1. At a suitably high temperature, $H_2O$ can be dissociated into $H_2(g)$ and $O_2(g)$ as shown in the following equilibrium,

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

If 80.00 moles of steam are initially confined in a 10.00 L vessel, and the temperature is sufficiently high to cause a 25.0% dissociation of the steam into hydrogen gas and oxygen gas, calculate the **equilibrium constant**, $K_c$, at this temperature. [7 pts] **Homework Problem**

\[
\begin{array}{c|c|c|c}
\text{Initial (M)} & 8.000 M & 0 & 0 \\
\text{Change (M)} & -2x & +2x & +x \\
\text{Equilibrium (M)} & 8.000 - 2x & 2x & x \\
\end{array}
\]

The amount of water that dissociates is:

$$8.000 M \times 0.25 = 2.000 M$$

The amount of water shown reacting in the ICE table is $2x$, so

$$2x = 2.000 M$$

$$x = 1.000 M$$

$$K_c = \frac{[\text{H}_2]^2[\text{O}_2]}{[\text{H}_2\text{O}]^2}$$

$$K_c = \frac{(2x)^2(1)}{(8.000 - 2x)^2}$$

$$K_c = \frac{(2)^2(1)}{(8.000 - 2)^2}$$

$$K_c = 0.1111$$

2. For the reaction, $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, $K_c = 50.2$ at 445°C. If the reaction is started with $[H_2] = [I_2] = [HI] = 1.75 \times 10^{-3}$ M at 445°C, which one of the following statements is true? [3 pts]

a) The system is at equilibrium since the concentrations are equal.

b) **The concentration of HI will rise as the system approaches equilibrium.**

c) The concentrations of HI and I$_2$ will increase as the system approaches equilibrium.

d) The concentrations of H$_2$ and HI will fall as the system approaches equilibrium.

e) The concentrations of H$_2$ and I$_2$ will increase as the system approaches equilibrium.

**Calculate Q.** $Q = 1$. Since $Q$ does not equal $K$, the system is not at equilibrium. $Q < K$. The system will shift to the right to establish equilibrium.
3. Hydrogen gas can be generated from methane by the following catalyzed reaction, performed in a closed container.

\[
\text{CH}_4 (g) + \text{H}_2\text{O} (g) + \text{heat} \rightleftharpoons \text{CO} (g) + 3 \text{H}_2 (g)
\]

Indicate the direction in which the **equilibrium position** would shift as a consequence of each of the following actions. [5 pts] **Homework Problem**

<table>
<thead>
<tr>
<th>Action</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>adding a catalyst to the mixture</td>
<td>No Effect</td>
</tr>
<tr>
<td>increasing the relative concentration of CH(_4) (by addition)</td>
<td>Right</td>
</tr>
<tr>
<td>decreasing the pressure by increasing the volume of the container</td>
<td>Right</td>
</tr>
<tr>
<td>decreasing the temperature</td>
<td>Left</td>
</tr>
<tr>
<td>decreasing the relative concentration of H(_2)O (by removal)</td>
<td>Left</td>
</tr>
</tbody>
</table>

4. Identify the two conjugate acid/base pairs involved in each of the following reactions. [4 pts]

a) \(\text{OCl}^- + \text{H}_2\text{O} \rightleftharpoons \text{HOCl} + \text{OH}^-\)

\[\text{OCl}^-/\text{HOCl} \quad \text{H}_2\text{O}/\text{OH}^-\]

b) \(\text{HCOOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HCOO}^-\)

\[\text{HCOOH}/\text{HCOO}^- \quad \text{H}_2\text{O}/\text{H}_3\text{O}^+\]

5. **True or False** [3 pts] **Homework Problem**

- **True** According to the Brønsted definition, an acid is a hydrogen ion donor.
- **False** If the \([\text{H}_3\text{O}^+] < 1.0 \times 10^{-7} \text{ M}\), the solution is acidic.
- **False** If the \([\text{OH}^-] > 1.0 \times 10^{-7} \text{ M}\), the solution is acidic.

6. Select the equation from the list (A-J) which illustrates the acid-base reaction that can take place between each of the following Bronsted-Lowry acids and bases. [4 pts] **Homework Problem**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Acid</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. (\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-)</td>
<td>Acid, H(_2)O; base, H(_3)S(^+)</td>
<td>A. acid, H(_2)O; base, H(_3)S(^+)</td>
</tr>
<tr>
<td>B. (\text{HSO}_4^- + \text{HCO}_3^- \rightleftharpoons \text{H}_2\text{CO}_3 + \text{SO}_4^{2-})</td>
<td>Acid, HSO(_4^-); base, HCO(_3^-)</td>
<td>B. acid, HSO(_4^-); base, HCO(_3^-)</td>
</tr>
<tr>
<td>C. (\text{H}_2\text{S} + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{H}_3\text{S}^+)</td>
<td>Acid, H(_2)S; base, H(_2)O</td>
<td>C. acid, H(_2)S; base, H(_2)O</td>
</tr>
<tr>
<td>D. (\text{HCO}_3^- + \text{HSO}_4^- \rightleftharpoons \text{H}_2\text{SO}_4 + \text{CO}_3^{2-})</td>
<td>Acid, H(_2)O; base, CN(^-)</td>
<td>D. acid, H(_2)O; base, CN(^-)</td>
</tr>
<tr>
<td>E. (\text{H}_2\text{O} + \text{H}_2\text{S} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HS}^-)</td>
<td>Acid, H(_2)O; base, CN(^-)</td>
<td>E. acid, H(_2)O; base, CN(^-)</td>
</tr>
<tr>
<td>F. (\text{H}_2\text{O} + \text{HCN} \rightleftharpoons \text{CN}^- + \text{H}_3\text{O}^+)</td>
<td>Acid, H(_2)O; base, CN(^-)</td>
<td>F. acid, H(_2)O; base, CN(^-)</td>
</tr>
</tbody>
</table>
G. \( \text{H}_2\text{CO}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CO}_3^- \)

H. \( \text{NO}_2^- + \text{HClO}_4 \rightleftharpoons \text{ClO}_4^- + \text{HNO}_2 \)

I. \( \text{NO}_2^- + \text{HClO}_4 \rightleftharpoons \text{HClO}_3 + \text{NO}_3^- \)

J. none of the above

7. What is the molar \( \text{H}_3\text{O}^+ \) ion concentration in an aqueous solution with an \( \text{OH}^- \) ion concentration of \( 5.5 \times 10^{-10} \text{ M} \)?

[3 pts] **Homework Problem**

\[
\text{K}_w = [\text{H}_3\text{O}^+][\text{OH}^-]
\]

\[
1.0 \times 10^{-14} = [\text{H}_3\text{O}^+](5.5 \times 10^{-10} \text{ M})
\]

\[
[\text{H}_3\text{O}^+] = 1.8 \times 10^{-5} \text{ M}
\]