Unit-16

Hydrogen, Nitrogen and Ammonia

INTRODUCTION TO HYDROGEN

- Hydrogen is first element in the periodic table.
- Its symbol is H and atomic number is 1.
- It’s a diatomic molecule (H_2).
- It’s abundant in universe, but not in the earth’s atmosphere.
- It is separate in the periodic table and doesn’t belong to any other group.
- It behaves like Alkali metals as well as Halogens, but doesn’t belong to both category.

The properties of hydrogen

1 It is the lightest of all gases – about 20 times lighter than air.

2 It is colourless, with no smell.

3 It combines with oxygen to form water.

$$2H_2\,(g) + O_2\,(g) \longrightarrow 2H_2O\,(l)$$

4 Hydrogen is more reactive than copper.

So it will take oxygen from copper(II) oxide, reducing it to copper.

The hydrogen is itself oxidised:

$$CuO\,(s) + H_2\,(g) \longrightarrow Cu\,(s) + H_2O\,(l)$$

INTRODUCTION TO NITROGEN

- Nitrogen is seventh element in the periodic table.
- Its symbol is N and atomic number is 7.
- It’s a diatomic molecule (N_2).
- It’s abundant in earth’s atmosphere, as 78% of air is Nitrogen.
- It belongs to V group in periodic table.
- It is a non metal.

The properties of nitrogen

1 It is a colourless gas, with no smell.

2 It is only slightly soluble in water.

3 It is very unreactive compared with oxygen.

4 It reacts with hydrogen to form ammonia:

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

5 Nitrogen also combines with oxygen at high temperature to form oxides: nitrogen monoxide (NO) and nitrogen dioxide (NO_2).

INTRODUCTION TO AMMONIA

- Ammonia is a chemical consisting of one atom of Nitrogen and 3 atoms of Hydrogen.
- Its chemical formula is NH_3.
- It’s a colourless gas with strong pungent smell.
- It’s lighter than air.

The properties of ammonia

1 It is a colourless gas with a strong, choking smell.
2 It is less dense than air.
3 It reacts with hydrogen chloride gas to form a white smoke.
The smoke is made of tiny particles of solid ammonium chloride:

$$NH_3\,(g) + HCl\,(g) \longrightarrow NH_4Cl\,(s)$$

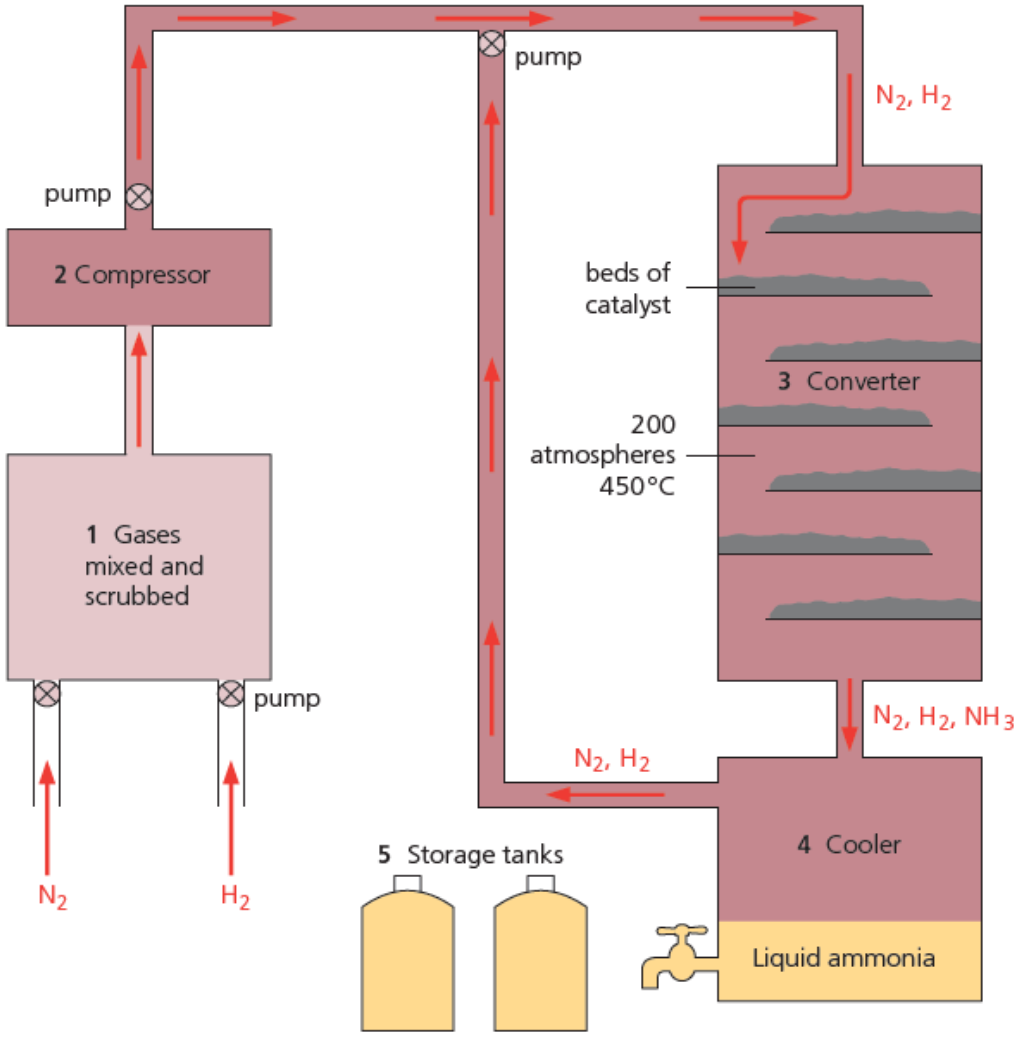
4 It is very soluble in water.
5 The solution in water is alkaline – it turns red litmus blue.
6 Since ammonia solution is alkaline, it reacts with acids to form salts.
For example with nitric acid it forms ammonium nitrate:

