Alternate solution for Problem 4.11, thanks to a question from Travis Addington:

The equilibrium constant for the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ is 20.0 at 40 °C and the vapor pressure of solid iodine at that temperature is 0.10 bar. If 12.7 g of solid iodine is placed in a 10 L vessel at 40 °C, what is the minimum amount of hydrogen gas that must be introduced in order to remove all the solid iodine?

Solution:

12.7 g of iodine = 0.050 mol of I_2. In class, we calculated the amount of hydrogen required to convert 0.050 mol of iodine into HI, and then added that to the amount of hydrogen needed to maintain the equilibrium along with 0.10 bar of iodine gas. Travis is correct, we need to account for the fact that 0.10 bar of iodine DOES NOT react but, rather, stays in vapor form to maintain the equilibrium. So, here is a "new, improved" solution.

$\mathrm{bar} := 10^5 \cdot \mathrm{Pa} \qquad R := 0.083145 \cdot L \cdot \mathrm{bar} \cdot K^{-1} \cdot \mathrm{mol}^{-1} \quad T := (273.15 + 40) \cdot K \qquad P_{I2} := 0.10 \cdot \mathrm{bar}$

No. of moles corr. to 0.10 bar of iodine vapor at 40 °C in 10.0 L volume:

$$n_{I2} := \frac{0.10 \cdot \mathrm{bar} \cdot 10.0 \cdot L}{R \cdot T} \qquad n_{I2} = 0.038\,\mathrm{mol}$$

Therefore, the amount of iodine that needs to be converted to HI by reaction is 0.012 mol. Now, 0.012 mol of I_2 gives 0.024 mol of HI on reaction. The partial pressure of HI at equilibrium is:

$$P_{HI} := \frac{0.024 \cdot \mathrm{mol} \cdot R \cdot T}{10.0 \cdot L} \qquad P_{HI} = 0.062\,\mathrm{bar}$$

The equilibrium constant expression is: $20 := \dfrac{P_{HI}^{\;2}}{P_{H2} \cdot P_{I2}}$ Therefore, solving for P_{H2}

$$P_{H2} := \frac{P_{HI}^{\;2}}{20 \cdot P_{I2}} \qquad P_{H2} = 1.952 \times 10^{-3}\,\mathrm{bar} \qquad n_{H2} := \frac{P_{H2} \cdot 10.0 \cdot L}{R \cdot T} \qquad n_{H2} = 7.499 \times 10^{-4}\,\mathrm{mol}$$

The total amount of hydrogen required is the amount of hydrogen present at equilibrium + the amount required to react with 0.012 mol of iodine = 0.012 mol hydrogen. Therefore the total amount of hydrogen required is:

$$(0.012 \cdot \mathrm{mol} + n_{H2}) = 0.013\,\mathrm{mol}$$