EXPERIMENT 24

LeChatelier’s Principle

INTRODUCTION

Chemical reactions in which a product is essentially unionized, is given off as a gas, or is precipitated, may be thought of as running to completion. Many of the reactions we have used in laboratory are important because they run to completion, yielding products, which are easily recovered. Reactions that run to completion are represented by chemical equations with a single-headed arrow:

\[ \text{Pb}^{2+} (aq) + 2\text{I}^- (aq) \rightarrow \text{PbI}_2 (s) \]

Most reactions, however, do not run to completion. The products, if formed at all, do not leave the container, but remain in contact and react to reform the original reactants. When both the forward and reverse reactions proceed at equal rates, an equilibrium is established. Under these conditions, the reaction vessel will contain a mixture of reactants and products, and there is no net change in the quantities of either reactants or products.

Reaction mixtures that have reached equilibrium are represented by chemical equations with a double-headed arrow:

\[ \text{Zn}^{2+} (aq) + 4\text{OH}^- (aq) \rightleftharpoons \text{Zn(OH)}_{4}^{2-} (aq) \]

\[ \text{HNO}_2 (aq) + \text{H}_2\text{O} (l) \rightleftharpoons \text{H}_3\text{O}^+ (aq) + \text{C}_2\text{H}_3\text{O}_2^- (aq) \]

Both temperature and concentration affect the quantities of reactants and products that will be present in an equilibrium mixture. In this experiment, you will explain the effect of concentration on various equilibria and apply LeChatelier’s Principle. **LeChatelier’s Principle** states that if a system is changed so that it is no longer at equilibrium, either the forward or reverse reaction will predominate until the system reaches equilibrium again.

When a temperature or concentration change is made to an equilibrium mixture, the mixture will no longer be in equilibrium. In other words, the forward and reverse reactions will no longer be proceeding at equal rates. If the forward reaction must predominate to make the mixture reach equilibrium again, the new equilibrium mixture will now contain more products than before. We state that the equilibrium point has now **shifted to the right**, indicating that more products are now present in the new equilibrium mixture. If the reverse reaction must predominate to make the mixture reach equilibrium again, the new equilibrium mixture will now contain more reactants than before. We state that the equilibrium point has now **shifted to the left**, indicating that more reactants are now present in the new equilibrium mixture.
In this experiment we will look at reactions that have colored reactants and products. If a change is made to an equilibrium mixture that causes it to create either more products (shift to the right) or more reactants (shift to the left), the appearance or disappearance of the colored species will allow us to determine which way the equilibrium has shifted.

In Part A, the equilibrium between acetic acid molecules and the ionized hydronium and acetate ions will be observed. An acid-base indicator, methyl red, will be used to show the equilibrium position. Methyl red gives the solution a yellow color when the acetic acid is in its unionized form, and a red to violet color when it is in its ionized form:

\[
\text{HC}_2\text{H}_3\text{O}_2\text{(aq)} + \text{H}_2\text{O}^+\text{(l)} \rightleftharpoons \text{H}_3\text{O}^+\text{(aq)} + \text{C}_2\text{H}_3\text{O}_2^-\text{(aq)}
\]

yellow \hspace{1cm} red to violet

By adding a reagent to the mixture, the reaction may shift to either the left (forming more reactants) or right (forming more products) to reestablish equilibrium. The color the solution turns will tell you which way the reaction shifted to reestablish equilibrium.

In Part B, the equilibrium between dichromate ions and chromate ions will be observed. The dichromate ions give the solution an orange color, while the chromate ions give the solution a yellow color:

\[
\text{Cr}_2\text{O}_7^{2-}\text{(aq)} + 2\text{OH}^-\text{(aq)} \rightleftharpoons 2\text{CrO}_4^{2-}\text{(aq)} + \text{H}_2\text{O}\text{(l)}
\]

orange \hspace{1cm} yellow

By adding reagents to the mixture, the reaction may shift to either the left (forming more reactants) or right (forming more products) to reestablish equilibrium. The color the solution turns will tell you which way the reaction shifted to reestablish equilibrium.

