# DP IB Chemistry: HL

Your notes

## 8.3 Acid Deposition

### Contents

## 8.3.1 Acid Deposition

Your notes

# Acid Deposition

### What is acid deposition?

- Rain is naturally acidic because of dissolved $CO_2$ which forms **carbonic acid**

$$H_2O\,(l) + CO_2\,(g) \rightleftharpoons H_2CO_3\,(aq)$$

- **Carbonic acid** is a **weak acid** and dissociates in the following equilibrium reaction giving a **pH of 5.6**

$$H_2CO_3\,(aq) \rightleftharpoons H^+\,(aq) + HCO_3^-\,(aq)$$

- For that reason **acid rain** is defined as rain with a pH of **below** 5.6
- **Acid deposition** includes all processes by which acidic components leave the atmosphere
  - This could be gases or precipitates
- There are two types of deposition: **wet acid deposition** and **dry acid deposition**
  - **Wet acid deposition** refers to rain, snow, sleet, hail, fog, mist and dew
  - **Dry acid deposition** refers to acidic particles and gases that fall to the ground as dust and smoke
- **Acid deposition** is formed when nitrogen or sulfur oxides dissolve in water to form $HNO_3$, $HNO_2$, $H_2SO_4$ and $H_2SO_3$

Your notes

# Acid Deposition Equations

## Formation of sulfur based acids

- **Fossil fuels** are often contaminated with small amounts of **sulfur impurities**
- When these contaminated fossil fuels are **combusted**, the sulfur in the fuels get **oxidised** to **sulfur dioxide**

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

- Sulfur dioxide may be further oxidised to sulfur trioxide

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

- The sulfur dioxide and sulfur trioxide then dissolve in rainwater droplets to form **sulfurous acid** and **sulfuric acid**

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

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

- These acids are components of acid rain which has several damaging impacts on the environment

## Formation of acid rain by nitrogen oxides

- The temperature in an internal combustion engine can reach over 2000 °C
- Here, nitrogen and oxygen, which at normal temperatures don't react, combine to form **nitrogen monoxide**:

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

- **Nitrogen monoxide** reacts further forming **nitrogen dioxide**:

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

- **Nitrogen dioxide** gas reacts with rain water to form a mixture of **nitrous** and **nitric acids**, which contribute to **acid rain**:

