HABER PROCESS

What is ammonia?

Ammonia is an important compound in the manufacture of fertilizer and other chemicals such as cleaning fluids and floor waxes.

It is made industrially by reacting nitrogen with hydrogen in the **Haber process**. It is a reversible reaction, so it never goes to completion.

Why is this a problem for companies making ammonia?

nitrogen + hydrogen ⇌ ammonia

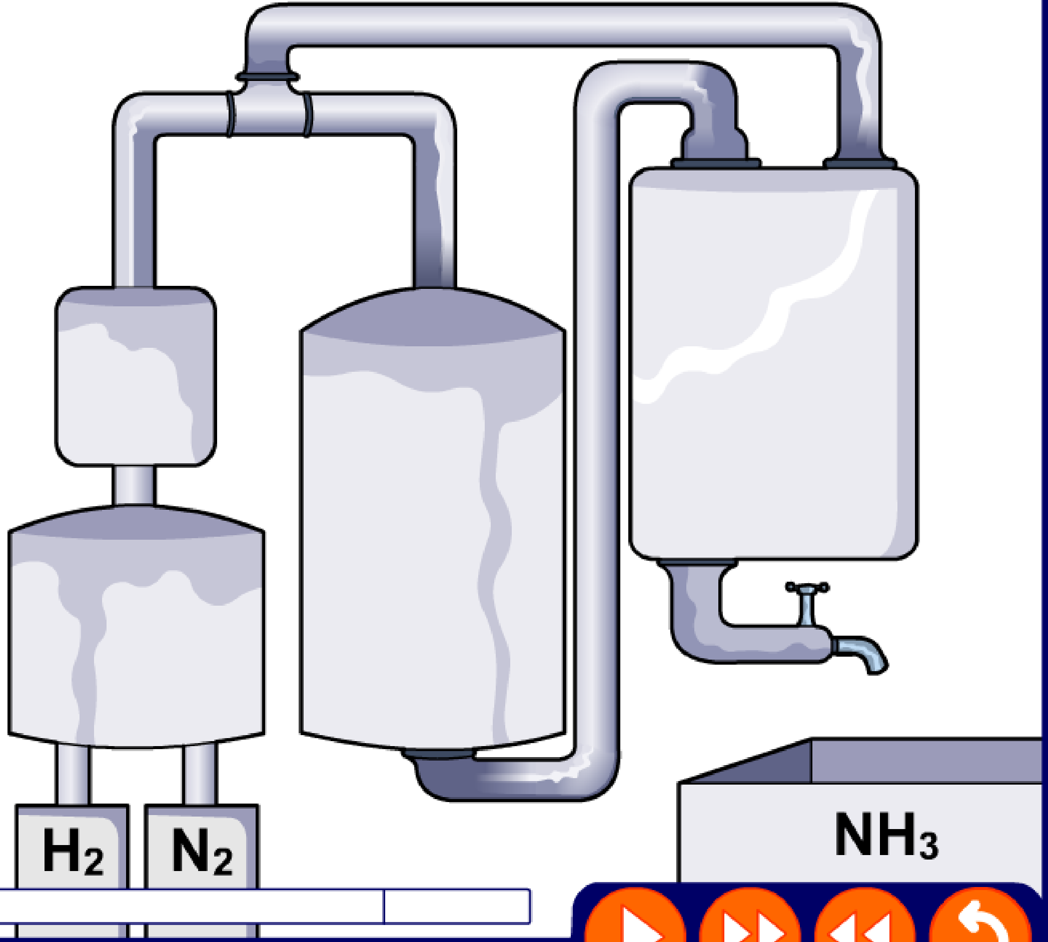
$$N_2 (g) + 3H_2 (g) \rightleftharpoons 2NH_3 (g)$$

