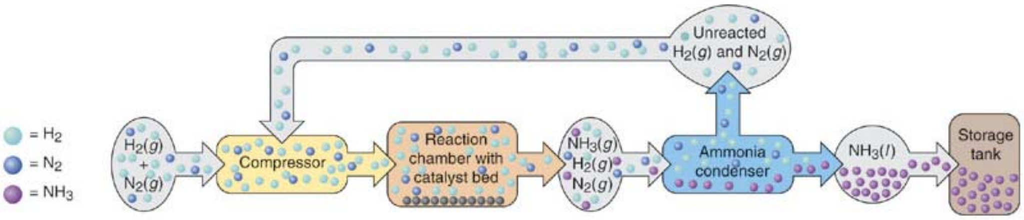
Chapter 1 Example Problem—the Haber Process



(Figure taken from Martin S. Silberberg, *Chemistry*, 4th ed., Boston: McGraw Hill, 2006)

$$N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g) \rightarrow 2\,NH_3(l)$$

A chemical engineer is testing a prototype for a new plant that will use the Haber process to synthesize ammonia. Both the reaction chamber and the ammonia condenser tank have volumes of 500. L. The engineer charges both the chamber and the tank with 30.0 atm of $N_2(g)$ at 29°C (no H_2 or NH_3 is present for these tests).

(a) The reaction chamber is heated to a typical temperature of 400.°C, and the condenser tank is cooled to a typical temperature of -50.°C. Assuming that N_2 behaves as a perfect gas, what are the pressures of N_2 in the chamber and the tank?

(b) The measured pressures in the reaction chamber and the condenser tank are 68.9 atm and 21.5 atm, respectively. What are the relative errors (in %) in your calculations in (a), and what went wrong in (a)?

(c) The van der Waals parameters for N_2 are $a = 1.352$ atm dm^6 mol^{-2} and $b = 3.87 \times 10^{-2}$ dm^3 mol^{-1}. First, what the heck is a cubic decimeter? Then, assuming N_2 behaves as a van der Waals gas, recompute the pressures at 400.°C and -50.°C.

(d) How do we account for the remaining discrepancies in the predicted and measured pressures?

(e) We calculated the moles of N_2 in part (c) assuming perfect behavior. Was this justified?