PART III: Problems

23. Referring to the following equilibrium,

\[ \text{C (s) + H}_2\text{O (g) \rightleftharpoons CO (g) + H}_2\text{(g)} \quad \Delta H = +2296 \text{ J/mol} \]

How would the system respond to the following changes to reestablish equilibrium (i.e., shift right, shift left, or no change). [6 pts]

[a] The temperature is increased. \textbf{shift right}

[b] Gaseous water is removed. \textbf{shift left}

[c] C (s) is added. \textbf{no change}

[d] The pressure is increased by decreasing the volume. \textbf{shift left}

[e] The pressure is increased by adding an inert gas. \textbf{no change}

[f] If the temperature is decreased, what happens to the value of the equilibrium constant (increase, decrease, or remain the same)? \textbf{decreases}

24. Consider the reaction

\[ \text{N}_2\text{ (g) + O}_2\text{ (g) \rightleftharpoons 2 NO (g)} \]

for which \( K_c = 0.10 \) at 2000°C. Starting with initial concentrations of 0.040 \( M \) of \( \text{N}_2 \) and 0.040 \( M \) of \( \text{O}_2 \), calculate the equilibrium concentrations of all species. [7 pts]

\[
\begin{array}{c|c|c|c}
\text{N}_2 (g) & + & \text{O}_2 (g) & \rightleftharpoons 2 \text{ NO (g)} \\
\hline
\text{Initial (M)}: & 0.040 & 0.040 & 0 \\
\text{Change (M)}: & -x & -x & +2x \\
\text{Equilibrium (M)}: & 0.040 - x & 0.040 - x & 2x \\
\end{array}
\]

\[
K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]}
\]

\[
0.10 = \frac{(2x)^2}{(0.040 - x)^2}
\]

\[
\sqrt{0.10} = \sqrt{\frac{(2x)^2}{(0.040 - x)^2}}
\]

\[
0.316 = \frac{2x}{0.040 - x}
\]

\[
0.0126 - 0.316x = 2x
\]

\[
x = 0.0055 \text{ M}
\]

[\text{N}_2] \underline{0.035 \text{ M}}

[\text{O}_2] \underline{0.035 \text{ M}}

[\text{NO}] \underline{0.011 \text{ M}}
25. A 0.100 M solution of the weak base aniline (C₆H₅NH₂) is found to have a pH of 8.79 at 25°C. Calculate the equilibrium constant, \( K_b \), for this weak base. [7 pts]

\[
C_6H_5NH_2 (aq) + H_2O (l) \rightleftharpoons C_6H_5NH_3^+ (aq) + OH^- (aq)
\]

<table>
<thead>
<tr>
<th>Initial (M):</th>
<th>0.100</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change (M):</td>
<td>(-x)</td>
<td>+x</td>
<td>+x</td>
</tr>
<tr>
<td>Equilibrium (M):</td>
<td>0.100 - x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

pOH = 5.21

\[
[OH^-] = 10^{-pOH} = 10^{-5.21} = 6.17 \times 10^{-6} \text{ M} = x
\]

\[
K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}
\]

\[
K_b = \frac{x^2}{0.100 - x}
\]

\[
K_b = \frac{(6.17 \times 10^{-6})^2}{0.100 - (6.17 \times 10^{-6})}
\]

\[K_b = 3.80 \times 10^{-10}\]