In Part C, the equilibrium between iron (III) ions and thiocyanate ions forming the complex ion \(\text{FeSCN}^{2+}\) will be observed. The iron (III) ions have a yellow color, thiocyanate ions are colorless, but the \(\text{FeSCN}^{2+}\) complex ion is blood red:

\[
\text{Fe}^{3+}\text{(aq)} + \text{SCN}^-\text{(aq)} \rightleftharpoons \text{FeSCN}^{2+}\text{(aq)}
\]

yellow \hspace{1cm} blood red

By adding reagents to the mixture, the reaction may shift to either the left (forming more reactants) or right (forming more products) to reestablish equilibrium. The color the solution turns will tell you which way the reaction shifted to reestablish equilibrium.
PROCEDURE

1. Students will work individually for this experiment. Except for the laboratory handout, remove all books, purses, and such items from the laboratory bench top, and placed them in the storage area by the front door. For laboratory experiments you should be wearing closed-toe shoes. Tie back long hair, and do not wear long, dangling jewelry or clothes with loose and baggy sleeves. Open you lab locker. Put on your safety goggles, your lab coat, and gloves.

PART A

2. Place approximately 25 mL of a 0.15% acetic acid solution into a 125 mL Erlenmeyer flask. Add 3 drops of methyl red indicator and swirl. Record your observations in the Data Table.

3. Transfer a small amount of sodium acetate from its reagent bottle to a weighing cup or a glass or porcelain container by pouring, then measure out approximately 1 gram of the sodium acetate into a 150-mL beaker.

   CAUTION: Never place your microspatula or scoopula into a reagent bottle. Any excess chemicals can be given to another student or disposed of the sink with water.

   NOTE: If any crystals are spilled on the balance or on the lab bench, clean them up immediately, and dispose of them down the sink with water. If there are any crystals left on the balance or the lab bench at the end of the lab period, the instructor will deduct one point from everyone’s lab score as a charge for cleaning up after you.

   Add the sodium acetate to your flask of acetic acid and swirl. Record your observations in the Data Table. The solution from Part A can be washed down the sink.

PART B

4. Place approximately 1 mL of 0.1 M potassium chromate in a small test tube. In another test tube put approximately 1 mL of 0.1 M potassium dichromate. Record the color of each in the Data Table.

5. Add a drop of 3 M sodium hydroxide to each test tube and swirl. Continue to add drops of the sodium hydroxide to each test tube and swirling until one of them definitely changes color. Record your observations in the Data Table. Save the solutions for step 5.

6. Add 3 M hydrochloric acid, a drop at a time, to the two solutions from step 4 until both solutions definitely change color. Record your observations in the Data Table. Neutralize the contents of each test tube with a couple of milliliters of saturated sodium thiosulfate solution, and dispose of the solutions in the waste bottle in Fume Hood A.
PART C

7. Mix approximately 1 mL each of 1 M iron (III) chloride solution and 1 M potassium thiocyanate solution in a 400-mL beaker.

8. Dilute the mixture with approximately 250 mL of water to give a color of light red to yellow-orange. Fill five medium test tubes three-quarters full with the diluted solution. Record the color of the solution in the first test tube in your Data Table.

9. **Clean and dry** your microspatula and a watch glass. Transfer a very small amount of iron (III) nitrate from its reagent bottle to the watch glass by *pouring*. To the second test tube, add 1 *small* microspatulaful of the iron (III) nitrate and mix.
   
   **CAUTION**: Never place your microspatula or scoopula into a reagent bottle.

   **NOTE**: In Part C of the experiment, if any crystals are spilled on the balance or on the lab bench, clean them up *immediately*, and place them in the 400-mL waste beaker on your lab bench that contains 10-15 mL of water. If there are *any* crystals left on the balance or the lab bench at the end of the lab period, the instructor will deduct one point from everyone’s lab score as a charge for cleaning up after you.

   Record the color of the resulting solution in your Data Table, as compared to the color in the first test tube.

10. **Clean and dry** your microspatula and watch glass. Transfer a very small amount of ammonium thiocyanate from its reagent bottle to the watch glass by *pouring*. To the third test tube, add 1 *small* microspatulaful of ammonium thiocyanate and mix. Record the color of the resulting solution in your Data Table, as compared to the color in the first test tube.

11. **Clean and dry** your microspatula and watch glass. Transfer a very small amount of sodium phosphate from its reagent bottle to the watch glass by *pouring*. To the fourth test tube, add 1 *small* microspatulaful of sodium phosphate and mix. Record the color of the resulting solution in your Data Table, as compared to the color in the first test tube.