$$NH_3\,(aq) + HNO_3\,(aq) \longrightarrow NH_4NO_3\,(aq)$$

Manufacturing of Ammonia

The Haber process

The process used to make ammonia is called the **Haber process**.



HABER PROCESS

1. The reactants are nitrogen and hydrogen. The nitrogen is obtained from air, and the hydrogen by reacting natural gas (methane) with steam, or by cracking hydrocarbons. See the details on the right. The two gases are mixed, and **scrubbed** (cleaned) to remove impurities.
2. The gas mixture is **compressed**. More and more gas is pumped in, until the pressure reaches 200 atmospheres.
3. The compressed gas flows to the **converter** – a round tank with beds of hot iron at 450 °C. The iron catalyses the reversible reaction. But only 15% of the mixture leaving the converter is ammonia.

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

4. The mixture is cooled until the ammonia condenses to a liquid. The nitrogen and hydrogen are recycled to the converter for another chance to react. Steps 3 and 4 are continually repeated.
5. The ammonia is run into tanks, and stored as a liquid under pressure.

Improving the yield of Ammonia

Making ammonia: a summary

$$N_2 + 3H_2 \underset{\text{endothermic}}{\overset{\text{exothermic}}{\rightleftharpoons}} 2NH_3$$

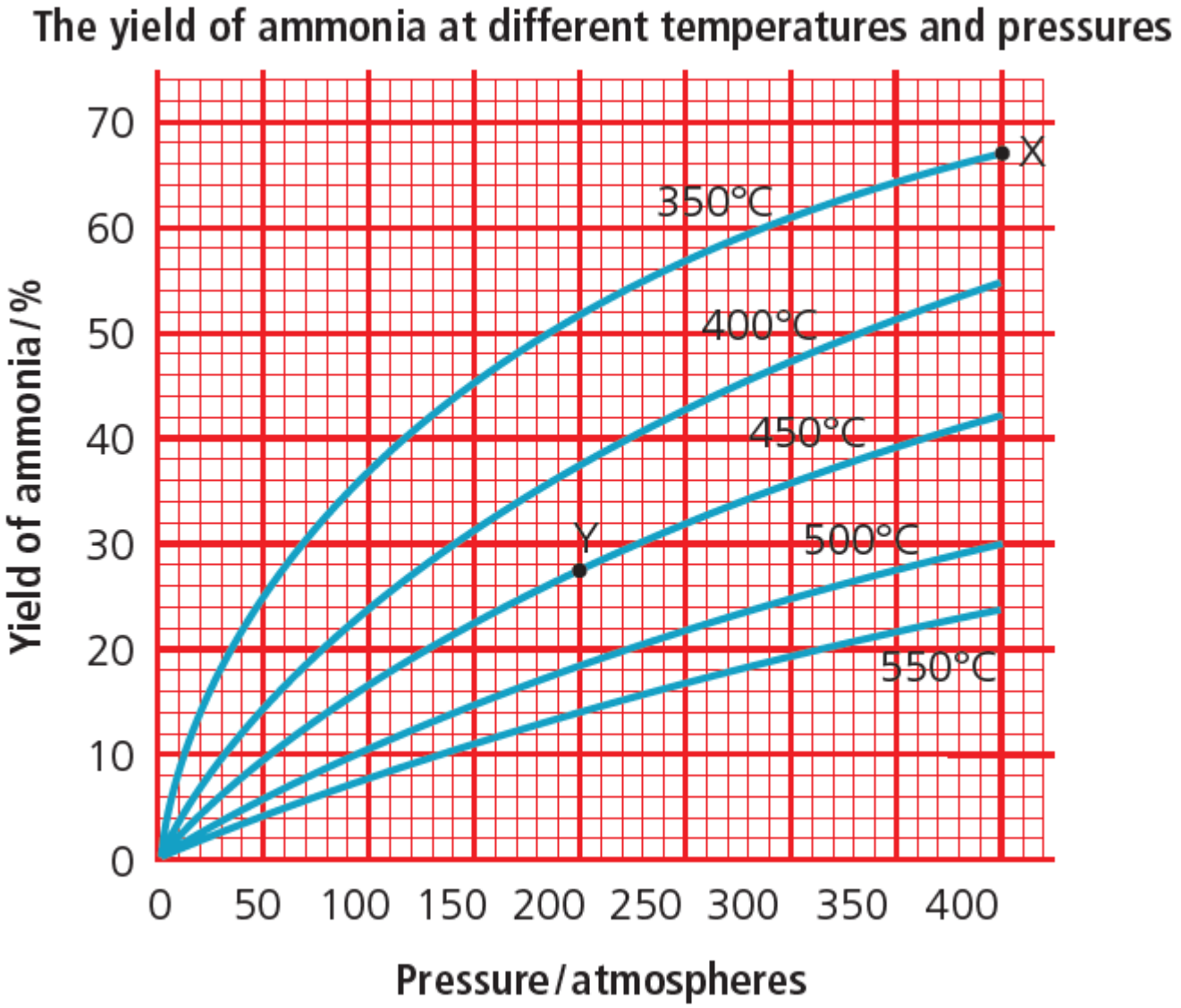
4 molecules 2 molecules

To improve the yield:

- quite high pressure
- remove ammonia

To get a decent reaction rate:

- moderate temperature
- use a catalyst



The chosen conditions

The temperature and pressure As you can see, the highest yield on the graph is at **X**, at 350 °C and 400 atmospheres.