The Haber process

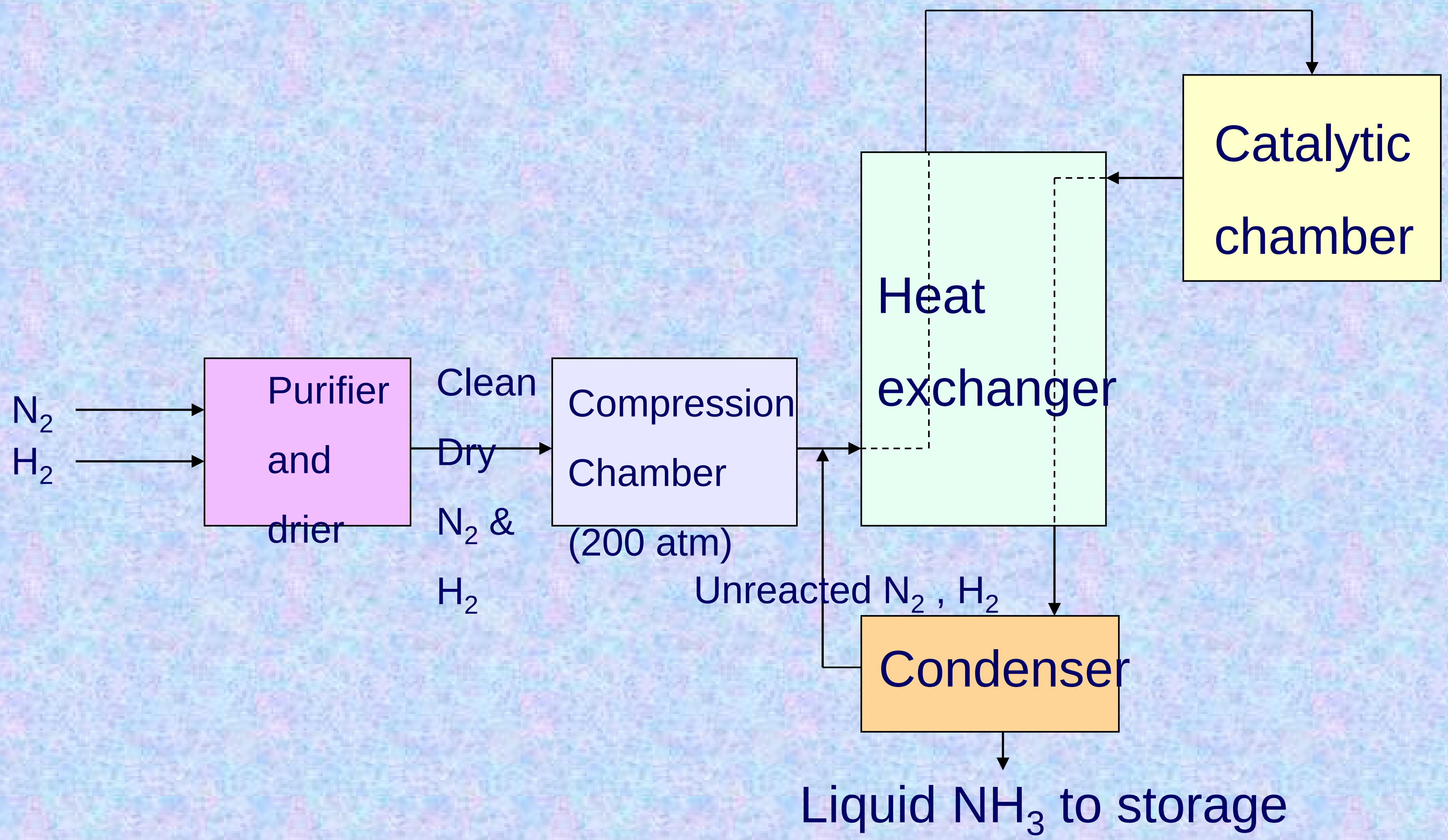
How is ammonia produced in the Haber process?

The Haber process is the industrial reaction used to make **ammonia** (NH_3) from **hydrogen** (H_2) and **nitrogen** (N_2).

Click "**play**" to find out what happens.



