Activity: Equilibrium Introduction

FOR THE TEACHER

Summary
In this activity, students perform a hands-on activity that models chemical equilibrium based on the article *Equilibrium: A Teaching/Learning Activity* by Audrey H. Wilson from the Journal of Chemical Education, Vol. 75, No. 9, September 1998.

Grade Level
High School

NGSS Alignment
This activity will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-6**: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

- **Scientific and Engineering Practices**:
  - Using Mathematics and Computational Thinking
  - Analyzing and Interpreting Data

AP Chemistry Curriculum Framework
This activity supports the following learning objectives:

- **Big Idea 6**: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.
  - **6.1** The student is able to, given a set of experimental observations regarding physical, chemical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes.
  - **6.4** The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, $K$, use the tendency of $Q$ to approach $K$ to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached.
  - **6.5** The student can, given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, $K$.
  - **6.6** The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, $K$, use stoichiometric relationships and the law of mass action ($Q$ equals $K$ at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction.

Objectives
By the end of this activity, students should be able to

- Recognize when equilibrium is reached.
- Recognize that at equilibrium the rate of the forward and reverse reactions are equal.
- Recognize that the concentration of products and reactants remain constant at equilibrium.
- Understand that equilibrium can be approached from many starting points and both directions.

Chemistry Topics
This activity supports students’ understanding of

- Chemical Equilibrium
Time

Teacher Preparation: 10 minutes
Lesson: 30 minutes

Materials (per group)
- 50 small items, such as toothpicks, matches, or pennies
- Student activity sheet
- Calculator

Safety
- No specific safety precautions need to be observed for this activity.

Teacher Notes
This activity is designed to introduce the concept of chemical equilibrium.

1. Divide students into small groups
2. Each group should have 50 small items, such as toothpicks, matches, or pennies and an activity sheet
3. Each group should be further divided into two groups – Reactants and Products
4. The Reactants and Products should start with the designated number of items and use the designated reaction rate.
5. For each step the Reactants and Products calculate how many of their items will “react” and be transferred to the other side.
   - If the calculated value is equal or greater than --.5, they should round up to the next whole number.
   - If the calculated value is less than --.5, they should round down to the last whole number
   - The calculated values should be entered into the data table.
   - The two groups will then swap their reacted items.
6. Repeat step 5 until equilibrium is reached.
7. Repeat the process for the values given for Activity 2 and 3.
8. When all groups have finished the activity, students should review their data and answer the follow up questions.
9. Lead a discussion about chemical equilibrium and have students use their data to support their answers.

   Note: After the initial activity you may want to have the groups use new initial conditions (concentration and reaction rate) and complete calculations in a new data table instead of using the small items and rounding.

   Answer key and student activity sheet are available as a download.

FOR THE STUDENT
Lesson

Chemical Equilibrium Introduction Activity

Objective
This activity is designed to introduce the concept of chemical equilibrium. At the end of this activity you should be able to recognize that when equilibrium is reached the rate of the forward and reverse reactions are equal and the concentration of products and reactants remain constant. You will also understand that equilibrium can be approached from many starting points and both directions.

Directions
Complete each of the following tasks using the tables on this activity sheet.
   1. Break up into groups of 2 or 4 students
2. Get 50 small items (toothpicks, matches, pennies) and an activity sheet
3. Divide your group into two smaller groups – Reactants and Products
4. The Reactants and Products should start with the designated number of items and reaction rate from the activity table.
5. For each step the Reactants and Products should calculate how many of their items will “react” and be transferred to the other side.
   o If the calculated value is equal or greater than -.5, round up to the next whole number.
   o If the calculated value is less than -.5, round down to the last whole number.
   o The calculated values should be entered into the data table.
   o The two groups will swap their reacted items.
6. Repeat step 5 until equilibrium is reached.
7. Repeat the process for the values given for Activity 2 and 3.
8. When you finish all three activities, review your data and answer the questions that follow.

**ACTIVITY 1** – Start with equal number of reactants and products. The rate of the forward reaction is greater than the rate of the reverse reaction.

<table>
<thead>
<tr>
<th>Step</th>
<th>Reactants - Rate $R \rightarrow P = 0.5$</th>
<th>Products - Rate $R \rightarrow P = 0.25$</th>
<th>Final</th>
<th>Reactants - Rate $R \rightarrow P = 0.5$</th>
<th>Products - Rate $R \rightarrow P = 0.25$</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>[Initial]</td>
<td>Amount Reacted</td>
<td>Amount Formed</td>
<td>[Final]</td>
<td>[Initial]</td>
<td>Amount Reacted</td>
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**ACTIVITY 2** – There are more reactants than products at the start of the reaction. The rate of the forward reaction is greater than the rate of the reverse reaction.

<table>
<thead>
<tr>
<th>Step</th>
<th>Reactants - Rate $R \rightarrow P = 0.5$</th>
<th>Products - Rate $R \rightarrow P = 0.25$</th>
<th>Final</th>
<th>Reactants - Rate $R \rightarrow P = 0.5$</th>
<th>Products - Rate $R \rightarrow P = 0.25$</th>
<th>Final</th>
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<tbody>
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<td>Initial</td>
<td>[Initial]</td>
<td>Amount Reacted</td>
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**ACTIVITY 3** – There are no products present at the beginning of the reaction. The temperature has increased.

<table>
<thead>
<tr>
<th>Step</th>
<th>Reactants - Rate $R \rightarrow P = 0.75$</th>
<th>Products - Rate $R \rightarrow P = 0.125$</th>
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<td>[Initial] Amount Reacted</td>
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1. Review your data and answer the following questions:
   o How did you recognize when equilibrium was reached?
   o Compare the rate of the forward and reverse reactions when equilibrium is reached?
   o What happens to the concentration of products and reactants when equilibrium is reached?
   o Do you have to initially have the same number of products and reactants present to reach equilibrium?
   o For Activity 3, were the forward and reverse reactions exothermic or endothermic?