13 Nitrogen and Sulfur

Lack of reactivity of nitrogen

$N\equiv N$

N_2 has a very strong triple bond. It has a bond energy of +944 kJ mol^{-1}. It takes a lot of energy to break this bond. This explains Nitrogen's un-reactivity

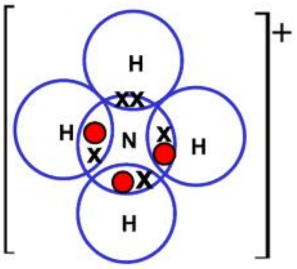
Ammonia

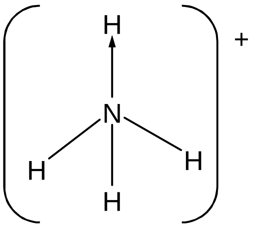
Basicity

Ammonia is a weak base. The lone pair of the nitrogen is able to accept a proton relatively easily to form the ammonium ion.

$$NH_{3\ (aq)} + H_2O_{\ (l)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

The ammonium ion NH_4^+





The dative covalent bond acts like an ordinary covalent bond when thinking about shape so in NH_4^+ the shape is tetrahedral

Displacement of ammonia from its salts

If sodium hydroxide is added to an ammonium salt and it is warmed, then ammonia gas will be evolved

$$NH_4^+{}_{(aq)} + OH^-{}_{(aq)} \rightarrow NH_{3\ (aq)} + H_2O_{\ (l)}$$

This reaction can be used as an analytical test for the presence of an ammonium ion. The ammonia will turn red litmus paper blue

Uses of ammonia

Making fertilisers

Reacting ammonia with acids can make fetilisers such as ammonium sulfate, ammonium nitrate or ammonium phosphate.

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

Ammonia + sulfuric acid → ammonium sulfate

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

Ammonia + nitric acid → ammonium nitrate

Making nitric acid

Ammonia is used to make nitric acid.

Uses of nitric acid

- make fertilisers such as ammonium nitrate.
- make explosives (e.g. TNT)
- making various dyes, drugs, polymers

Environmental consequences of nitrate fertilisers

Nitrates are very soluble so easily wash in to rivers from fields with rain. The nitrates then fertilise the algae in rivers. The algae block out sunlight, and other plants die. Bacteria feeding on decaying plants use up the oxygen in the water and all river life dies. This process is called **Eutrophication**

Nitrogen Oxides NO_x

Nitrogen oxides form from the reaction between N_2 and O_2 inside the car engine.
The **high temperature** and **spark** in the engine provides sufficient energy to break strong N_2 bond

$N_2 + O_2 \rightarrow 2NO$ $\quad$ $N_2 + 2O_2 \rightarrow 2NO_2$

Catalytic converters

These remove CO, NO_x and unburned hydrocarbons (e.g. octane, C_8H_{18}) from the exhaust gases, turning them into 'harmless' CO_2, N_2 and H_2O.

$$2\ CO + 2\ NO \rightarrow 2\ CO_2 + N_2$$

$$C_8H_{18} + 25\ NO \rightarrow 8\ CO_2 + 12½\ N_2 + 9\ H_2O$$

Converters have a ceramic honeycomb coated with a thin layer of catalyst metals **Platinum, Palladium, Rhodium** – to give a large surface area.

Nitrogen oxide Pollutants

NOx gases react to form smog and acid rain in the atmosphere

Nitrogen monoxide can react in the atmosphere to form nitrogen dioxide $2NO + O_2 \rightarrow 2NO_2$

Nitrogen dioxide catalyses the conversion of sulphur dioxide to sulphur trioxide.
The first step of the reaction is

$$NO_{2\,(g)} + SO_{2\,(g)} \rightarrow SO_{3\,(g)} + NO_{(g)}$$

The second step of the reaction is

$$NO_{(g)} + \frac{1}{2} O_{2\,(g)} \rightarrow NO_{2\,(g)}$$

The nitrogen dioxide is regenerated at the end of the reaction so is classed as a catalyst.

Sulfur: the formation of atmospheric sulfur dioxide

Sulfur containing impurities are found in petroleum fractions which produce SO_2 when they are burned.

$S + O_2 \rightarrow SO_2$ $CH_3SH + 3O_2 \rightarrow SO_2 + CO_2 + 2H_2O$

Coal is high in sulfur content, and large amounts of sulfur oxides are emitted from power stations.

The sulfur dioxide goes on to form acid rain
In the first step reactions in the atmosphere form SO_3

$$2SO_2 + O_2 \longrightarrow 2\,SO_3$$

The SO_3 dissolves in atmospheric water to form acid

$SO_3 + H_2O \longrightarrow H_2SO_4$ sulphuric acid

Consequences of acid rain

- Decline in fish populations in rivers
- Dissolves minerals Mg, Ca, and K from the soil
- Dissolves waxy coatings that protect leaves from bacteria
- Corrodes metals, and limestone buildings