A Case Study of the Haber Process

Consider the Haber Process for the manufacture of ammonia, $NH_{3\,(g)}$:

$$N_{2\,(g)} + 3\,H_{2\,(g)} \rightleftharpoons 2\,NH_{3\,(g)}$$

Answer the following questions:

1. What are the three raw materials in the Haber Process?

2. Give four uses of ammonia.

3. Look at the information in Table 1. What would be the effect on the yield of ammonia on decreasing the temperature?

Table 1

Pressure (atm)	NH_3 present at equilibrium (%)					
	100 °C	200 °C	300 °C	400 °C	500 °C	700 °C
10	-	50.7	14.7	3.9	1.2	0.2
25	91.7	63.6	27.4	8.7	2.9	-
50	94.5	74.0	39.5	15.3	5.6	1.1
100	96.7	81.7	52.5	25.2	10.6	2.2
200	98.4	89.0	66.7	38.8	18.3	-
400	99.4	94.6	79.7	55.4	31.9	-
1000	-	98.3	92.6	79.8	57.5	12.9

4. Draw a graph of the data shown in table 1 with *percentage conversion to NH_3* on the y-axis and *pressure in atmospheres* on the x-axis. Draw separate lines on the same graph for the six different temperatures.

5. Suggest why the process is not operated at even lower temperatures.

6. What is the ratio of nitrogen to hydrogen, by volume, of the gases entering the catalyst chamber?

7. What practical reasons can you think of for not using very high pressure?

8. The boiling points N_2, H_2 and NH_3 are -196 ^{O}C , -253 °C and -33 ^{O}C respectively. How do you think the ammonia could be separated from unreacted nitrogen and hydrogen?

9. The boiling points of these gases are higher at higher pressure. Use your knowledge of particles to explain this.

10. Some of the ammonia is distributed as liquid ammonia by road using tankers. Suggest an advantage of distributing ammonia as liquid rather than gas.

11. What happens to the unreacted nitrogen gas and hydrogen gas after the ammonia is removed?

12. If the condition are 200 atmospheres and 425 ^{O}C what yield of ammonia is obtained at equilibrium?

13. In practice the yield obtained under these condition is 15%. Can you explain why this value is lower than your answer to question 12.

14. What would be the effect on the yield on ammonia of increasing the pressure?

15. Suggest why the process is not operated at even higher pressures.

16. The forward reaction in the Haber Process is exothermic (? H^{o} = -92 kJ mol^{-1}).
Explain how the experimental results in Table 1 are in agreement with Le Chatelier's Principle.

17. Pick out the conditions of temperature and pressure from those listed in Table 1 that would give:

a. the highest yield on ammonia

b. the fastest rate of conversion to ammonia

18. Find out the conditions normally used in the Haber Process. Explain in detail why each of the condition is chosen.