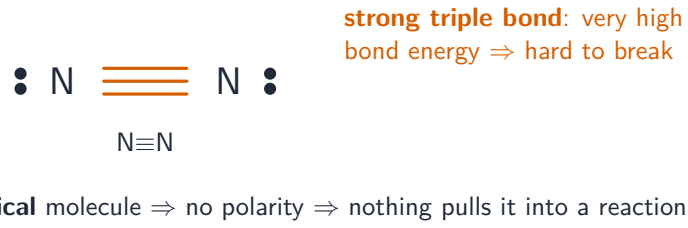
Nitrogen and sulfur

A-Level Chemistry

Why nitrogen is unreactive

Nitrogen gas, N_2, makes up most of the air but reacts with very little. There are two reasons:

- the two nitrogen atoms are joined by a **triple bond** 三键, which has a very high **bond energy** 键能. A lot of energy is needed to break it.
- the molecule has no **polarity** 极性—it is perfectly symmetrical, so nothing pulls other molecules towards it.



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

Ammonia and the ammonium ion

Ammonia is converted into nitrogen fertilisers on a huge scale.

Basicity of ammonia

The **basicity** 碱性 of ammonia (its ability to act as a base) comes from the **lone pair** 孤对电子 of electrons on the nitrogen atom. Using the Brønsted–Lowry theory, ammonia

is a base because this lone pair can accept a **proton** 质子 (H^+):

$$NH_3 + H^+ \rightarrow NH_4^+$$

The ammonium ion

When the lone pair forms a bond to H^+, it makes the **ammonium ion** 铵离子, NH_4^+. Because both shared electrons came from the nitrogen, this new bond is a **coordinate bond** 配位键. The ion has four identical N–H bonds and a tetrahedral shape.

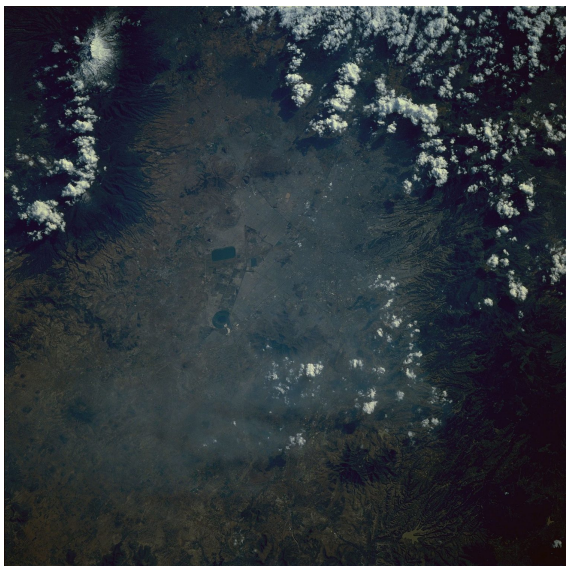
Displacement of ammonia from its salts

If you warm an ammonium salt with a base (such as sodium hydroxide), you push out ammonia gas. This is an acid–base **displacement** 置换:

$$NH_4Cl + NaOH \rightarrow NaCl + NH_3 + H_2O$$

The sharp smell of ammonia, and damp red litmus turning blue, is a test for an ammonium salt.

Oxides of nitrogen and air pollution



Oxides of nitrogen and sulfur contribute to smog and air pollution.

Image: NASA, Public domain (commons.wikimedia.org)

Where they come from

Oxides of nitrogen (NO and NO_2, together called NO_x) come from two sources:

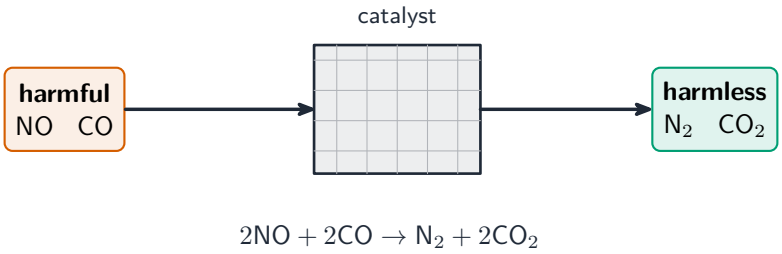
- **natural**: lightning gives enough energy for nitrogen and oxygen in the air to combine.
- **man-made**: the high temperature inside an **internal combustion engine** 内燃机 makes nitrogen and oxygen react:

$$N_2 + O_2 \rightarrow 2NO$$

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:

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



In a catalytic converter the harmful gases NO and CO react over the catalyst to form harmless N_2 and CO_2

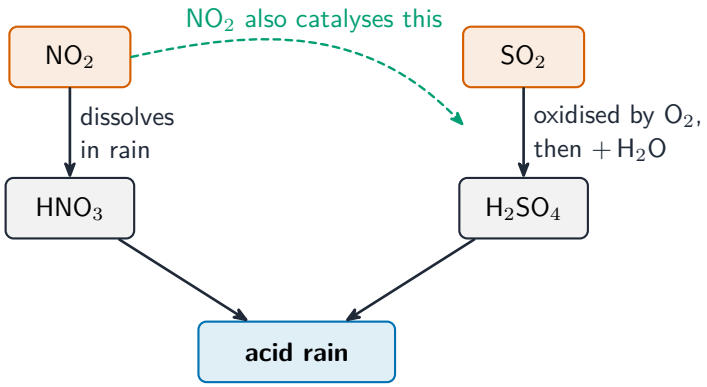
Photochemical smog

In sunlight, NO and NO_2 react with unburned **hydrocarbons** to form peroxyacetyl nitrate (PAN). PAN is a harmful part of **photochemical smog** 光化学烟雾, the brown haze seen over busy cities.

Acid rain

The oxides of nitrogen also help make **acid rain** 酸雨 in two ways:

- directly: NO_2 dissolves in rain to form nitric acid.
- as a catalyst: NO_2 speeds up the oxidation of atmospheric **sulfur dioxide** 二氧化硫 (SO_2) into SO_3, which then forms sulfuric acid in the rain.



Nitrogen and sulfur oxides make acid rain: NO_2 forms nitric acid directly and also catalyses the oxidation of SO_2 to sulfuric acid