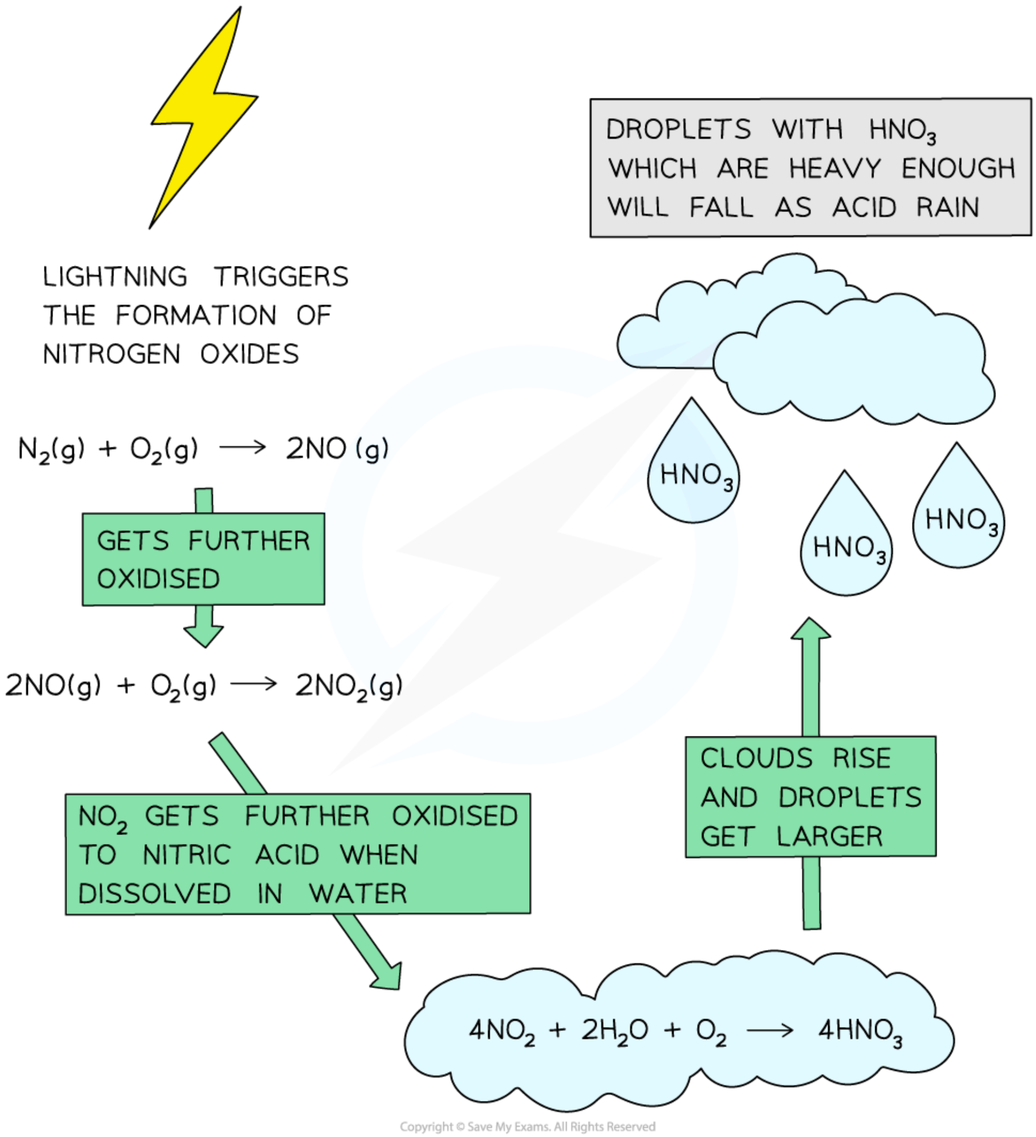
$$2NO_2(g) + H_2O(l) \rightarrow HNO_2(aq) + HNO_3(aq)$$

- Lightning strikes can also trigger the formation of nitrogen monoxide and nitrogen dioxides in air
- Nitrogen dioxide gas reacts with rain water and more oxygen to form **nitric acid**

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

- When the clouds rise, the temperature decreases, and the droplets get larger
- When the droplet containing these acids are heavy enough, they will fall down as **acid rain**

Your notes




*The diagram shows the formation of acid rain by the oxidation of nitrogen dioxide*

