

NITROGEN AND ITS COMPOUNDS

Nitrogen

- occurs in Group V
- electronic configuration ... $1s^2 2s^2 2p^2$
- exists as a **diatomic molecule** N_2
- very **unreactive** - triple bond between atoms has a high bond dissociation enthalpy
- makes up 79% of atmospheric gases

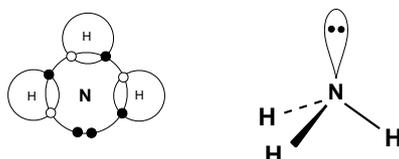
Oxidation states

Exhibits the whole range of oxidation states

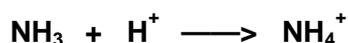
| | | | |
|-----------|----------|----------|------------------------|
| +5 | HNO_3 | NO_3^- | <i>oxidising agent</i> |
| +4 | NO_2 | | |
| +3 | HNO_2 | NO_2^- | |
| +2 | NO | | |
| +1 | N_2O | | |
| 0 | N_2 | | |
| -1 | NH_2OH | | |
| -2 | N_2H_4 | | |
| -3 | NH_3 | NH_4^+ | <i>reducing agent</i> |

Ammonia

- covalent** hydride of nitrogen
- higher than expected boiling point due to intermolecular **hydrogen bonding**
- pyramidal** in shape due to repulsion between 3 bond pairs and 1 lone pair

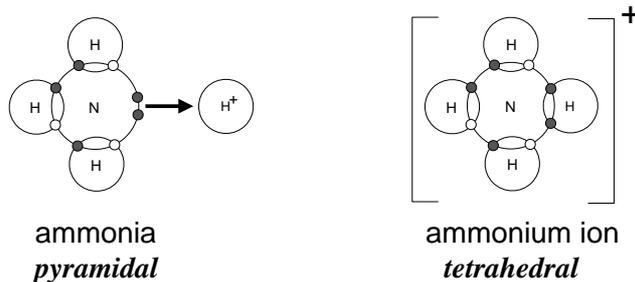


- acts as a **Lewis base** due to lone pair on nitrogen
- acts as a **Bronsted-Lowry** base as it can pick up protons



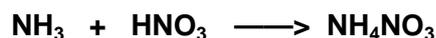
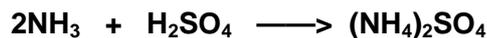
Ammonium ion

- ammonia can use its lone pair to form a co-ordinate (dative covalent) bond to a proton

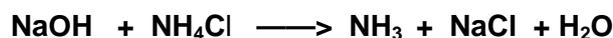


Ammonium salts

- formed when ammonia reacts with acids



- ammonia is displaced from its salts by treating them with a stronger base

**Haber Process**

Ammonia is prepared industrially by the Haber Process

*Typical conditions*

| | |
|-------------|-----------------------------|
| Pressure | 20000 kPa (200 atmospheres) |
| Temperature | 380-450°C |
| Catalyst | iron |

Equilibrium theory favours

| | |
|-----------------|---|
| low temperature | exothermic reaction - higher yield at lower temperature |
| high pressure | decrease in number of gaseous molecules |

Kinetic theory favours

| | |
|------------------|---|
| high temperature | greater average energy + more frequent collisions |
| high pressure | more frequent collisions for gaseous molecules |
| catalyst | lower activation energy |

Compromise conditions

| | | |
|------------------|------------------------------------|----|
| Which is better? | A low yield in a shorter time | or |
| | a high yield over a longer period. | |

The conditions used are a **compromise** with the catalyst enabling the rate to be kept up, even at a lower temperature.

Other factors

- the higher the pressure, the more expensive the plant will be
- the higher the temperature the more fuel is needed

Other points

- unreacted gases are recycled**
- ammonia is removed as a liquid

Products

- ammonia can be **converted to nitric acid**
- nitric acid is used to make **dyes and explosives**
- nitric acid and ammonia produce **ammonium nitrate** - a **fertilizer**

Fertilizers

- nitrates encourage leaf and grass growth
- water supplies can become contaminated by fertilizers
- nitrates encourage algae growth which leads to de-oxygenation of streams and reduction in wildlife - eutrophication

Nitrogen**oxides NO_x**

- nitrogen forms several oxides, including

| | |
|-----------------------|--------------------------------|
| NO | nitric oxide |
| N₂O | nitrous oxide - 'laughing gas' |
| NO₂ | nitrogen dioxide |
- many are **formed during the burning of fossil fuels**
- high temperature processes allow nitrogen to combine with oxygen
- nitrogen oxides encourage **photochemical smog** and **breathing problems**
- major pollutants from car exhausts
- removed using catalytic converters

Catalytic converters

In the catalytic converter ...

CO is converted to CO₂NO_x are converted to N₂unburnt hydrocarbons to CO₂ and H₂O

- catalysts are made of finely divided rare metals such as palladium, rhodium, platinum
- leaded petrol must not pass through the catalyst as the lead deposits on the catalyst's surface and "poisons" it, thus blocking sites for reactions to take place.

ACID RAIN*Origin*

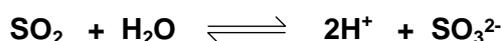
Rain has always been acidic due to the presence of dissolved nitrogen oxides formed when oxygen and nitrogen combine during lightning storms.

Fuels

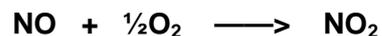
The burning of fossil fuels has made the problem of acid rain much worse. Fossil fuels contain sulphur and its compounds which burn to produce sulphur dioxide

*Reactions*

Sulphur dioxide dissolves in water to produce a **weak acid** (*sulphurous acid*)



Nitrogen oxides catalyses the oxidation of sulphur dioxide to sulphur(VI) oxide



Sulphur(VI) oxide dissolves in water to produce a **strong acid** (*sulphuric acid*)

*Effects*

- erosion of rocks
- damage to stone buildings
- increasing acidity in rivers and lakes
- de-forestation

SULPHUR DIOXIDE

General

- simple covalent molecule
- angular in shape - repulsion between 2 lone pairs and 2 double bond pairs
- sulphur is in oxidation state +4
- reducing agent
- dissolves in water to produce a weak acidic solution

Effects

- Good**
- food preservative - dried fruit includes sulphur dioxide in its packaging
 - decontaminant - 'disinfects' glass vessels in home brewing
- Bad**
- pollutant
 - major source of acid rain
 - causes breathing disorders

SULPHURIC ACID

Contact Process

Sulphuric acid is prepared industrially by the Haber Process



Typical conditions

| | |
|-------------|--|
| Pressure | Just over 100 kPa (1 atmosphere) |
| Temperature | 550°C |
| Catalyst | V_2O_5 vanadium(V) oxide |

All the reasons for using the above are the same as in the Haber Process

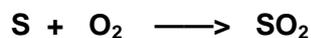
Compromise conditions

The conditions used are a **compromise** with the catalyst enabling the rate to be kept up, even at a lower temperature.

- NB** The **pressure is not high** as any increase in yield isn't justified by the expense of stronger reaction vessels and creating the high pressure. A large increase in pressure had little effect on the yield.

Other points

- sulphur dioxide is produced by burning sulphur or sulphur compounds



- unreacted gases are recycled
- sulphur trioxide is absorbed by conc sulphuric acid then diluted



Uses of H_2SO_4

making fertilisers
 making detergents
 paper industry
 electrolysis
 making paints