

Nitrogen & Sulfur

A-Level Chemistry ■ Topic 12

A-Level Chemistry



What we will cover

- 1 Why nitrogen is unreactive
- 2 Ammonia & the ammonium ion
- 3 Oxides of nitrogen
- 4 Smog & acid rain



nitrogen oxides cause smog



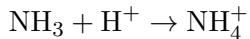
Why nitrogen is unreactive

The molecule also has no **polarity** – it is perfectly symmetrical, so nothing pulls other molecules towards it. N_2 has a **triple bond** (bond energy $\approx 945 \text{ kJ mol}^{-1}$) and a non-polar molecule. Breaking $\text{N}\equiv\text{N}$ needs a lot of energy, so nitrogen is inert at room temperature.

The Haber process forces it: high T , high p , and an iron catalyst.

Ammonia and the ammonium ion

NH_3 is a weak base: the nitrogen lone pair accepts H^+ to give the **ammonium** ion NH_4^+ .



Test: damp red litmus turns blue. With HCl you get white NH_4Cl smoke.

Displacement of ammonia from its salts

The reaction

Warm any ammonium salt with a strong alkali (NaOH) and **displacement** occurs: $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$.

The test

Ammonia gas turns damp red litmus **blue** – the standard test for an ammonium salt.

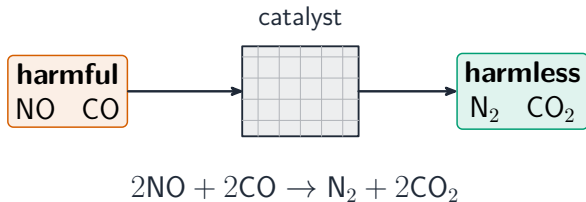
Why it works

The alkali is a stronger base than water, so it takes the proton back off the ammonium ion.

Warm, alkali, damp red litmus. Three words that identify NH_4^+ in any qualitative-analysis question.



Oxides of nitrogen



NO_x comes from lightning and hot **engines** ($\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$).

A **catalytic converter** lets them react away: $2\text{NO} + 2\text{CO} \rightarrow \text{N}_2 + 2\text{CO}_2$.

Where they come from

Oxides of nitrogen (NO and NO₂, together called NO_x) come from two sources:

- **natural**: lightning gives enough energy for nitrogen and oxygen in the air to combine.
- **man-made**: the high temperature inside an **internal combustion engine** makes nitrogen and oxygen react:

Removing them from car exhaust

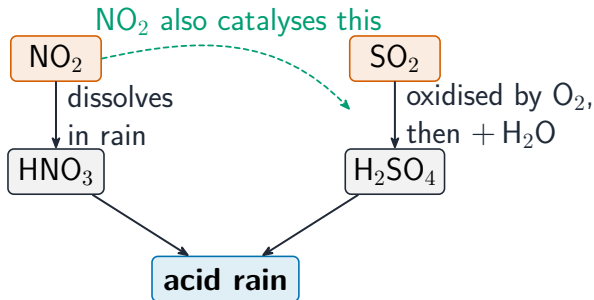
A **catalytic converter** cleans the **exhaust gases** .

It lets the harmful gases react together to form harmless ones:

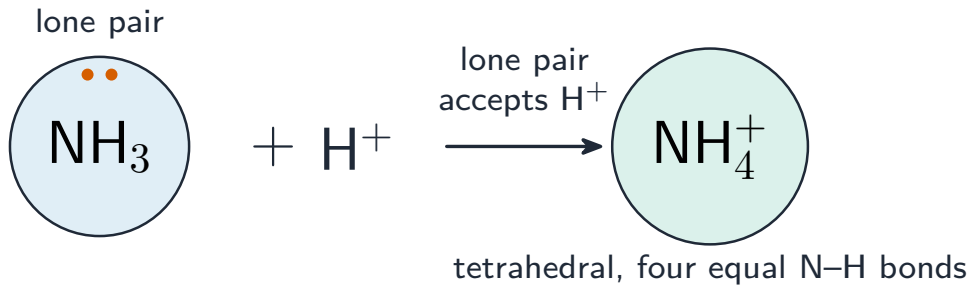
Smog and acid rain

NO_2 also acts as a *catalyst*: it speeds the oxidation of atmospheric **sulfur dioxide** to SO_3 , which becomes sulfuric acid in the rain.

- NO_x + hydrocarbons in sunlight → **photochemical smog**
- NO_2 forms nitric acid & catalyses $\text{SO}_2 \rightarrow \text{SO}_3 \rightarrow$ **acid rain**



Basicity of ammonia



Ammonia acts as a base because the lone pair on its nitrogen accepts a proton, making the ammonium ion

Ammonia and the ammonium ion, continued



Ammonia is converted into nitrogen fertilisers in industrial plants on a huge scale.

Why nitrogen is unreactive, continued



strong triple bond: very high
bond energy $\Rightarrow$ hard to break

symmetrical molecule $\Rightarrow$ no polarity $\Rightarrow$ nothing pulls it into a reaction

Nitrogen is unreactive for two reasons: a very strong triple bond, and a symmetrical, non-polar molecule

Photochemical smog



Photochemical smog over a big city. The brown layer is trapped low down, exactly where the traffic fumes are – sunlight turns those nitrogen oxides and unburned hydrocarbons into the haze you can see

Exam tips

- N_2 is unreactive because of its **strong triple bond** (very high bond energy) – state this exactly.
- **Ammonia** is a base and a ligand because of its **lone pair**; the ammonium ion forms by a dative bond.
- Explain how **oxides of nitrogen** form (high temperature in engines) and their link to acid rain and photochemical smog.
- Give balanced equations and correct observations for reactions of ammonia and the ammonium ion.



Worked example – the lone pair on nitrogen

Explain why ammonia acts as a base, and why NO from a car engine is a pollutant.

- N in NH_3 has a **lone pair**, so it accepts a proton: $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$.
- The lone pair forms a **dative bond** to H^+ – that is what a Brønsted base does.
- In an engine the spark is hot enough for $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$.
- NO oxidises to NO_2 , which **catalyses acid rain** and makes photochemical smog.

The lone pair is the whole story: it makes NH_3 a **base**, a **ligand** and a **nu-cleophile** – one feature, three exam topics.

Topic 12 – key takeaways

1

Nitrogen

strong triple bond; non-polar;
unreactive

2

Ammonia

lone pair accepts H^+ ; coordinate
bond

3

NO_x

from engines; cleaned by catalytic
converters

4

Pollution

photochemical smog & acid rain

Check yourself

- 1 Why is N_2 so unreactive?
- 2 What kind of bond forms when NH_3 gains H^+ ?
- 3 What does a catalytic converter turn NO and CO into?
- 4 Name a pollution problem caused by NO_x .



Answers 1. strong triple bond & non-polar 2. a coordinate bond 3. N_2 and CO_2
4. smog / acid rain