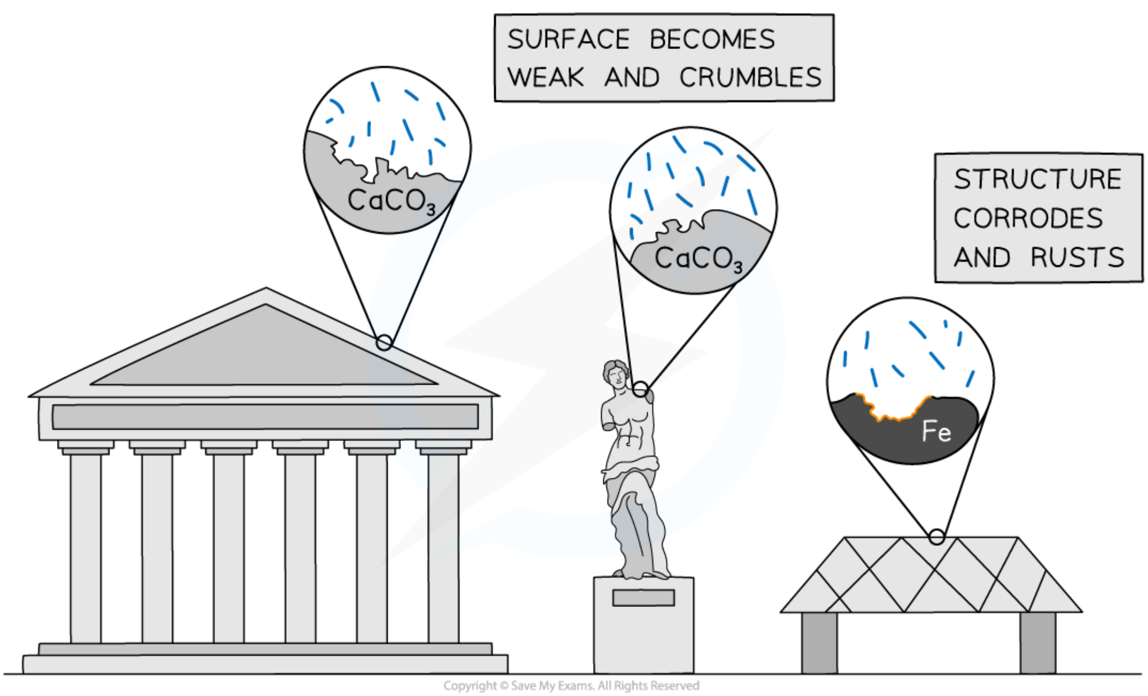
# 8.3.2 Effects of Acid Deposition

Your notes

## Effects of acid deposition

### Effect on materials

- **Acid deposition** can react with metals and rocks (such as **limestone**) causing buildings and statues to get damaged




***The impact of acid deposition can be seen on buildings, statues and metallic structures, particularly in polluted cities***

- Limestone and marble both contain calcium carbonate
- The calcium carbonate reacts with sulfuric or nitric acids causing stonework to corrode and weaken:

$$CaCO_3 (s) + H_2SO_4 (aq) \rightarrow CaSO_4 (aq) + CO_2 (g) + H_2O (l)$$

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

- In addition dry deposition also affects limestone:

$$CaCO_3 (s) + H_2SO_4 (aq) \rightarrow CaSO_4 (aq) + CO_2 (g) + H_2O (l)$$

- Metallic structures, such as iron bridges, are vulnerable to corrosion by wet and dry deposition forming the salt of the metal:

