10 Ammonia

Set B **Answer key**

A Multiple choice

5 MARKS

1 **D** The process involves a non-reversible reaction. [1]

The Haber process is reversible: ammonia breaks down into nitrogen and hydrogen as it forms.

2 **C** 1 only [1]

A high pressure increases both. A high temperature speeds up the reaction but lowers the yield, and a catalyst speeds up the reaction without changing the yield.

3 **D** 2000 dm^3 of nitrogen and 6000 dm^3 of hydrogen [1]

Volume of ammonia if the reaction were complete = $600 \times \frac{100}{15} = 4000\ dm^3$.

$N_2 : H_2 : NH_3 = 1 : 3 : 2$, so 2000 dm^3 of nitrogen and 6000 dm^3 of hydrogen are needed.

4 **C** 45 cm^3 [1]

15 cm^3 of nitrogen reacts with 45 cm^3 of hydrogen to form 30 cm^3 of ammonia. 15 cm^3 of hydrogen is left over, so the total is 30 + 15 = 45 cm^3.

5 **D** The damp red litmus paper turns blue first, and both papers end red. [1]

Ammonia (M_r 17) diffuses faster than hydrogen chloride (M_r 36.5), so it reaches the papers first and turns the red paper blue. Hydrogen chloride arrives later and turns both papers red.

B Structured questions

19 MARKS

6 **(a)** By the cracking of crude oil fractions (hydrocarbons). [1]

(b) Nitrogen has the electronic structure 2.5, with 5 valence electrons. [1]

It needs three more electrons to fill its valence shell, so it shares one electron with each of three hydrogen atoms. [1]

(c) As the temperature increases, the yield decreases. [1]

(d) It increases the yield of ammonia. [1]

(e) A higher pressure is a safety risk (risk of explosion) *or* the plant is too expensive to build to withstand it. **[1]**

(f) They are recycled: sent over the catalyst again. **[1]**

7 **(a)** The yield of ammonia decreases (from 38.5% to 14.1%) as the temperature increases (from 350 °C to 550 °C). **[1]**

(b) From 100 to 300 atm the yield increases by 30.1 − 14.5 = 15.6%, and from 550 °C to 350 °C it increases by 38.5 − 14.1 = 24.4%. **[1]**

This is 0.078% for every 1 atm and 0.122% for every 1 °C. **[1]**

No, I do not agree: decreasing the temperature produces a larger increase in the yield. **[1]**

(c) It contributes to greenhouse gas emissions, leading to global warming. **[1]**

8 **(a)** $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ **[1]**

From the equation, 1 volume of nitrogen reacts with 3 volumes of hydrogen. **[1]**

(b) About 450 °C, about 250 atm and a finely divided iron catalyst (all three for the mark). **[1]**

(c) Upward delivery **[1]**

because ammonia is less dense than air. **[1]**

(d) NH_3 : NO = 1 : 1 by volume, so the theoretical volume of NO = 440 dm^3 **[1]**

Volume collected = $\frac{40}{100} \times 440 = 176\ dm^3$ **[1]**