

Nitrogen & Sulfur

A-Level Chemistry • Topic 12

A-Level Chemistry



Nitrogen & Sulfur

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

1 Nitrogen

Nitrogen & Sulfur

↳ Nitrogen

Why nitrogen is unreactive

The molecule also has no **polarity** 极性 – it is perfectly symmetrical, so nothing pulls other molecules towards it.

N₂ has a **triple bond** (bond energy $\approx 945 \text{ kJ mol}^{-1}$) and a non-polar molecule. Breaking N $\equiv$ N needs a lot of energy, so nitrogen is inert at room temperature.

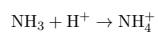
The Haber process forces it: high *T*, high *p*, and an iron catalyst.

Nitrogen & Sulfur

↳ Nitrogen

Ammonia and the ammonium ion

NH₃ is a weak base: the nitrogen lone pair accepts H⁺ to give the **ammonium** 铵 ion NH₄⁺.



Test: damp red litmus turns blue. With HCl you get white NH₄Cl smoke.

Nitrogen & Sulfur

↳ Nitrogen

Displacement of ammonia from its salts

The reaction

Warm any ammonium salt with a strong alkali (NaOH) and **displacement** 置换 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

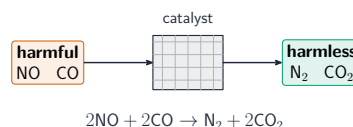
The alkali is a stronger base than water, so it takes the proton back off the ammonium ion.

Warm, alkali, damp red litmus. Three words that identify NH₄⁺ in any qualitative-analysis question.

2 Pollution

Nitrogen & Sulfur
└ Pollution

Oxides of nitrogen



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

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

Nitrogen & Sulfur
└ Pollution

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** 内燃机 makes nitrogen and oxygen react:

Nitrogen & Sulfur
└ Pollution

Removing them from car exhaust

A **catalytic converter** 催化转化器 cleans the **exhaust gases** 尾气.

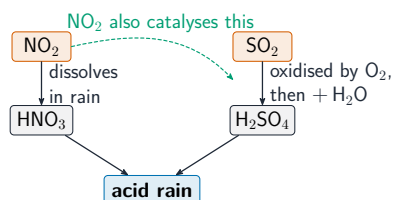
It lets the harmful gases react together to form harmless ones:

Nitrogen & Sulfur
└ Pollution

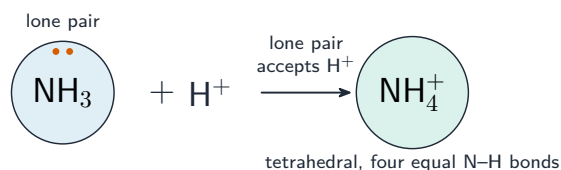
Smog and acid rain

NO₂ also acts as a *catalyst*: it speeds the oxidation of atmospheric **sulfur dioxide** 二氧化硫 to SO₃, which becomes sulfuric acid in the rain.

- NO_x + hydrocarbons in sunlight → **photochemical smog** 光化学烟雾
- NO₂ forms nitric acid & catalyses SO₂ → SO₃ → **acid rain** 酸雨



Basicity of ammonia



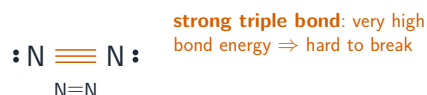
Ammonia acts as a base because the lone pair on its nitrogen accepts a proton, making the ammonium ion

Ammonia and the ammonium ion, continued



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

Why nitrogen is unreactive, continued



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.

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Recap

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** 配位鍵 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 **nucleophile** – one feature, three exam topics.

Topic 12 – key takeaways

1 Nitrogen

strong triple bond; non-polar;
unreactive

3 NO_x

from engines; cleaned by catalytic
converters

2 Ammonia

lone pair accepts H⁺; coordinate
bond

4 Pollution

photochemical smog & acid rain

Check yourself

- 1 Why is N₂ so unreactive?
- 2 What kind of bond forms when NH₃ 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. N₂ and CO₂
4. smog / acid rain