

Nitrogen and sulfur

A-Level Chemistry 9701 · Topic 12 revision notes

Everything from the 3 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Nitrogen, ammonia and the ammonium ion
2. Nitrogen oxides and pollution
3. Sulfur dioxide and acid rain

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1 Nitrogen, ammonia and the ammonium ion

Syllabus 12.1

Nitrogen is unreactive because the **$\text{N}\equiv\text{N}$ triple bond is very strong** (944 kJ mol^{-1}) and the molecule is **non-polar**, so it does not attract electrophiles or nucleophiles. Ammonia is a **Brønsted-Lowry base**: the lone pair on nitrogen accepts a proton, forming the ammonium ion, NH_4^+ , by a dative bond. NH_3 is pyramidal (107°) and NH_4^+ tetrahedral (109.5°). Ammonium salts react with warm alkali to release ammonia, which turns damp red litmus blue. Ammonium salts are used as **fertilisers**; their value depends on the percentage of nitrogen by mass.

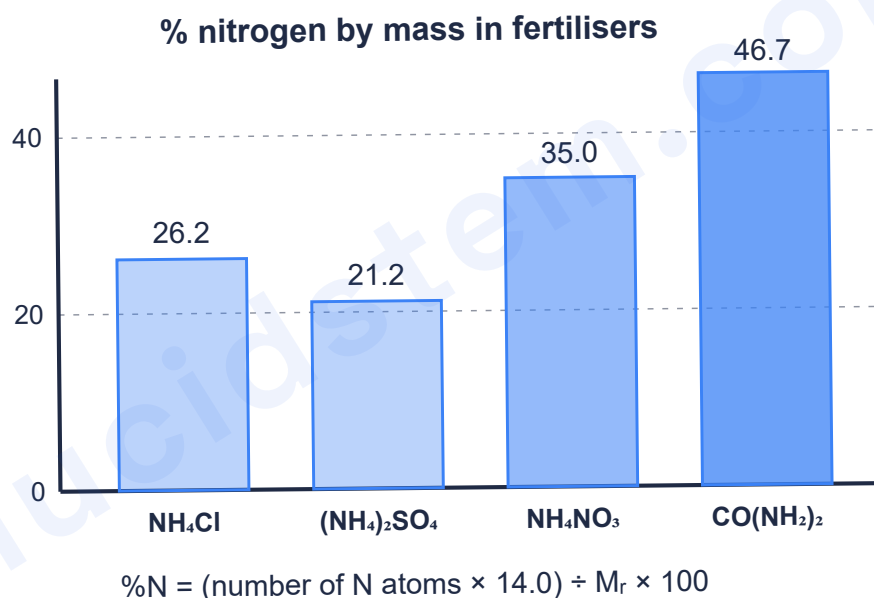


Fig. 1: percentage of nitrogen by mass in common nitrogen fertilisers

Lone pair accepts the proton.

- ✓ **N_2 inert:** strong triple bond, non-polar.
- ✓ **NH_3** pyramidal 107° ; **NH_4^+** tetrahedral 109.5° .
- ✓ **$\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$** ; red litmus blue.
- ✓ **%N:** count every N atom.

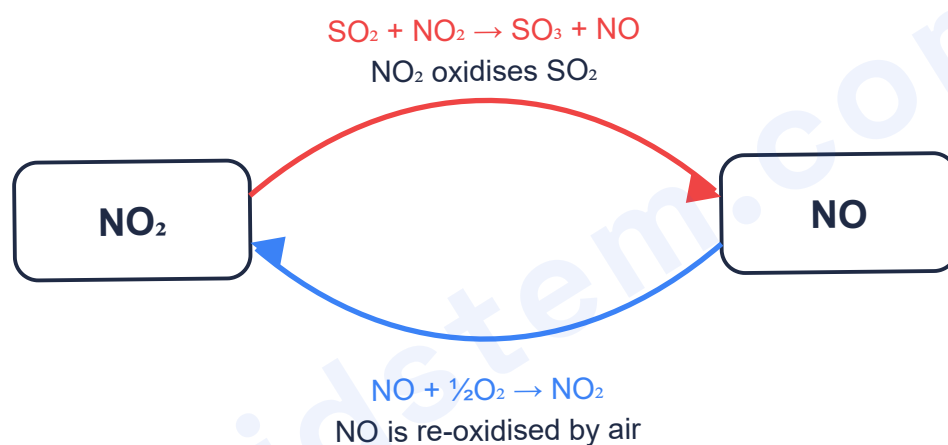
Watch out!

Nitrogen is unreactive because of its **strong triple bond and lack of polarity**, not because it is small or a gas. When calculating percentage of nitrogen, count **every** nitrogen atom: NH_4NO_3 has two, $(\text{NH}_4)_2\text{SO}_4$ has two, urea has two.

2 Nitrogen oxides and pollution

Syllabus 12.1

At the very high temperatures inside an engine (or in lightning), nitrogen and oxygen react: $N_2 + O_2 \rightarrow 2NO$. In air NO is oxidised to NO_2 . **Catalytic converters** remove NO and CO together: $2CO + 2NO \rightarrow 2CO_2 + N_2$. In the atmosphere NO_2 acts as a **catalyst** for the oxidation of SO_2 to SO_3 , and NO_2 also forms nitric acid, so both add to **acid rain**. NO and unburnt hydrocarbons in sunlight form **photochemical smog** containing peroxyacetyl nitrate (PAN). Nitrate fertilisers washed into water cause **eutrophication**.