12. **Clean and dry** your microspatula and watch glass. Transfer a very small amount of potassium chloride from its reagent bottle to the watch glass by *pouring*. To the fifth test tube, add 1 *small* microspatulaful of potassium chloride and mix. Record the color of the resulting solution in your Data Table, as compared to the color in the first test tube. Place the solutions from Part C in the waste beaker on your lab bench, then dispose of them in the waste bottle in Fume Hood A.

13. Clean and wipe dry your laboratory work area and all apparatus. When you have completed your lab report have the instructor inspect your working area. Once your working area has been checked your lab report can then be turned in to the instructor.
## DATA TABLE

### PART A

<table>
<thead>
<tr>
<th>Methyl Red Color</th>
<th>Acetic Acid Solution</th>
<th>Acetic Acid with Sodium Acetate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PART B

<table>
<thead>
<tr>
<th>Color</th>
<th>Potassium Chromate Solution</th>
<th>Potassium Dichromate Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Color with Sodium Hydroxide</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Color with Hydrochloric Acid</td>
<td></td>
</tr>
</tbody>
</table>

### PART C

<table>
<thead>
<tr>
<th>Diluted Solution of Iron (III) Chloride and Potassium Thiocyanate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
</tr>
<tr>
<td>Color with Iron (III) Nitrate</td>
</tr>
<tr>
<td>Color with Ammonium Thiocyanate</td>
</tr>
<tr>
<td>Color with Sodium Phosphate</td>
</tr>
<tr>
<td>Color with Potassium Chloride</td>
</tr>
</tbody>
</table>
POSTLAB QUESTIONS

1. Referring to the acetic acid equilibrium reaction in the introduction:

   \[ \text{HC}_2\text{H}_3\text{O}_2(aq) + \text{H}_2\text{O}^+(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq) \]

   yellow \hspace{50pt} \text{red to violet}

   (a) Which way did the equilibrium shift when sodium acetate was added to the acetic acid solution?

   ____________________________________________________________________________________

   (b) Explain why.

   ____________________________________________________________________________________
   ____________________________________________________________________________________
   ____________________________________________________________________________________
   ____________________________________________________________________________________

2. Referring to the dichromate-chromate equilibrium reaction in the introduction:

   \[ \text{Cr}_2\text{O}_7^{2-}(aq) + 2\text{OH}^-(aq) \rightleftharpoons 2\text{CrO}_4^{2-}(aq) + \text{H}_2\text{O}(l) \]

   orange \hspace{50pt} \text{yellow}

   (a) Which way did the equilibrium shift when sodium hydroxide was added to the solutions?

   ____________________________________________________________________________________

   (b) Explain why.

   ____________________________________________________________________________________
   ____________________________________________________________________________________
   ____________________________________________________________________________________
   ____________________________________________________________________________________
   ____________________________________________________________________________________

   (c) Which way did the equilibrium shift when hydrochloric acid was added to the solutions?

   ____________________________________________________________________________________

   (d) Explain why.

   ____________________________________________________________________________________
   ____________________________________________________________________________________
   ____________________________________________________________________________________
   ____________________________________________________________________________________
3. Referring to the iron-thiocyanate equilibrium reaction in the introduction:

\[
\text{Fe}^{3+} (aq) + \text{SCN}^- (aq) \rightleftharpoons \text{FeSCN}^{2+} (aq)
\]
yellow \hspace{2cm} \text{blood red}

(a) Which way did the equilibrium shift when iron (III) nitrate was added to the solution?
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

(b) Explain why.
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

(c) Which way did the equilibrium shift when ammonium thiocyanate was added to the solution?
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

(d) Explain why.
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

(e) Which way did the equilibrium shift when sodium phosphate was added to the solution?
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

(f) Explain why.
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

(g) Although the solution may have lightened due to dilution when the potassium chloride was added, the equilibrium did not shift. Explain why.
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
4. The equilibrium constant is 22.2 for the following reaction:

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

Calculate the equilibrium molarity of HOCl if a container initially has \([\text{HOCl}] = 3.00 \text{ M, [H}_2\text{O}] = 0 \text{ M, and [Cl}_2\text{O}] = 0 \text{ M.}\]