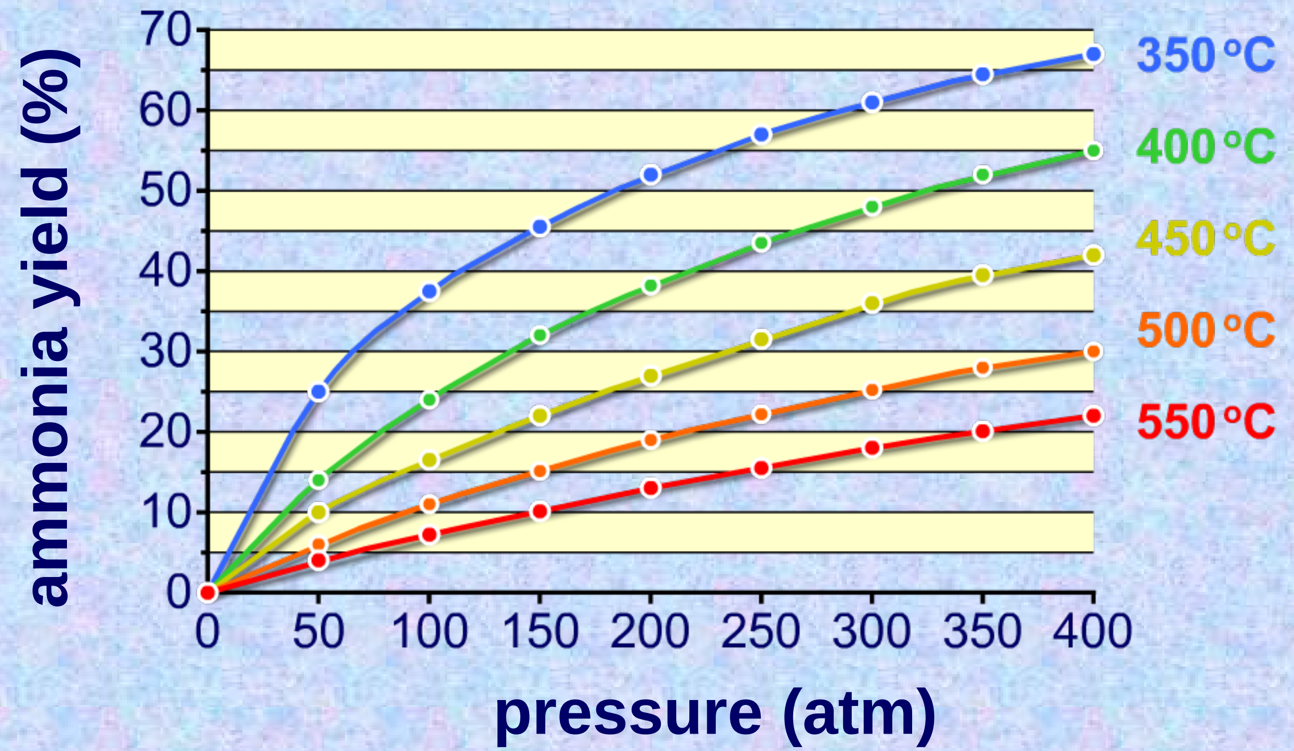
A flow diagram



What is yield?

The amount of product made in a reaction is called the **yield** and is usually expressed as a percentage.

The yield of ammonia produced by the Haber process depends on the **temperature** and **pressure** of the reaction.



What is the Haber compromise?

The highest yield of ammonia is theoretically produced by using a low temperature and a high pressure.

In practice, though, these conditions are not used. Why?

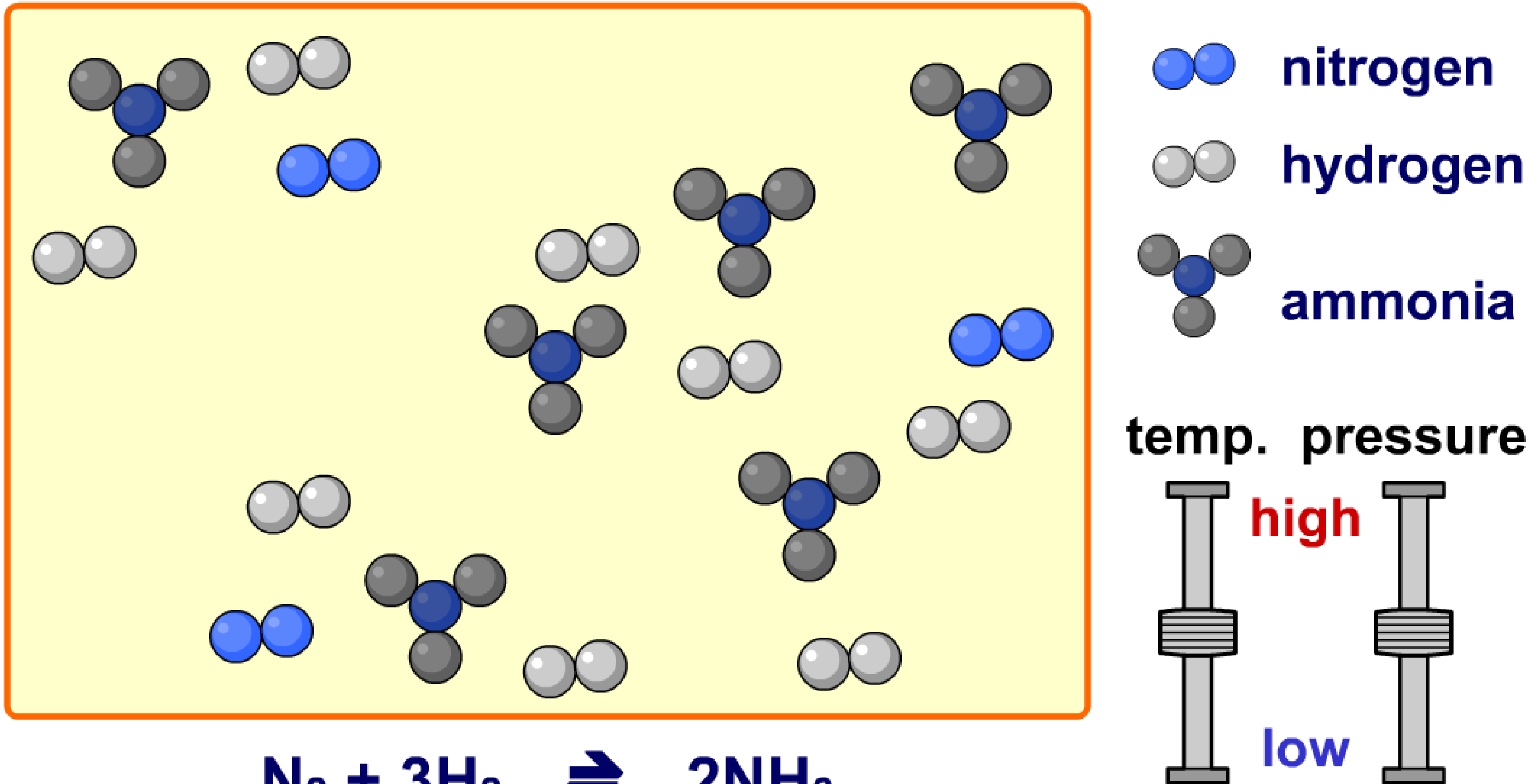
Lowering the temperature slows down the rate of reaction. This means it takes longer for ammonia to be produced.

