Problem: 12-14

Given: The reaction $CO_2 + H_2 \rightleftharpoons CO + H_2O$ at 298 K.

Find: The equilibrium constant using Table B.13 and derive an expression to get it from Table B.14

Assume: $P = 1\ atm$

$$\hat{g} = \hat{h} - T\hat{s} = \hat{h} - T\hat{\phi}$$

From Table B.13

$$\begin{aligned}
\hat{h}(CO_2) &= -169183\ Btu/lbmole \\
\hat{h}(H_2) &= 0\ Btu/lbmole \\
\hat{h}(CO) &= -47517\ Btu/lbmole \\
\hat{h}(H_2O) &= -103968\ Btu/lbmole \\
\hat{\phi}(CO_2) &= 51.032\ Btu/lbmole \cdot R \\
\hat{\phi}(H_2) &= 31.194\ Btu/lbmole \cdot R \\
\hat{\phi}(CO) &= 47.272\ Btu/lbmole \cdot R \\
\hat{\phi}(H_2O) &= 45.079\ Btu/lbmole \cdot R \\
\hat{g}(CO_2) &= -169183 - (537)(51.032) = -196587\ Btu/lbmole \\
\hat{g}(H_2) &= 0 - (537)(31.194) = -16751\ Btu/lbmole \\
\hat{g}(CO) &= -47517 - (537)(47.272) = -72902\ Btu/lbmole \\
\hat{g}(H_2O) &= -103968 - (537)(45.079) = 128175\ Btu/lbmole
\end{aligned}$$

$$\begin{aligned}
\Delta G_r &= \hat{g}(CO) + \hat{g}(H_2O) + \hat{g}(CO_2) + \hat{g}(H_2) \\
&= -72902 - 128175 + 196587 + 16751 \\
&= 12261\ Btu/lbmole
\end{aligned}$$

$$\begin{aligned}
\ln K &= -\frac{\Delta G_r}{\mathcal{R}T} = \frac{(-12261\ Btu/lbmole)}{\left(1.986\ \frac{Btu}{lbmole \cdot R}\right)(537\ R)} \\
&= -11.497
\end{aligned}$$

$$\log_{10} K = \frac{\ln K}{\ln 10} = \frac{-11.497}{2.303} = \boxed{-4.99}$$

$$\begin{aligned} K = \frac{X_{CO} X_{H_2O}}{X_{CO_2} X_{H_2}} &= \left(\frac{X_{CO} X_{O_2}^{1/2}}{X_{CO_2}}\right) \left(\frac{X_{H_2O}}{X_{H_2} X_{O_2}^{1/2}}\right) \\ &= \frac{K(CO_2 \rightleftharpoons CO + \frac{1}{2}O_2)}{K(H_2O \rightleftharpoons H_2 + \frac{1}{2}O_2)} \end{aligned}$$

$$\begin{aligned} \log_{10} K &= log_{10} \left[\frac{K(CO_2 \rightleftharpoons CO + \frac{1}{2}O_2)}{K(H_2O \rightleftharpoons H_2 + \frac{1}{2}O_2)}\right] \\ &= log_{10}(CO_2 \rightleftharpoons CO + \frac{1}{2}O_2) - log_{10}K(H_2O \rightleftharpoons H_2 + \frac{1}{2}O_2) \\ &= -45.043 - (-40.047) \\ &= -4.996 \end{aligned}$$