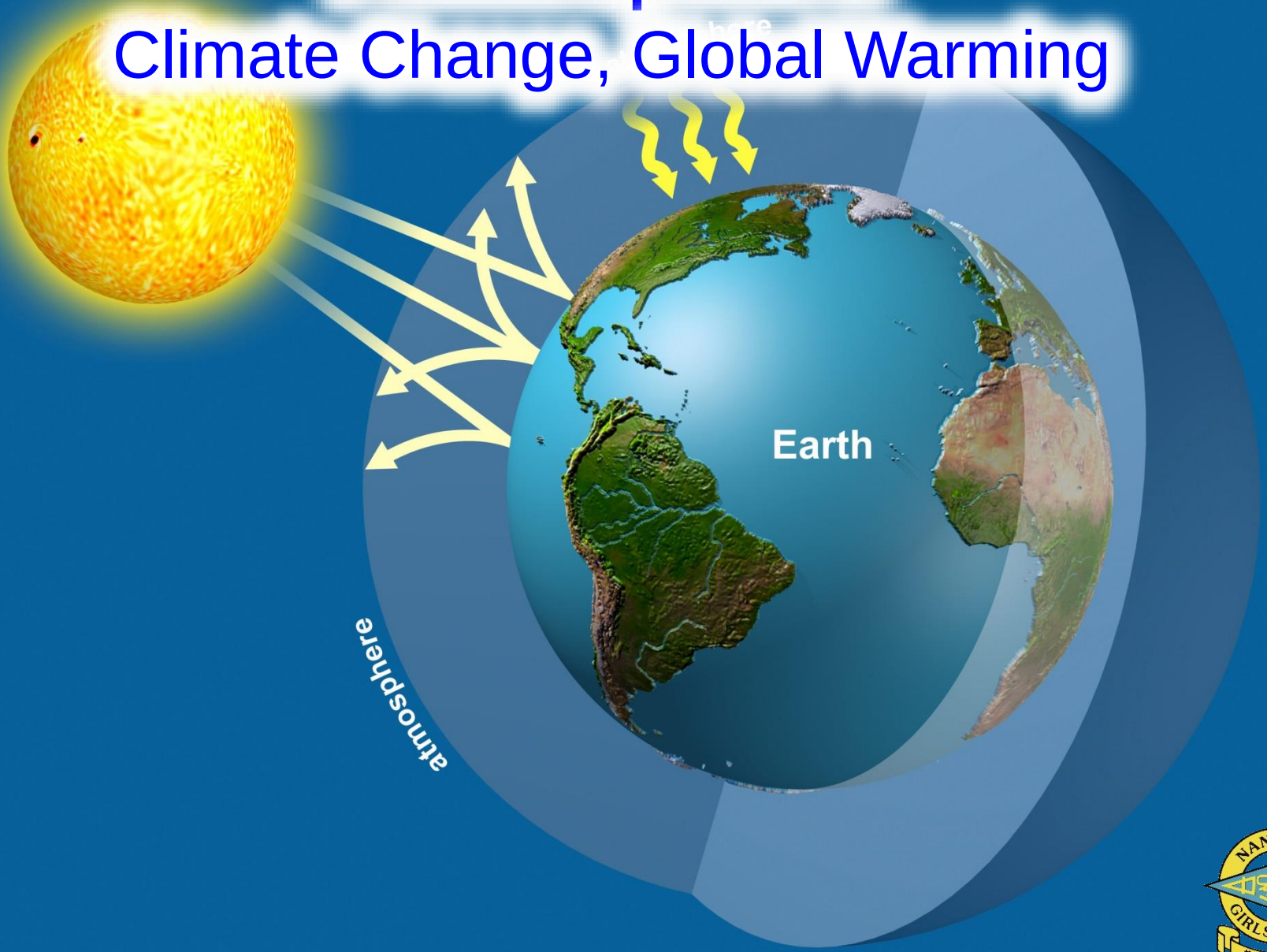
Atmosphere

Climate Change, Global Warming



Atmosphere

Climate Change, Global Warming



Atmosphere

Climate Change, Global Warming

- Carbon dioxide and water vapour have important roles to play in maintaining a fairly uniform temperature on the Earth's surface. These gases allow visible radiation from the sun to reach the Earth's surface, but trap some of the infrared radiation that is emitted by the Earth. Heat energy is therefore retained in the atmosphere. This produces a warming effect called the *greenhouse effect*.