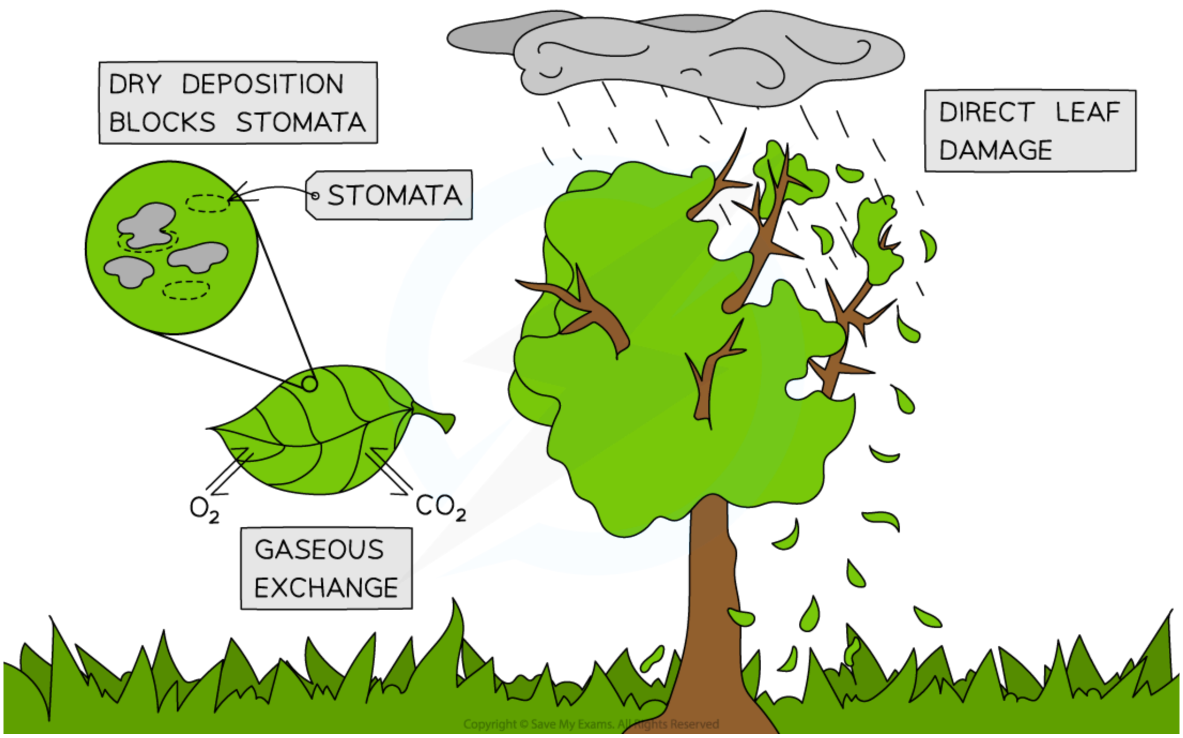
Your notes

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

$$Fe\ (s) + SO_2\ (g) + O_2\ (g) \rightarrow FeSO_4\ (s)$$

## Effect on plants

- Apart from **acid deposition** directly falling on leaves and killing plants, acid particulates can block stomata ( plant pores) and prevent gaseous exchange