But the Haber process uses 450 °C and 200 atmospheres, at **Y** on the graph. Why? Because at 350 °C, the reaction is too slow. 450 °C gives a better rate.

And second, a pressure of 400 atmospheres needs very powerful pumps, and very strong and sturdy pipes and tanks, and a lot of electricity. 200 atmospheres is safer, and saves money.

So the conditions inside the converter do not give a high yield. But then the ammonia is removed, so that more will form. And the unreacted gases are recycled, for another chance to react. So the final yield is high.

The catalyst Iron speeds up the reaction. But it does not change the yield!

FERTILISERS (NPK FERTILIZERS)

Every crop a farmer grows takes compounds from the soil. Some get replaced naturally. But in the end the soil gets worn out. New crops will not grow well. So the farmer has to add **fertilisers**.

A fertiliser is any substance added to the soil to make it more fertile.

Animal manure is a natural fertiliser. **Synthetic fertilisers** are made in factories, and sprinkled or sprayed on fields. Here are some examples.

ammonium nitrate, NH_4NO_3 ammonium sulfate, $(NH_4)_2SO_4$

potassium sulfate, K_2SO_4 ammonium phosphate, $(NH_4)_3PO_4$

Examples of reactions to make synthetic fertilisers

1 Ammonia reacts with nitric acid to give ammonium nitrate. This fertiliser is an excellent source of nitrogen:

$$\underset{\text{ammonia}}{NH_3\,(aq)} + \underset{\text{nitric acid}}{HNO_3\,(aq)} \longrightarrow \underset{\text{ammonium nitrate}}{NH_4NO_3\,(aq)}$$

2 Ammonia reacts with sulfuric acid to give ammonium sulfate:

$$\underset{\text{ammonia}}{2NH_3\,(aq)} + \underset{\text{sulfuric acid}}{H_2SO_4\,(aq)} \longrightarrow \underset{\text{ammonium sulfate}}{(NH_4)_2SO_4\,(aq)}$$