Atmosphere

Climate Change, Global Warming

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Atmosphere

Climate Change, Global Warming

- Gases that trap radiation are called *greenhouse gases*. Examples of greenhouse gases are carbon dioxide and methane.

- A natural greenhouse effect is essential for maintaining the proper temperature needed to sustain life on Earth. Without these greenhouse gases, The Earth's surface temperature would be approximately –40 °C and it would be permanently covered in ice.

Atmosphere

Climate Change, Global Warming

- Scientists are concerned that the Earth is overheating. Activities like the burning of fossil fuels and large-scale cutting down of forests are causing some greenhouse gases, especially carbon dioxide, to build-up rapidly in the atmosphere. This means that carbon dioxide is being added to the atmosphere at a higher rate than photosynthesis can remove the excess gas. This will 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.

Atmosphere

Climate Change, Global Warming

Atmosphere

Climate Change, Global Warming

- If nothing is done to reduce the production of greenhouse gases, scientists predict that the Earth's average temperature could increase by 1 °C to 3 °C within the next 100 years. The possible consequences of global warming are…

More occurrences of unusual weather conditions such as warm spells, droughts, unexpected storms and hurricanes, floods and tsunamis in some parts of the world.

Atmosphere

Climate Change, Global Warming

Atmosphere

Climate Change, Global Warming

- If nothing is done to reduce the production of greenhouse gases, scientists predict that the Earth's average temperature could increase by 1 °C to 3 °C within the next 100 years. The possible consequences of global warming are…

A decrease in crop yields world-wide because the areas that are currently covered by vegetation may become deserts.

Atmosphere

Climate Change, Global Warming

Atmosphere

Climate Change, Global Warming

- If nothing is done to reduce the production of greenhouse gases, scientists predict that the Earth's average temperature could increase by 1 °C to 3 °C within the next 100 years. The possible consequences of global warming are…

The melting of large quantities of ice at the in the North and South Poles. This will cause ocean levels to rise and flood low lying countries.


Atmosphere
Climate Change, Global Warming
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GIRLS' HIGH