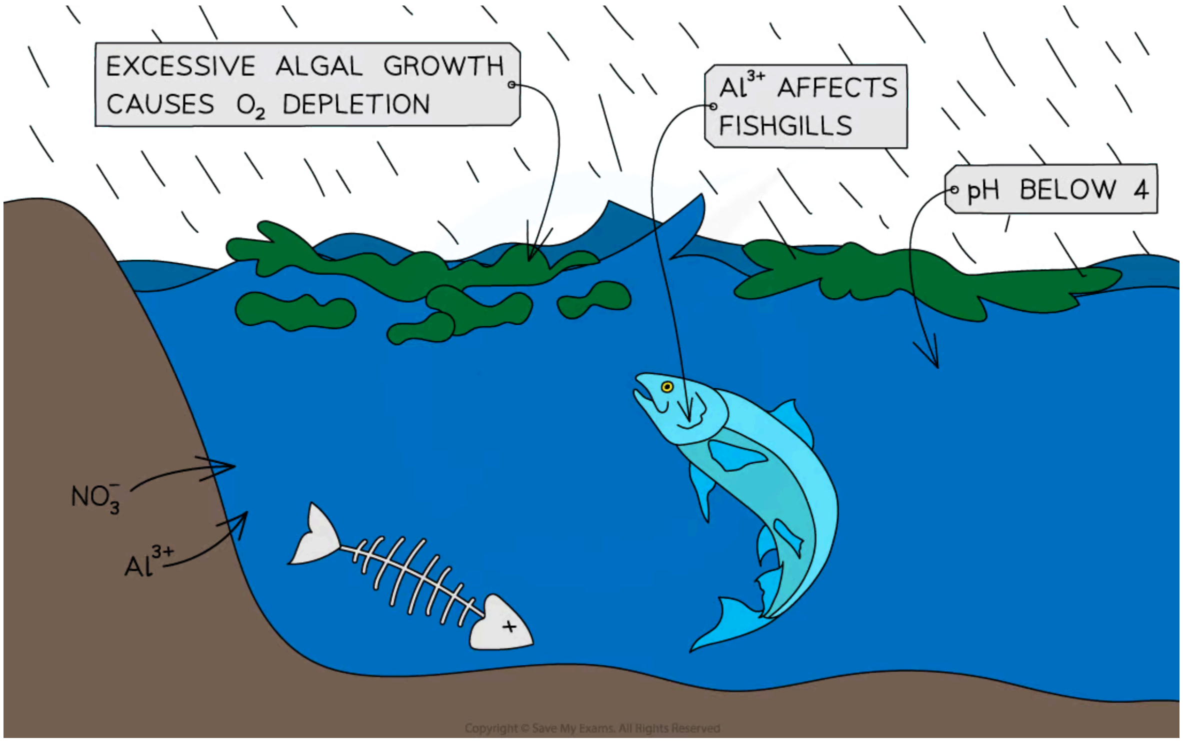



*The impact of acid deposition on plant life*

- Acid rain can fall on soils and release important minerals such as magnesium, calcium and potassium which are leached (washed out) from soils and are therefore unavailable to plants
- Aluminium ions released from rocks are toxic to many plants and damage their roots

## Effect on water

- When **acid rain** falls on rivers and lakes the pH can fall to levels that are unable to support life




*The impact of acid deposition on waterways*

- Below about pH 4, aluminium ions are released from rocks when they are held as aluminium hydroxide

$$Al(OH)_3\,(s) + 3H^+\,(aq) \longrightarrow Al^{3+}\,(aq) + 3H_2O\,(l)$$

- Alumnium ions are toxic to fish as they damage the gills and prevent fish from efficiently absorbing oxygen
- Nitrate ions from nitric acid in **acid rain** can contibute to over-fertilization of waterways and lead to **eutrophication**
  - **Eutrophication** is excessive algal growth that results in oxygen depletion and stagnation of waterways

## Effect on human health

- Although acid rain is too dilute to cause any direct impact on the skin, acidic particulates in the air can increase the risk of respiratory diseases such as bronchitis, asthma and emphysema
- When acid rain comes into contact with metal pipes there is an increased risk that toxic metal ions will be released into the water supply such as $Cu^{2+}$, $Al^{3+}$ and $Pb^{2+}$

## 8.3.3 Reducing Sulfur Oxide Emissions

Your notes

# Reducing Sulfur Oxide Emissions

- The removal of sulfur from fossil fuels can either take place **pre-combustion** or **post-combustion**
- The oxides of sulfur, $SO_2$ and $SO_3$, are both **acidic** and **toxic gases**
- **Sulfur dioxide** is produced naturally during volcanic eruptions, but large quantities have been and continue to be emitted by burning coal, oil and natural gas

### Pre-combustion

- **Pre-combustion** of sulfur takes place for coal and petroleum, although it is expensive to remove all the sulfur, so a small percentage often remains
  - For example, the average sulfur content of gasoline is 347ppm (this is the same as 347 mg per litre)
- It is essential to remove most of the sulfur as it damages the workings of internal combustion engines
- The sulfur is removed by reacting it with hydrogen in a process called **hydrodesulfurization**
- The sulfur is recovered and used in the manufacture of sulfuric acid

### Post-combustion

- Post-combustion is carried out on in coal-fired power stations
- The waste gases from burning the coal contain sulfur dioxide
- The waste gases are passed through a wet slurry of calcium oxide and calcium carbonate which react with the $SO_2$ and produce calcium sulfate

$$CaO\ (s) + SO_2\ (g) + \tfrac{1}{2}O_2\ (g) \rightarrow CaSO_4\ (s)$$

$$CaCO_3\ (s) + SO_2\ (g) + \tfrac{1}{2}O_2\ (g) \rightarrow CaSO_4\ (s) + CO_2\ (g)$$

- The calcium sulfate is also known as **gypsum** and is used to make plasterboard and other useful building materials

**What does the future hold?**

- Global policies working towards combating **global warming** will have the additional benefit in **reducing acid deposition**
- As we switch away from burning fossil fuels for energy there will be a **fall** in the emission of oxides of sulfur and nitrogen, which can only be a good thing for the environment
- Ultimately reducing the emission of primary pollutants is achieved by greater use of **renewable energy sources**, greater use of public transport and more **efficient energy transfer systems**