10.4 The Haber process and NPK fertilisers

Name: _____ Class: _____ Date: _____ **Total: 34 marks**

KEY WORDS Haber process • compromise conditions • NPK fertiliser

Objective

Explain the Haber process conditions and NPK fertiliser production. Chemistry only. Original questions for spec statement 4.10.4.

1 Key knowledge and worked examples

Haber: N_2 (from **air**) + 3 H_2 (from **natural gas + steam**) $\rightleftharpoons$ 2 NH_3 (exothermic forward). Conditions: **iron catalyst, ~450 °C, ~200 atm**; cool – **ammonia liquefies out**; unreacted gases **recycled**.

(HT) The compromise: higher pressure → more NH_3 (fewer gas molecules) but costly and unsafe; lower temperature → more NH_3 (exothermic) but slow – so 450 °C gives an acceptable rate at an acceptable yield; the catalyst speeds the approach to equilibrium without shifting it.

NPK fertilisers – compounds of nitrogen, phosphorus, potassium for growth: ammonia → **nitric acid**; NH_3 + HNO_3 → **ammonium nitrate**; **potassium chloride/sulfate** mined; phosphate rock treatment: nitric acid → calcium nitrate/phosphoric acid; sulfuric acid → single superphosphate (phosphate + sulfate); phosphoric acid → triple superphosphate (phosphate).

Worked example (4 marks, HT). Explain why 200 atm rather than 1000 atm is used.

Higher pressure favours the forward reaction – fewer gas molecules – so yield would rise; but very high pressures need expensive, strong plant and add safety risk; ~200 atm balances yield against cost and safety; with recycling of unreacted gases, the overall conversion stays economic.

2 Practice

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

2.2 Name the catalyst. [1]

2.3 What happens to unreacted nitrogen and hydrogen? [1]

3 Exam-style questions

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

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

3.3 Ammonium nitrate is made from ammonia. Outline the acid-making and neutralisation stages, then give two criteria for comparing industrial production with a laboratory preparation. [4]

3.4 Name the products from treating phosphate rock with nitric acid, sulfuric acid and phosphoric acid. Distinguish single and triple superphosphate. [4]

3.5 A feed contains 2 mol nitrogen and 6 mol hydrogen. On one Haber pass, 1 mol nitrogen reacts. Use the balanced equation to calculate ammonia made and both unreacted amounts. Explain why recycling is not proof of zero resource use. [5]

3.6 *(HT)* An operator claims an iron catalyst raises the equilibrium percentage of ammonia, and a much higher temperature must improve both yield and rate. Correct both claims for the exothermic forward reaction. [4]

3.7 A laboratory makes a pure ammonium salt by controlled neutralisation followed by crystallisation. A factory uses integrated continuous processes to make the same salt. Give two useful comparison criteria and explain why "laboratory titration always produces an impure solution" is not a valid verdict. [4]