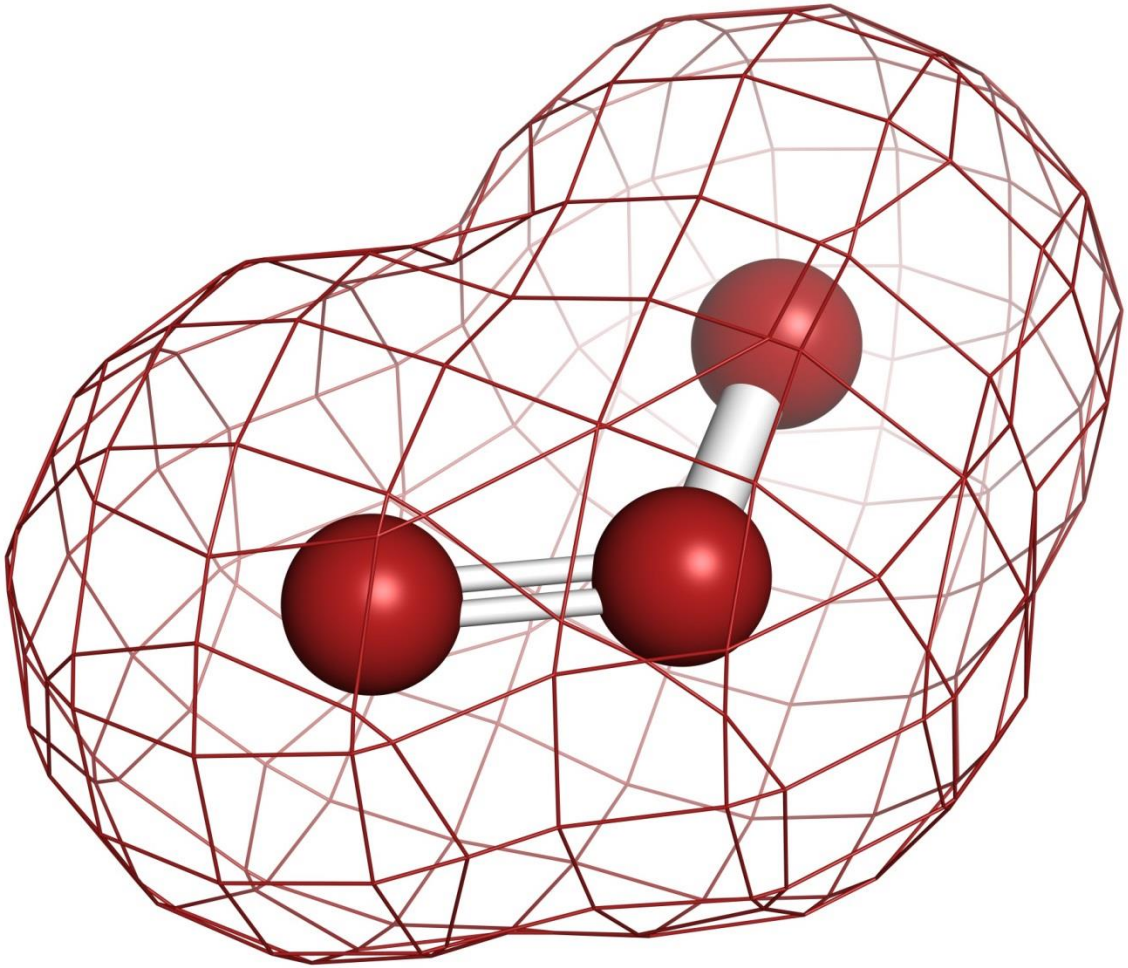
Atmosphere

Climate Change, Global Warming

- If nothing is done to reduce the production of greenhouse gases, scientists predict that the Earth's average temperature could increase by 1 °C to 3 °C within the next 100 years. The possible consequences of global warming are…

The rapid evaporation of water from the Earth's surface. As a result, carbon dioxide dissolved in the oceans will be released into the atmosphere. This will further increase the greenhouse effect.

Atmosphere
The Ozone Layer



Atmosphere

The Ozone Layer

- Ozone, O_3, is an *allotrope* of oxygen. It is a pale blue gas with a pungent odour.

- Ozone is considered a pollutant at ground level. It is toxic when present in concentrations above 100 ppm (parts per million). However, in the *stratosphere* (a layer of the atmosphere 20-50 km above the Earth's surface) ozone is very important.

- Ozone is formed in the Earth's upper atmosphere by the effect of sunlight on oxygen:

oxygen $\rightarrow$ ozone

$$3O_2(g) \xrightarrow{\text{sunlight}} 2O_3(g)$$

Atmosphere

The Ozone Layer

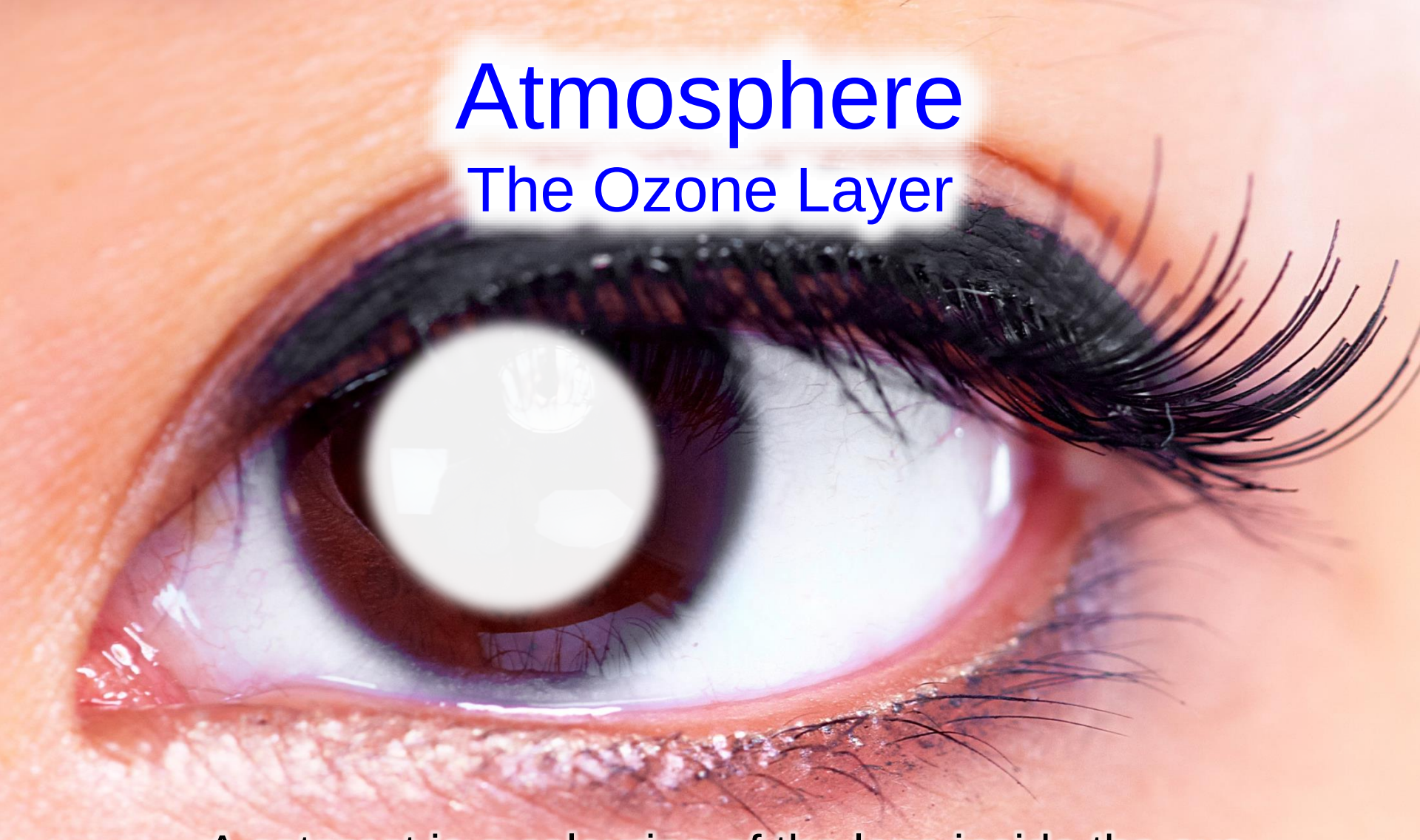
Atmosphere

The Ozone Layer

- The ozone layer is important because it filters some of the harmful *ultraviolet* (UV) *radiation* from the sun.
- Too much ultraviolet radiation can cause *skin cancer*, genetic mutations and eye damage, *e.g. cataracts*.

