Exercise walk-through

Nitrogen and sulfur ▪ 12.1

eXercise

You must be able to

- explain the lack of reactivity of nitrogen
- explain the basicity of ammonia and the formation of the ammonium ion
- describe the sources, catalytic removal, and role in acid rain of nitrogen oxides

Method — Unreactive nitrogen

N≡N

strong triple bond: very high bond energy ⇒ hard to break

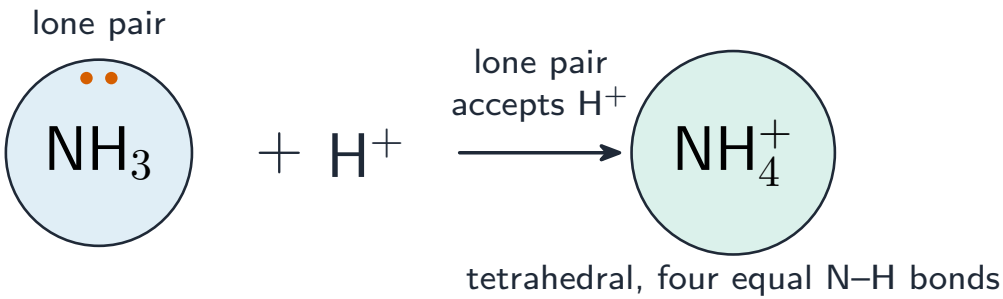
symmetrical molecule ⇒ no polarity ⇒ nothing pulls it into a reaction

Two nitrogen atoms joined by a triple bond, a strong, non-polar molecule

Method — Ammonia as a base

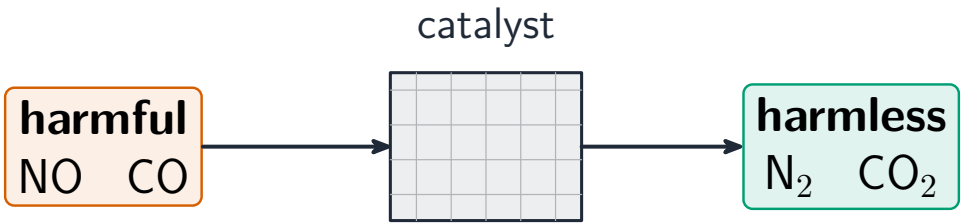
The new N–H bond is a **coordinate bond** (both electrons from N). Warming an ammonium salt with a base displaces ammonia: $NH_4Cl + NaOH \rightarrow NaCl + NH_3 + H_2O$.

Method — Ammonia as a base



Ammonia's lone pair accepting a proton to form the tetrahedral ammonium ion

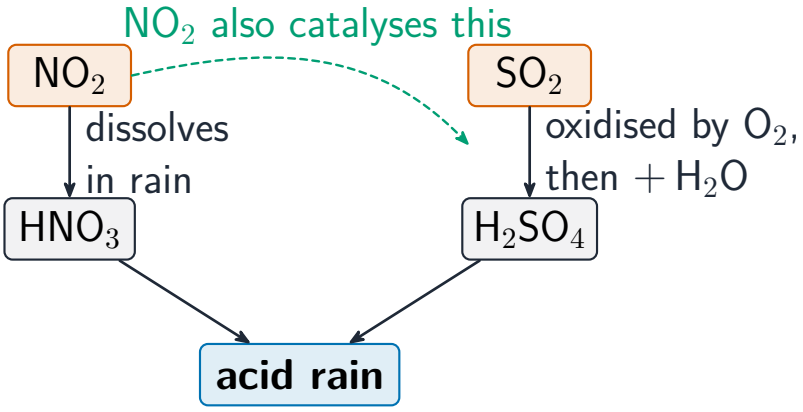
Method — Nitrogen oxides and acid rain



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

NO and CO reacting over a catalyst to form harmless N and CO

Method — Nitrogen oxides and acid rain



NO forming nitric acid and catalysing SO → SO → sulfuric acid

Practice 2.1 ▪ 2 marks

State **two** reasons why nitrogen gas is unreactive.

Solution 2.1

Method: Unreactive nitrogen

Worked steps

the N≡N triple bond is very strong (high bond energy) B1; the molecule is non-polar / symmetrical B1.

Practice 2.2 ▪ 1 mark

Write the equation for ammonia acting as a base towards H .

Solution 2.2

Method: Ammonia as a base

Worked steps

$NH_3 + H^+ \rightarrow NH_4^+$ B1.

Exam-style 3.1 ▪ 1 mark

Ammonia acts as a Brønsted–Lowry base because:

A it donates a proton

B the lone pair on nitrogen accepts a proton

C it is a gas

D it contains hydrogen

Solution 3.1

Method: Ammonia as a base

A it donates a proton

B the lone pair on nitrogen accepts a proton ✓

C it is a gas

D it contains hydrogen

Worked steps

B. The lone pair on nitrogen accepts a proton.

Exam-style 3.2 ▪ 1 mark

In a catalytic converter, nitrogen monoxide is removed by reacting with:

A oxygen

B carbon monoxide

C water

D sulfur dioxide

Solution 3.2

Method: Nitrogen oxides and acid rain

A oxygen

B carbon monoxide ✓

C water

D sulfur dioxide

Worked steps

B. $2\mathrm{NO} + 2\mathrm{CO} \rightarrow \mathrm{N_2} + 2\mathrm{CO_2}$.

Exam-style 3.3 ▪ 2 marks

(a) Describe how nitrogen monoxide is formed inside a car engine, and write an equation.
(b) Explain the **two** ways that oxides of nitrogen contribute to acid rain.

Solution 3.3

Method: Nitrogen oxides and acid rain

Worked steps

(a) the high temperature in the engine makes nitrogen and oxygen from the air react M1; $N_2 + O_2 \rightarrow 2NO$ A1.

(b) directly: NO dissolves in rain to form nitric acid M1; as a catalyst: NO catalyses the oxidation of SO to SO M1, which forms sulfuric acid in the rain A1.

Exam-style 3.4 ▪ 2 marks

Describe a chemical test for an ammonium salt.

Solution 3.4

Method: Ammonia as a base

Worked steps

warm the salt with sodium hydroxide M1; ammonia gas is given off — sharp smell and damp red litmus turns blue A1.