

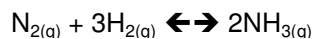
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AP WORKSHEET 13b: The Haber Process



The Haber process is the name given to the industrial scale manufacture of ammonia from hydrogen and nitrogen gases. It utilizes the equilibrium reaction shown below.



Under a typical set of conditions a mixture of 1 mole of nitrogen gas to every 3 moles of hydrogen gas are exposed to the temperatures shown in the table below and the equilibrium is established. In each case, the system is under a total pressure of 10.0 atm.

| Temperature in °C | Partial pressure of NH ₃ in atm |
|-------------------|--|
| 355 | 0.741 |
| 455 | 0.211 |
| 555 | 0.081 |

(a) For each temperature calculate the partial pressure of each reactant. (6)

(b) For each temperature, calculate K_p . (6)

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- (c) Comment on the sign of ΔH for the reaction. (2)
- (d) The experiment is repeated and the conditions adjusted so the total pressure is 40.0 atm. The partial pressure of ammonia at equilibrium under these new conditions is found to be 11.4 atm.
- (i) Without doing any calculations, comment upon the significance of the data in terms of Le Chatelier's principle. (2)
- (ii) Calculate K_p under the new conditions. (4)
- (e) The reaction is often carried out using a catalyst. What is the purpose of the catalyst and how does it affect the value of K for the reaction? (1)