Equilibrium/ Le Chatelier’s Principle
Modified from an activity originally created by participating teachers – 2008 Summer Green Chemistry workshop

View video as demonstration guide: https://www.youtube.com/watch?v=fBdYL3hB4uI#t=379

Replacement: Traditionally, equilibrium experiments and Le Chatelier’s Principle are illustrated using the following experiments:

(A) \( \text{CoCl}_4^{2-} + 6\text{H}_2\text{O} \rightleftharpoons \text{Co(H}_2\text{O)}_6^{2+} + 4\text{Cl}^- \)

This experiment is used to demonstrate the effects of both temperature changes and concentration changes on an equilibrium mixture.

(B) \( \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O} \rightleftharpoons 2\text{CrO}_4^{2-} + 2\text{H}^+ \)

This experiment is used to demonstrate the effects of concentration changes on an equilibrium mixture.

(C) \( \text{Fe}^{3+} + \text{CNS}^- \rightleftharpoons \text{Fe(CNS)}^{2+} \)

This experiment is also be used to demonstrate the effects of concentration changes on an equilibrium mixture.

In this experiment, the above materials are replaced by everyday non-toxic materials.

Objective of lesson: To give students an understanding of the concept of chemical equilibrium and to demonstrate Le Chatelier’s Principle, i.e. if a stress is applied to a system at equilibrium, the system re-adjusts to relieve the stress applied. Part I is do be done as a demo and discussed in class as an introduction to Le Chatelier’s Principle and the concept of equilibrium.

Learning Outcomes: At the end of this lesson, students will be able to:
- Explain the concept of chemical equilibrium.
- Distinguish between static and dynamic equilibrium.
- State Le Chatelier’s Principle.
- Describe how to set up an experiment that is at chemical equilibrium.
- Predict the effect of adding a stress to the system at equilibrium.

Time Allocation: 2 x 45 minute class periods

Materials required:
- Candle
• 1 balloon
• Soda water
• 5 Erlenmeyer Flasks
• Black tea
• Vinegar
• Ammonia – cleaning solution
• Tincture of iodine
• Starch
• Universal indicator
• Drinking straw.
• Hot plate
• Ice bath
• Glass stirring rods

Procedure:
• Introduce the lesson covering the following points:
  o You may have come across the word “equilibrium” in your study of physics
  o If you look up the meaning of “equilibrium” in a dictionary you will find it explained using words like “state of balance”. A meter stick which is suspended at its center of gravity is said to be balanced or in equilibrium. A meter stick suspended at its center of gravity remains stationary or static. Thus, this type of equilibrium is often referred to as static equilibrium. In other words, the entire system is not moving.
  o Consider now the case of a man running on a treadmill. Overall, there is no change in the position of the man. He is running forward at the same speed as the belt is moving in the opposite direction. The two opposing motions balance each other. This is an example of a type of equilibrium called dynamic equilibrium, the word dynamic means “moving”.
  o Another example of a dynamic equilibrium is if you walk down an escalator at the same speed as it is moving up. There is no overall change in your position because the two opposing motions are balanced.
  o Chemical equilibrium is a state of dynamic balance where the rate of the forward reaction is the same as the rate of the backward reaction.
  o Examples of reactions at equilibrium
    \[
    \text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3
    \]
    \[
    2\text{NO}_2(g) \rightleftharpoons \text{N}_2\text{O}_4(g)
    \]

Activity 1 - Done as Demo
• Introduce to class idea of bottle of soda water. Does equilibrium exist inside the bottle?
• What gas is present in the bottle (dissolved and above the solution)?
• Remove gas from bottle by shaking and then trapping the gas in the balloon.
• Test for gas by pouring some of gas over lighted candle – diagram 2 (b). What can we deduce?
• Bubble gas into litmus indicator or cabbage juice (or better limewater). The gas is acidic (or turns limewater milky)– what is name of acid in the soda water?
• Discuss equilibrium inside bottle

\[
\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3
\]

Activity 2 & 3 – Done in groups of 2-4 students (students use Student Handout)

Activity 2
• Introduce concept of starch-iodine complex. Is this an example of an equilibrium reaction?
• Add a few drops of tincture of iodine to some starch solution. Note the formation of a blue-black color.
• Heat the solution to about 80 °C. Note that the blue-black color disappears. What can we deduce from this?
• Cool the container by placing it in ice. What do we observe.
• Discuss equilibrium with class:

\[
\text{Iodine} + \text{starch} \rightleftharpoons \text{Starch-Iodine complex}
\]

\[
\text{colorless} \rightleftharpoons \text{blue-black}
\]

Which direction is exothermic and which is endothermic? How do we explain our results?