Atmosphere

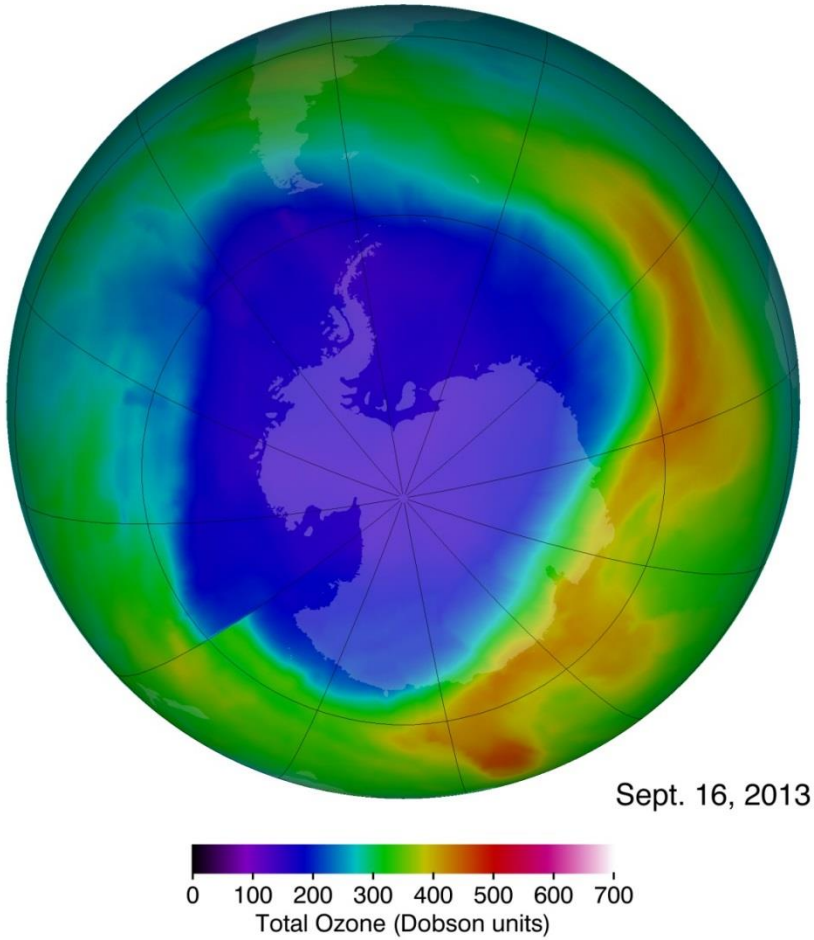
The Ozone Layer



- A cataract is a colouring of the lens inside the eye which leads to a decrease in vision.

Atmosphere

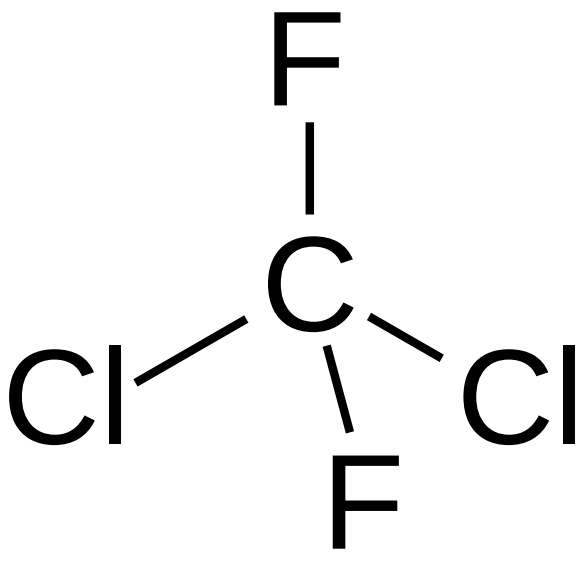
The Ozone Layer

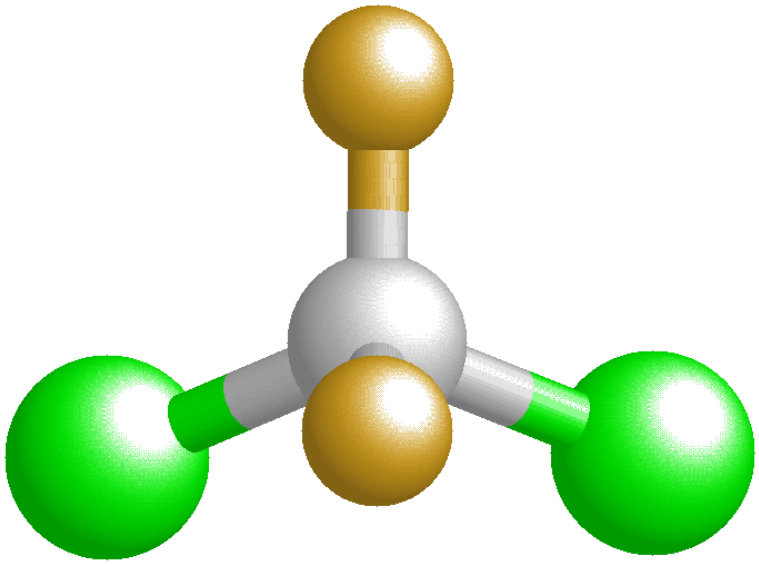


- Since 1976, there has been a *rapid decrease* in the amount of ozone in the stratosphere above the South Pole. Scientists have discovered that one major cause of the ozone depletion are a group of chemicals called *chlorofluorocarbons*.

Atmosphere

The Ozone Layer





Chlorofluorocarbons

Dichlorodifluoromethane – CCl_2F_2

Atmosphere

The Ozone Layer

- Propellants in aerosols, as well as coolants in refrigerators and air conditioners, release chlorofluorocarbons into the atmosphere.

Chlorofluorocarbons are very stable chemicals and last for many years in the Earth's atmosphere. When they reach the stratosphere, they react with - and destroy - the protective ozone layer.

