

Solutions

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

2.2 Iron.

2.3 They are recycled back into the reactor.

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.

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.

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.