\[
\text{Iodine} + \text{starch} \rightleftharpoons \text{Starch-Iodine complex}
\]

\[
\text{colorless} \rightleftharpoons \text{blue-black}
\]

\[
\text{exo} \rightleftharpoons \text{endo}
\]

Activity 3
• Place some black tea solution in three 125 mL Erlenmeyer flasks. One of these will be used as a control.
• To one of the flasks, add a few drops of vinegar. Note the change in color to a lighter color compared to the control.
• To another conical flask, add a few drops of ammonia cleaning solution. Note the change to a darker color compared to the control.
• Discuss shifting of equilibrium

\[
\text{Tea} + \text{H}^+ \rightleftharpoons \text{TeaH}^+
\]

\[
\text{dark} \rightleftharpoons \text{light color}
\]
Le Chatelier’s Principle
Student Sheet

Name(s): ____________________________Date: ________

Problem: How can Le Chatelier’s principle be used to predict the direction in which a system at equilibrium will shift when conditions are altered?

Materials: Tincture of Iodine, starch solution, black tea solution, vinegar, ammonia cleaning solution water, test tube rack, 6 test tubes, 250 ml beakers (2), hot water bath and cold water bath.

Prelab: The equilibrium system that we will look at in the Prelab to study is as follows:

\[ \text{CuCl}_2(\text{aq}) \rightleftharpoons \text{Cu}^{+2}(\text{aq}) + 2 \text{Cl}^-(\text{aq}) + \text{heat} \]

(green) (blue) (colorless)

1. Write out the balanced reaction between AgNO\(_3\) (aq) and CuCl\(_2\) (aq) and identify the precipitate formed.

   a) Does precipitation mean that the concentration of the compound that is the solid increases or decreases in solution?

2. For each change listed, predict the equilibrium shift, using the reactions above and your knowledge of Le Chatelier’s principle:

<table>
<thead>
<tr>
<th>Stress</th>
<th>Direction of Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raise temperature</td>
<td></td>
</tr>
<tr>
<td>Lower temperature</td>
<td></td>
</tr>
<tr>
<td>Add Ag(^+)NO(_3)</td>
<td></td>
</tr>
<tr>
<td>Add Na(^-)Cl</td>
<td></td>
</tr>
</tbody>
</table>

3. In the actual lab we are going to do uses reactants/products that are more benign to the environment.

\[ \text{Iodine + starch} \rightleftharpoons \text{Starch-Iodine complex} \]

(colorless) (blue-black)
Le Chatelier’s Principle
Lab direction Student Sheet

Name(s) _______________________________  Hour _____
Date __________

Procedure:
ACTIVITY 1:

1. Add a few drops of tincture of iodine to about 10mL of starch solution to each of the three test tubes. Make observations.
2. Heat one the test tube solutions to about 80°C and note the color in your chart.
3. Cool one the other test tubes by placing it in an ice-water bath.
4. Fill in the data table below with the observed color of the solution after each stress is added. The control group is the tube which is not stressed and the color of all stressed tubes can be compared to it.

Data:

<table>
<thead>
<tr>
<th>Stress</th>
<th>Resulting Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>Raise temperature</td>
<td></td>
</tr>
<tr>
<td>Lower temperature</td>
<td></td>
</tr>
</tbody>
</table>

ACTIVITY 2:

1. Place some black tea solution in three 50mL Erlenmeyer flasks. One of these will be used as a control.
2. To one of the flasks, add a few drops of vinegar. Note the change in color.
3. To another flask, add a few drops of ammonia cleaning solution. Note change in color.
4. Fill in the data table below with the observed color of the solution after each stress is added.

<table>
<thead>
<tr>
<th>Stress</th>
<th>Resulting Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>Vinegar addition</td>
<td></td>
</tr>
<tr>
<td>Ammonia addition</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion Questions:

1. In Activity 1, what affect did heating the test tube have on the concentration of Starch-Iodine complex? Explain how you know this by using Le Chatelier’s Principle.

2. What affect did cooling the test tube have on the concentration of Starch-Iodine complex? Explain how you know this by using Le Chatelier’s Principle.
3. Which direction is exothermic ________________.
   Which is endothermic?______________________ How do you explain your results?

4. In Activity 2 how could you determine whether or not a change occurred in equilibrium? Explain.

5. For each reaction in Activity 2, explain how each change can be explained by Le Chatelier's Principle. Be specific about what chemical was added that was part of your equilibrium system and discuss shifting of equilibrium.

6. Did these activities help you to understand Le Chatelier's Principle? Why or why not?

7. Which 12 Principles of Green Chemistry were used in this lab? What else could have been done to “green” up this lab?