Atmosphere

The Ozone Layer

chlorofluorocarbon → chlorofluorocarbon radical + chlorine radical

$$CCl_2F_2(g) \xrightarrow{\text{ultraviolet radiation}} CClF_2\cdot(g) + Cl\cdot(g)$$

chlorine radical + ozone → oxygen + chlorine monoxide radical

$$Cl\cdot(g) + O_3(g) \rightarrow O_2(g) + ClO\cdot(g)$$

chlorine monoxide radical + oxygen radical → oxygen + chlorine radical

$$ClO\cdot(g) + \cdot O\cdot(g) \rightarrow O_2(g) + Cl\cdot(g)$$

Atmosphere

The Ozone Layer

chlorofluorocarbon → chlorofluorocarbon radical + chlorine radical

$$CCl_2F_2(g) \xrightarrow{\text{ultraviolet radiation}} CClF_2\cdot(g) + Cl\cdot(g)$$

chlorine radical + ozone → oxygen + chlorine monoxide radical

$$Cl\cdot(g) + O_3(g) \rightarrow O_2(g) + ClO\cdot(g)$$

chlorine monoxide radical + oxygen radical → oxygen + chlorine radical

$$ClO\cdot(g) + \cdot O\cdot(g) \rightarrow O_2(g) + Cl\cdot(g)$$

One chlorofluorocarbon molecule can destroy many ozone molecules.

Atmosphere

The Ozone Layer

Atmosphere

The Ozone Layer

- Over the past few decades, there has been a significant increase in the incidence of skin cancer in countries such as Australia as people are exposed to higher levels of ultraviolet radiation. Volunteers can be seen quite regularly on the beaches handing out T-shirts, sunblock and leaflets that warn about the dangers of sunbathing.

Atmosphere

The Ozone Layer

- Many countries have now agreed to ban the use of chlorofluorocarbons. However, even if the use of chlorofluorocarbons were to completely stop immediately, depletion of the ozone layer would continue for many years to come due to the chlorofluorocarbons that are already present in the Earth's atmosphere.

Atmosphere

Could I please have a summary?

Atmosphere

Pollutant	Produced by…	Causes…	Reduced by…
Carbon Monoxide, CO	Incomplete combustion of carbon containing substances.	Toxic gas binds to haemoglobin causing headaches, fatigue, death.	Catalytic converters that convert CO to CO_2.
Carbon Dioxide, CO_2	Complete combustion of carbon containing substances. Respiration.	Greenhouse gas causes climate change in the form of global warming.	Reduce combustion of carbon containing substances.
Methane, CH_4	Bacterial decay of organic matter.	Greenhouse gas causes climate change in the form of global warming.	Reduce / reuse / recycle organic waste.
Oxides of Nitrogen, NO and NO_2	Internal combustion engines and jet engines. Lightning.	Acidic NO_2 causes acid rain. NO and NO_2 cause respiratory problems.	Catalytic converters that convert NO and NO_2 to N_2.
Ozone, O_3	Photochemical reactions.	Eye irritation and respiratory problems.	Reduce emissions of unburned hydrocarbons.
Sulfur Dioxide, SO_2	Combustion of fossil fuels. Volcanic eruptions.	Acidic SO_2 causes acid rain and respiratory problems.	Removal of SO_2 from flue gas using $CaCO_3$.
Unburned Hydrocarbons, *e.g.* C_8H_{18}	Incomplete combustion of fuels.	Form photochemical smog and ozone. Respiratory problems and cancer.	Catalytic converters that convert C_8H_{18} into CO_2 and H_2O.

Atmosphere

Community Focus

Atmosphere
Community Focus

- What is the *Pollutant Standards Index* (PSI) value in Singapore is today?

- What is the National Environment Agency's health advisory for today?


Atmosphere
Community Focus

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Community Focus

- Why does Singapore experience a yearly *haze*?

Consider the geographical and social reasons in your discussion.

Atmosphere

Community Focus

Atmosphere

Community Focus

- Which atmospheric pollutants are contained within the yearly *haze* that Singapore experiences due to “slash-and-burn” cultivation in neighbouring countries?

- To what extent are paper facemasks effective at removing atmospheric pollutants contained within the *haze*?

how does haze hurt the body?