NO_2 is regenerated: it catalyses the formation of SO_3 (and acid rain)

Fig. 1: NO_2 catalyses the oxidation of SO_2 and is regenerated

Made hot, removed by catalysts, regenerated in air.

- ✓ **Engine:** $N_2 + O_2 \rightarrow 2NO$.
- ✓ **Converter:** $2CO + 2NO \rightarrow 2CO_2 + N_2$.
- ✓ **NO_2** catalyses $SO_2 \rightarrow SO_3$.
- ✓ **Eutrophication:** algae bloom, decay, oxygen loss.

Watch out!

In the oxidation of SO_2 , NO_2 is a **catalyst**: it is used in the first step and regenerated in the second, so it is not used up overall. A catalytic converter removes CO, NO and hydrocarbons; it produces CO_2 , it does not remove it.

3 Sulfur dioxide and acid rain

Syllabus 12.2

Fossil fuels contain sulfur, which burns to **sulfur dioxide** (S +4). In the air SO_2 is oxidised to SO_3 (S +6), helped by the NO_2 catalyst, and dissolves in rain to form sulfuric acid, a major cause of **acid rain**. Acid rain damages limestone buildings, lakes, fish and trees. SO_2 can be removed from power-station flue gases by reacting it with calcium carbonate or calcium oxide. In small amounts SO_2 is a **food preservative**, because it is an antioxidant and kills bacteria. Industrially, SO_2 is converted to SO_3 in the **Contact process** to make sulfuric acid.

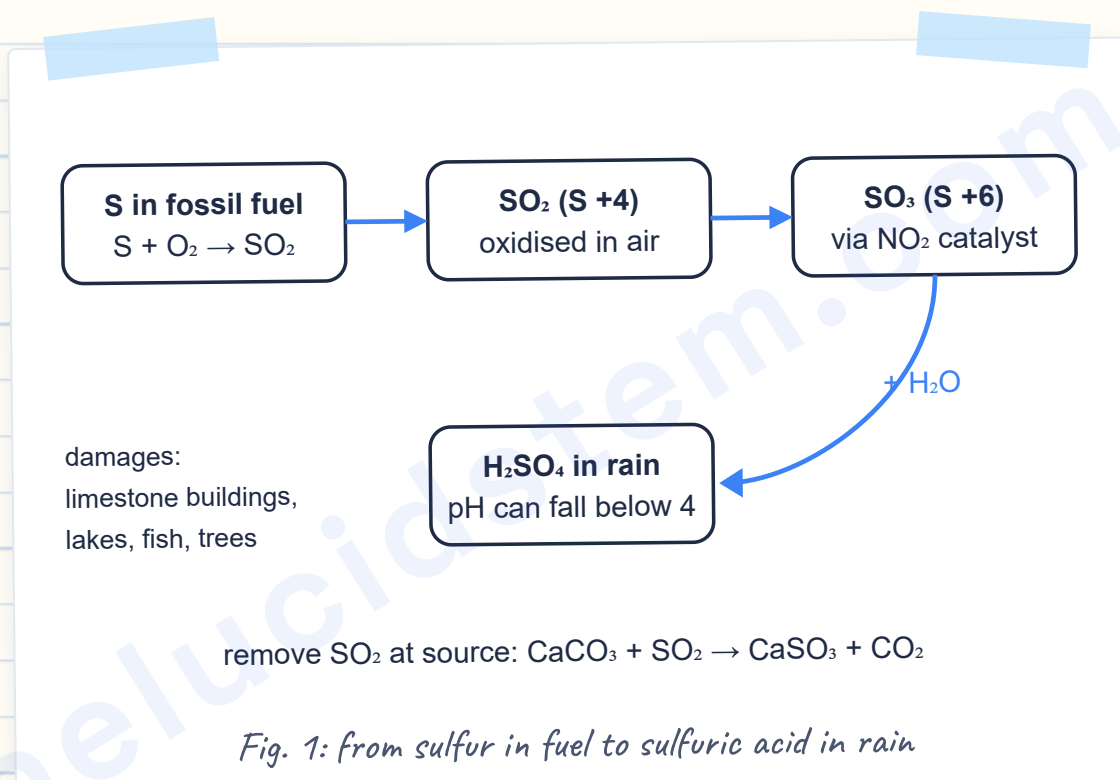


Fig. 1: from sulfur in fuel to sulfuric acid in rain

+4 in SO_2 , +6 in SO_3 and H_2SO_4

- ✓ **Source:** sulfur in fossil fuels.
- ✓ **Acid rain:** $\text{SO}_2 \rightarrow \text{SO}_3 \rightarrow \text{H}_2\text{SO}_4$.
- ✓ **Remove:** $\text{CaCO}_3 + \text{SO}_2 \rightarrow \text{CaSO}_3 + \text{CO}_2$.
- ✓ **Contact:** V_2O_5 , 450 °C, 1 to 2 atm.

Watch out!

Acid rain is caused by **sulfur and nitrogen oxides**, not by carbon dioxide; rain is naturally slightly acidic (about pH 5.6) from dissolved CO_2 , but SO_2 and NO_2 push it much lower. Remember the oxidation number of sulfur: +4 in SO_2 and H_2SO_3 , +6 in SO_3 and H_2SO_4 .