1. For the reaction, \( \text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g}) \), \( K_c = 50.2 \) at 445°C. If the reaction is started with \([\text{H}_2] = [\text{I}_2] = [\text{HI}] = 1.75 \times 10^{-3} \text{ M} \) at 445°C, which one of the following statements is true? [3 pts]

a) The concentrations of HI and I\(_2\) will increase as the system approaches equilibrium.
b) The concentrations of H\(_2\) and HI will fall as the system approaches equilibrium.
c) The concentrations of H\(_2\) and I\(_2\) will increase as the system approaches equilibrium.
d) The system is at equilibrium since the concentrations are equal.
e) The concentration of HI will rise 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.

2. Hydrogen gas can be generated from methane by the following catalyzed reaction, performed in a closed container.

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

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

- Decreasing the pressure by increasing the volume of the container
- Decreasing the temperature
- Decreasing the relative concentration of H\(_2\)O (by removal)
- Adding a catalyst to the mixture
- Increasing the relative concentration of CH\(_4\) (by addition)

3. At a suitably high temperature, H\(_2\)O can be dissociated into H\(_2\)(g) and O\(_2\)(g) as shown in the following equilibrium,

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

If 80.00 moles of steam are initially confined in a 5.00 L vessel, and the temperature is sufficiently high to cause a 12.5% dissociation of the steam into hydrogen gas and oxygen gas, calculate the equilibrium constant, \( K_c \), at this temperature. [7 pts] Homework Problem

\[
\begin{array}{c|c|c|c}
\text{Initial (M)} & 16.00 \text{ M} & 0 & 0 \\
\text{Change (M)} & -2x & +2x & +x \\
\text{Equilibrium (M)} & 16.00 - 2x & 2x & x
\end{array}
\]

The amount of water that dissociates is:

\[(16.00 \text{ M})(0.125) = 2.000 \text{ M}\]

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

\[2x = 2.000 \text{ M}\]
\[x = 1.000 \text{ M}\]
\[ K_c = \frac{[\text{H}_3\text{O}^+][\text{O}_2]}{[\text{H}_2\text{O}]^2} \]
\[ K_c = \frac{(2x)^2(x)}{(16.00 - 2x)^2} \]
\[ K_c = \frac{(2)^2(1)}{(16.00 - 2)^2} \]

\[ K_c = 0.02041 \]

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

- **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.
- **True** According to the Brønsted definition, an acid is a hydrogen ion donor.

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

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

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

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

   \(\text{OCl}^-/\text{HOCl}\) \(\text{H}_2\text{O}/\text{OH}^-\)

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**

   - **E** acid, \(\text{H}_2\text{S}\); base, \(\text{H}_2\text{O}\)
   - **J** acid, \(\text{H}_2\text{O}\); base, \(\text{CN}^-\)
   - **B** acid, \(\text{HSO}_4^-\); base, \(\text{HCO}_3^-\)
   - **A** acid, \(\text{H}_2\text{O}\); base, \(\text{HCO}_3^-\)
   - **A.** \(\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-\)
   - **B.** \(\text{HSO}_4^- + \text{HCO}_3^- \rightleftharpoons \text{H}_2\text{CO}_3 + \text{SO}_4^{2-}\)
   - **C.** \(\text{H}_2\text{S} + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{H}_3\text{S}^+\)
   - **D.** \(\text{HCO}_3^- + \text{HSO}_4^- \rightleftharpoons \text{H}_2\text{SO}_4 + \text{CO}_3^{2-}\)
   - **E.** \(\text{H}_2\text{O} + \text{H}_2\text{S} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HS}^-\)
   - **F.** \(\text{H}_2\text{O} + \text{HCN} \rightleftharpoons \text{CN}^- + \text{H}_3\text{O}^+\)
   - **G.** \(\text{H}_2\text{CO}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CO}_3^{2-}\)
   - **H.** \(\text{NO}_2^- + \text{HClO}_4 \rightleftharpoons \text{ClO}_4^- + \text{HNO}_2\)
   - **J.** none of the above
What is the molar $\text{H}_3\text{O}^+$ ion concentration in an aqueous solution with an $\text{OH}^-$ ion concentration of $6.2 \times 10^{-11} \text{M}$?

[3 pts] **Homework Problem**

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$1.0 \times 10^{-14} = [\text{H}_3\text{O}^+](6.2 \times 10^{-11} \text{ M})$$

$$[\text{H}_3\text{O}^+] = 1.6 \times 10^{-4} \text{ M}$$