Assignment 6:

1. Hebden p.60 #31acegj, 32, 35 abcd & p.62 #36, 40, 41, 44-46

2. Given the following equation and data:
   \[ \text{CB} + \text{R} \rightleftharpoons \text{CBR} \]
   \[ K_{eq} = 12.0 \text{ at } 200^\circ\text{C} \]
   \[ K_{eq} = 20.0 \text{ at } 300^\circ\text{C} \]
   Is the forward reaction exothermic or endothermic? Support your answer with explanations.

3. Given the following equation and data:
   \[ \text{CH}_4(\text{g}) + 2\text{H}_2\text{S}(\text{g}) \rightleftharpoons \text{CS}_2(\text{g}) + 4\text{H}_2(\text{g}) \]
   \[ K_{eq} = 1.0 \times 10^{-2} \text{ at } 500^\circ\text{C} \]
   \[ K_{eq} = 2.4 \times 10^{-3} \text{ at } 800^\circ\text{C} \]
   a) Is the forward reaction endothermic or exothermic? Explain.
   b) What effect will increasing the [H_2S] have on the value of \( K_{eq} \)?

4. For the following reaction:
   \[ \text{CO}_2(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \quad \Delta H = -96 \text{ kJ} \]
   What effect will decreasing the temperature have on the value of \( K_{eq} \)? Support your answer with explanations.

VII) Type 1 \( K_{eq} \) Problems

For Type 1 \( K_{eq} \) problems, the data provided in the question is exclusively equilibrium data.

Example:

1. For the following reaction:
   \[ 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) + 192 \text{ kJ} \]
   Equilibrium concentrations were found to be as follows:
   \[ [\text{SO}_2] = 2.0 \text{M}, [\text{O}_2] = 0.50 \text{M}, [\text{SO}_3] = 1.6 \text{M} \]
   Calculate the value of \( K_{eq} \).

   \[
   K_{eq} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]} = \frac{(1.6)^2}{(2.0)^2(0.5)} = 1.3
   \]
Example:
2. At equilibrium, a 2.00L vessel contained 0.750mol CO, 0.276mol H₂O, 0.600mol CO₂, and a $K_{eq} = 0.986$. Calculate the moles of H₂ at equilibrium.

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

\[
\begin{align*}
[\text{CO}] &= \frac{0.750\text{mol}}{2.00\text{L}} = 0.375\text{M} \\
[\text{CO}_2] &= \frac{0.600\text{mol}}{2.00\text{L}} = 0.300\text{M} \\
[\text{H}_2\text{O}] &= \frac{0.276\text{mol}}{2.00\text{L}} = 0.138\text{M} \\
[\text{H}_2] &= ?
\end{align*}
\]

\[
K_{eq} = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]} = 0.986 = \frac{(0.300)[\text{H}_2]}{(0.375)(0.138)}
\]

\[
[\text{H}_2] = \frac{(0.986)(0.375)(0.138)}{0.300} = 0.170\text{M}
\]

\[
\therefore 0.340\text{ mol H}_2
\]

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**VIII) Type 2 $K_{eq}$ Problems**

Type 2 $K_{eq}$ problems provide some initial data and some equilibrium data for certain substances, which you are to use to calculate the $K_{eq}$ constant. Use an 'ICE' table for assistance.

Example:
1. A mixture of H₂ and I₂ was prepared by placing 0.100mol of H₂ and 0.100mol of I₂ into a 1.00L flask. At equilibrium, the I₂ concentration dropped to 0.020M. Calculate the $K_{eq}$.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>H₂(g)</th>
<th>I₂(g)</th>
<th>⇌ 2HI(g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>0.100M</td>
<td>0.100M</td>
<td>0</td>
</tr>
<tr>
<td>Change</td>
<td>-0.050M</td>
<td>-0.050M</td>
<td>+ 0.110M</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>0.050M</td>
<td>0.050M</td>
<td>0.110M</td>
</tr>
</tbody>
</table>

\[
K_{eq} = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = \frac{(0.110)^2}{0.050 \times 0.050} = 6.4
\]
Assignment 7

Type 1 Problems

1. For the following reaction at equilibrium:
   \[ \text{CH}_4(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + 3\text{H}_2(g) \]
   
   \[ [\text{CH}_4] = 0.600\text{M} \quad [\text{H}_2\text{O}] = 0.060\text{M} \]
   
   \[ [\text{CO}] = 0.200\text{M} \quad [\text{H}_2] = 0.700\text{M} \]
   
   Calculate the \( K_{eq} \) for this reaction. Are the reactants or products favoured?

2. For the following reaction:
   \[ \text{CO}(g) + \text{H}_2\text{O}(l) \rightleftharpoons \text{CO}_2(g) + \text{H}_2(g) \]
   
   At equilibrium in a 1.0L container, 0.020mol of CO, 0.010mol \( \text{H}_2\text{O} \), 0.030mol \( \text{CO}_2 \), and 0.010mol of \( \text{H}_2 \) are present.
   
   a) Calculate the \( K_{eq} \)
   
   b) State whether reactants or products are favoured
   
   c) If \( \text{H}_2 \) is removed from the system and equilibrium is re-established, how does the value of \( K_{eq} \) change?

3. For the following reaction:
   \[ \text{CO}(g) + 2\text{H}_2(g) \rightleftharpoons \text{CH}_3\text{OH}(g) \quad K_{eq} = 1.00 \]
At equilibrium in a 2.0L container, 0.420mol CO and 0.100mol H₂ are present. Calculate the number of moles of CH₃OH present.

4. For the following reaction and data:
   \[ \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \]

<table>
<thead>
<tr>
<th>[N₂] (M)</th>
<th>[H₂] (M)</th>
<th>[NH₃] (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>0.200</td>
<td>0.400</td>
</tr>
<tr>
<td>Trial 2</td>
<td>?</td>
<td>0.300</td>
</tr>
</tbody>
</table>

Find [N₂] in Trial 2.

Type 2 Exercises (ICE diagrams)

5. A mixture consisting of 1.00mol CO(\text{g}) and 1.00mol H₂O(\text{g}) is placed in a 10.00L container. At equilibrium, 0.665mol CO₂(\text{g}) and 0.665mol H₂(\text{g}) are present.
   \[ \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g}) \]
   Calculate the \( K_{eq} \) for this reaction.

6. When 1.00M HBr is placed into a flask, the following equilibrium is achieved:
   \[ 2\text{HBr}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \]
   At equilibrium, 0.140M H₂ is present. Calculate the \( K_{eq} \).

7. A 5.00L vessel was initially filled with 6.00mol SO₂, 2.50mol NO₂, and 1.00mol SO₃.
   \[ \text{SO}_2(\text{g}) + \text{NO}_2(\text{g}) \rightleftharpoons \text{SO}_3(\text{g}) + \text{NO}(\text{g}) \]
   At equilibrium, the vessel was found to contain 3.00mol SO₃. What is the \( K_{eq} \) for the reaction?

8. 0.50mol of NOCl was introduced into a 1.0L flask and allowed to come to equilibrium:
   \[ 2\text{NOCl}(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \]
   At equilibrium, there was 0.10mol of Cl₂. What is the \( K_{eq} \)?