PART III: Problems

23. Referring to the following equilibrium,

\[
C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g) \quad \Delta H = +2296 \text{ J/mol}
\]

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

[a] C (s) is added. \( \text{no change} \)

[b] The pressure is increased by decreasing the volume. \( \text{shift left} \)

[c] The pressure is increased by adding an inert gas. \( \text{no change} \)

[d] The temperature is increased. \( \text{shift right} \)

[e] Gaseous water is removed. \( \text{shift left} \)

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

24. A 0.250 \( M \) solution of the weak base aniline \( (C_6H_5NH_2) \) is found to have a pH of 8.99 at 25°C. Calculate the equilibrium constant, \( K_b \), for this weak base. [7 pts]

\[
\begin{array}{c|c|c}
\text{Initial (M):} & 0.250 & 0 \quad 0 \\
\text{Change (M):} & -x & +x \quad +x \\
\text{Equilibrium (M):} & 0.250 - x & x \quad x \\
\end{array}
\]

pOH = 5.01

\[
[\text{OH}^-] = 10^{-\text{pOH}} = 10^{-5.01} = 9.77 \times 10^{-6} \quad M = x
\]

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

\[
K_b = \frac{x^2}{0.250 - x}
\]

\[
K_b = \frac{(9.77 \times 10^{-6})^2}{0.250 - (9.77 \times 10^{-6})}
\]

\[
K_b = 3.82 \times 10^{-10}
\]
25. Consider the reaction

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

for which \( K_c = 0.10 \) at 2000°C. Starting with initial concentrations of 0.060 \( M \) of \( \text{N}_2 \) and 0.060 \( M \) of \( \text{O}_2 \), calculate the equilibrium concentrations of all species. [7 pts]

<table>
<thead>
<tr>
<th>Species</th>
<th>Initial (M)</th>
<th>Change (M)</th>
<th>Equilibrium (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{N}_2 )</td>
<td>0.060</td>
<td>-( x )</td>
<td>0.060 - ( x )</td>
</tr>
<tr>
<td>( \text{O}_2 )</td>
<td>0.060</td>
<td>-( x )</td>
<td>0.060 - ( x )</td>
</tr>
<tr>
<td>( 2 \text{NO} )</td>
<td>0</td>
<td>+2( x )</td>
<td>2( x )</td>
</tr>
</tbody>
</table>

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

\( 0.10 = \frac{(2x)^2}{(0.060 - x)^2} \)

\( \sqrt{0.10} = \frac{2x}{0.060 - x} \)

\( 0.316 = \frac{2x}{0.060 - x} \)

\( 0.0190 - 0.316x = 2x \)

\( x = 0.0082 \ M \)

\[ [\text{N}_2] \ 0.052 \ M \]

\[ [\text{O}_2] \ 0.052 \ M \]

\[ [\text{NO}] \ 0.016 \ M \]