Increasing the pressure means stronger, more expensive equipment is needed. This increases the cost of producing the ammonia.

A compromise is reached to make an acceptable yield in a reasonable timeframe while keeping costs down.

Temperature, pressure and yield

How do temperature and pressure affect the Haber process?



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HABER PROCESS

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Conditions	Pressure	20000 kPa (200 atmospheres)
	Temperature	380-450°C
	Catalyst	iron

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high temperature	**greater average energy + more frequent collisions**
high pressure	**more frequent collisions for gaseous molecules**
catalyst	**lower activation energy**

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Compromise conditions

Which is better? A low yield in a shorter time or
a high yield over a longer period.

The conditions used are a compromise with the catalyst enabling the rate to be kept up, even at a lower temperature.

HABER PROCESS

IMPORTANT USES OF AMMONIA AND ITS COMPOUNDS

MAKING FERTILISERS

80% of the ammonia produced goes to make fertilisers such as ammonium nitrate (NITRAM) and ammonium sulphate

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

MAKING NITRIC ACID

ammonia can be oxidised to nitric acid

nitric acid is used to manufacture...

- fertilisers (ammonium nitrate)
- explosives (TNT)
- polyamide polymers (NYLON)

The Haber compromise

To produce a high yield of ammonia, but with a fast rate of reaction and without the need for overly expensive equipment, the Haber process is carried out at **450 °C** and **200 atmospheres**.

The most important factor in deciding what conditions to use is therefore not yield, but **total cost**.

What costs are involved in the industrial production of ammonia?

- raw materials
- energy
- equipment
- wages

Maximizing productivity

What else can be done to maximise productivity in the manufacture of ammonia?

- An iron catalyst is used to increase the rate of reaction. It speeds up both the forward and backward reaction, so the position of equilibrium is not affected.
- The ammonia is cooled, liquefied and then removed as it is produced. This causes the equilibrium to shift to the right to produce more ammonia.
- Unreacted nitrogen and hydrogen are recycled and given another chance to react.

Stages of the Haber process

What is the order of stages in the Haber process?

1. Hydrogen is mixed with nitrogen, obtained from air.
2. The gases are heated to 450ºC.
3. Unreacted nitrogen and hydrogen are recycled.
4. The gases are passed over an iron catalyst.
5. The gases are compressed to 200 atmospheres.
6. Liquid ammonia is pumped off to be sold.
7. Steam is reacted with methane to make hydrogen.
8. Ammonia gas is produced, then cooled to a liquid.

? C solve

Glossary

- **closed system –** A system in which reactants and products cannot be added or removed once the reaction has begun.
- **dynamic –** An equilibrium in which the forward and backward reactions take place at the same rate, so no overall change takes place.
- **Haber process –** The industrial-scale process for making ammonia from nitrogen and hydrogen.
- **irreversible –** A reaction that is impossible or very difficult to reverse.
- **reversible –** A reaction in which the product(s) can be turned back into the reactants.
- **yield –** The amount of product obtained from a reaction, usually expressed as a percentage.