Air pollutants can trigger underlying health conditions and affect the body in numerous ways.

Nose

During inhalation, particles and chemicals irritate the nose, which secretes mucus to flush out the particles. As more mucus is produced, the nasal passage becomes blocked and the nose swells. The reaction is magnified in people who have allergic rhinitis.

Airways and lungs

The particles may inflame the airways and the lungs as they travel downwards. The airways and lungs produce phlegm to try to get rid of the particles. The airways spasm to provoke a cough to expel the foreign matter.

Skin

Those with eczema may find it becoming itchy and inflamed. Using moisturiser three to four times a day can help protect the skin.

Eyes

The particles and chemicals can cause burning sensations, irritate the eye into tearing to clean itself and inflame the conjunctiva, the surface layer on the white of the eyeball. Avoid wearing contact lenses and put on wrap-around glasses. Use preservative-free lubricants every hour to remove allergens.

Heart

With the nose and airways inflamed, the body is under stress and the heart pumps faster, increasing the blood pressure. The body also releases chemicals that make blood clot more easily. Higher blood pressure and the formation of blood clots can cause a heart attack, stroke or heart failure

General precautions

People with chronic diseases, especially serious ones such as heart and lung diseases, should stay indoors and avoid physical activity outdoors when the PSI hits about 80. Kids and elderlys should avoid too.

Source: Singapore General Hospital

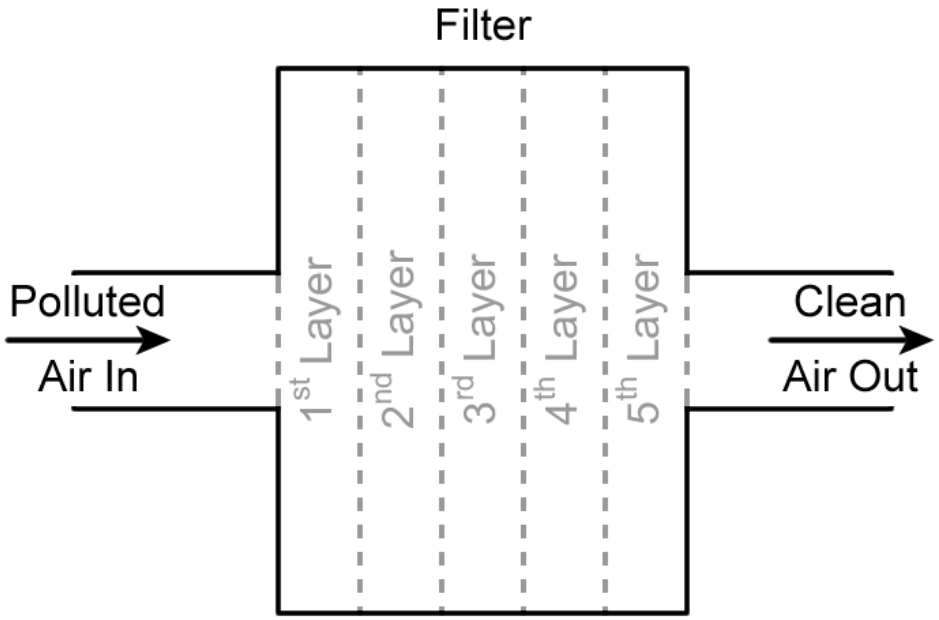
Atmosphere

Applied Learning

Atmosphere

Applied Learning

Filter



Atmosphere

Applied Learning

- Singapore's Civil Defence Force have asked you to design a new filter for their gas mask. The filter must be capable of removing common pollutants as well as dust and microorganisms from the air.

1) Which chemicals / materials will you use to make the different layers within the filter?

2) Justify why you would use these chemicals / materials.

3) Which tests could you perform on the clean air in order to determine how effective the filter is?

Atmosphere


MAURITANIA
ALGERIA
NIGER
LIBYA
CHAD
SUDAN
EGYPT
CAMEROON
ANGOLA
ETHIOPIA
SOMALIA
KENYA
TANZANIA
MOZAMBIQUE
SAUDI ARABIA
YEMEN
OMAN
AFGHANISTAN
PAKISTAN

Atmosphere

- **Enduring Understanding:**

Care for the world you live in.

Atmosphere

Presentation on

Atmosphere Part Two

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