

Exercise walk-through

# 10.4

## The Haber process and NPK fertilisers – chemistry only (4.10.4.1–4.10.4.2)

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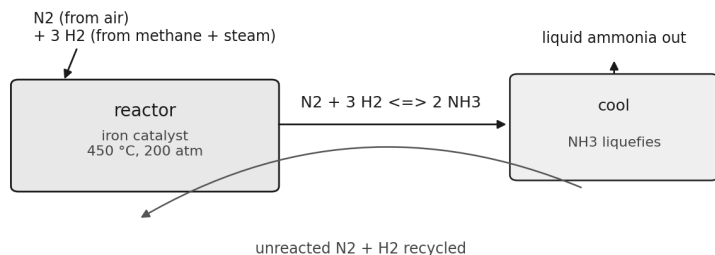
# Potable water



desalination alternative: distillation or reverse osmosis — high energy cost

- Potable — safe to drink, but not pure.
- UK — source, filter beds, sterilise with chlorine, ozone or UV.
- Desalination where fresh water runs short — at an energy price.

# The Haber process



- N<sub>2</sub> from air + H<sub>2</sub> from methane and steam — over iron, 450 °C, 200 atm.
- Ammonia liquefies out; unreacted gases recycle.
- (HT) every condition is a compromise of rate, yield and cost.

## Exercises 2.1·2.3

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**2.1** Give the source of the nitrogen and the hydrogen for the process. [2]

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**2.2** Name the catalyst. [1]

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**2.3** (*HT*) What happens to unreacted nitrogen and hydrogen? [1]

## Exercises 2.1·2.3

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**2.1** Give the source of the nitrogen and the hydrogen for the process. [2]

**2.1** Nitrogen from the air; hydrogen from natural gas/methane reacted with steam.

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**2.2** Name the catalyst. [1]

**2.2** Iron.

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**2.3** (*HT*) What happens to unreacted nitrogen and hydrogen? [1]

**2.3** They are recycled back into the reactor.

## Exercises 3.1·3.2

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**3.1** Describe how ammonia is separated and the process made economic.

[4]

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**3.2** (*HT*) The forward reaction is exothermic. Explain the effect of raising the temperature on yield and rate, and the chosen compromise.

[5]

## Exercises 3.1·3.2

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**3.1** Describe how ammonia is separated and the process made economic. [4]

**3.1** The mixture is cooled; ammonia's boiling point is higher, so it liquefies and is tapped off; the unreacted nitrogen and hydrogen are recycled – nothing is wasted; continuous operation with cheap raw materials (air, methane) keeps the process economic.

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**3.2** (*HT*) The forward reaction is exothermic. Explain the effect of raising the temperature on yield and rate, and the chosen compromise. [5]

**3.2** Raising temperature shifts equilibrium in the endothermic direction – the reverse – so the ammonia yield falls; but the rate rises – more collisions exceed activation energy; a low temperature would give high yield but impractically slow production;  $\sim 450\text{ }^{\circ}\text{C}$  is the compromise giving acceptable rate at acceptable yield; the iron catalyst raises the rate further without changing the yield.

## Exercise 3.3

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**3.3** (*HT*) Ammonium nitrate is made from ammonia. Outline the steps, and state why industrial production beats the laboratory titration route. [4]

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**3.3** (*HT*) Ammonium nitrate is made from ammonia. Outline the steps, and state why industrial production beats the laboratory titration route. [4]

**3.3** Ammonia is oxidised over a platinum/rhodium catalyst to nitrogen oxides and absorbed in water to give nitric acid; ammonia + nitric acid  $\rightarrow$  ammonium nitrate – a neutralisation. Industrially: raw materials are cheap and abundant, and continuous large-scale output; a titration produces only small, impure batches of solution, not a solid fertiliser product.