HW 13

Q1
What are the units of $K_p$ and $K_c$ for each of the following?

(a) $\text{NH}_4\text{S(s)} \rightleftharpoons \text{NH}_3(g) + \text{H}_2\text{S(g)}$

$K_p \text{ atm}^{-2}$

$K_c \text{ M}^2$

(b) $\text{P}_4(g) + 5 \text{O}_2(g) \rightleftharpoons \text{P}_4\text{O}_{10}(s)$

$K_p \text{ atm}^{-6}$

$K_c \text{ M}^{-6}$

$$K = [\text{NH}_3][\text{H}_2\text{S}]$$

$$K = \frac{1}{[\text{P}_4][\text{O}_2]^5}$$

Q2
Consider the following reaction:

$2 \text{H}_2\text{S(g)} \rightleftharpoons 2 \text{H}_2(g) + \text{S}_2(g)$

$K_p$ was measured to be 0.0365 atm for this reaction at 385 K. What is the value of $K_c$ at 385 K?

$K_c = \frac{0.00115}{[\text{H}_2\text{S}]} \text{ M}$

$$K_c = \frac{(K_p)}{(RT)^\Delta n_g} = \frac{0.0365}{(0.0821(385))^{\frac{3}{2}}} = 0.00115 \text{ M}$$

What is the value for $K_p$ for the following reaction at 385 K?

$\text{H}_2(g) + \frac{1}{2} \text{S}_2(g) \rightleftharpoons \text{H}_2\text{S(g)}$

$K_p = 5.23 \text{ atm}^{-1/2}$

The reaction is reverse and half of the starting reaction, hence $-1/2$.

$$K_2 = K_1^{-0.5} = (0.0365)^{-0.5} = 5.23 \text{ atm}^{-\frac{1}{2}}$$

Q3
What is the equilibrium concentration of $\text{Pb}^{2+}$ ion in a solution of $\text{PbX}_2$ that is 0.0420 M in $\text{X}^{1-}$ ion?

$\text{PbX}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2\text{X}^{1-}(aq)$

$K = 1.00\text{e-06}$

$$[\text{Pb}^{2+}] = \frac{5.67\text{e-04}}{2} \text{ M}$$
\[ K = [X^-]^2 [Pb^{2+}] \rightarrow [Pb^{2+}] = \frac{K}{[X^-]^2} = \frac{1 \times 10^{-6}}{(0.042)^2} = 5.67 \times 10^{-4} \]

Q4

HX is a weak acid that reacts with water according to the following equation:

\[ \text{HX(aq) + H}_2\text{O(l)} \rightarrow \text{H}_3\text{O}^{+}(aq) + X^- (aq) \quad K_a = 2.51 \times 10^{-5} \]

What is the equilibrium concentration of hydronium ion in a solution that is 0.0526 M in HX and 0.253 M in \( X^- \) ion?

\[ [\text{H}_3\text{O}^{+}] = \sqrt{\frac{5.22 \times 10^{-6}}{0.0526}} \text{ M} \]

\[ K_a = \frac{[\text{H}_3\text{O}^{+}][X^-]}{[\text{HX}]} \rightarrow [\text{H}_3\text{O}^{+}] = \frac{K_a [\text{HX}]}{[X^-]} = \frac{2.51 \times 10^{-5}(0.0526)}{0.253} = 5.22 \times 10^{-6} \]

Q5

At some temperature, \( K = 16.2 \) for the following reaction:

\[ \text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g}) \]

The initial partial pressures of \( \text{H}_2 \) and \( \text{CO}_2 \) are each 1.90 atm.

What is the final pressure of \( \text{CO} \)?

\[ P_{\text{CO}} = 1.52 \text{ atm} \]

\[ \begin{array}{c|c|c|c|c|c} & \text{H}_2(\text{g}) & + & \text{CO}_2(\text{g}) & \rightarrow & \text{H}_2\text{O}(\text{g}) & + & \text{CO}(\text{g}) \\
\text{I} & 1.9 & 1.9 & 0 & 0 \\
\text{C} & \times-x & \times-x & +x & +x \\
\text{E} & 19-x & 1.9-x & x & x \\
\end{array} \]

\[ K = \frac{x^2}{(1.9-x)^2} = 16.2 \rightarrow x = 1.52 \text{ atm} \]

What is the final total pressure?

\[ P_{\text{total}} = 3.80 \text{ atm} \]

**Just add the starting partial pressures because the total P will not change.** \( 2(1.9) = 3.8 \text{ atm} \)

Q6

An equilibrium mixture contains 0.800 mol HI, 0.270 mol \( I_2 \), and 0.150 mol \( H_2 \) in a 1.00-L flask. What is the equilibrium constant for the following reaction?

\[ 2\text{HI(g)} \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g}) \]

\[ K_c = 0.0633 \]
\[ K = \frac{[I_2][H_2]}{[HI]^2} = \frac{0.27(0.15)}{(0.8)^2} = 0.0633 \]

How many moles of I\(_2\) must be removed in order to double the number of moles of H\(_2\) at equilibrium?

\[ 0.367 \text{ mol I}_2 \]

\[ \begin{array}{ccc}
2\text{HI}(g) & \rightleftharpoons & \text{H}_2(g) + \text{I}_2(g)
\end{array} \]

\[
\begin{array}{|c|c|c|c|}
\hline
\text{E} & 0.8 & 0.27 & 0.15 \\
\hline
\text{I} & 0.8 & 0.27-x & 0.15 \\
\hline
\text{C} & -0.15 & +0.15 & +0.15 \\
\hline
\text{E} & 0.65 & 0.42-x & 0.3 \\
\hline
\end{array}
\]

\[ K = \frac{[I_2][H_2]}{[HI]^2} \rightarrow \frac{(0.42-x)(0.3)}{(0.65)^2} = 0.0633 \rightarrow x = 0.367 \text{ mol I}_2 \]

Hint: If you remove I\(_2\), you have new "initial" concentrations. Think about which of these you know, and which final concentrations you know.