Lab: Dynamic Equilibrium Simulation
FOR THE TEACHER

Summary
In this lab, students will explore equilibrium using paper clips to mimic a chemical reaction.

Grade Level
High School

AP Chemistry Curriculum Framework
This lab activity supports the following unit, topics and learning objectives.

- **Unit 7: Equilibrium**
  - **Topic 7.1: Introduction to Equilibrium**
    - TRA-6.A: Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations.
  - **Topic 7.2: Direction of Reversible Reactions**
    - TRA-6.B: Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions.
  - **Topic 7.9: Introduction to Le Châtelier’s Principle**

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

- Better understand what it means for a system to reach equilibrium.

Chemistry Topics
This lab supports students’ understanding of

- Equilibrium
- Le Châtelier’s Principle

Time
**Teacher Preparation:** 30 minutes
**Lesson:** 1 hour

Materials
For each group:

- ~60 paper clips
- timer

Safety

- No notable safety precautions need to be observed for this lab.

Teacher Notes

- Students should work in groups of four: Two people will put paper clips together, one person will take paper clips apart, and one person will be the timer and record data.
- Students are required to generate their own data table for the three parts.
FOR THE STUDENT
Lesson

Dynamic Equilibrium Simulation Lab

Background
You will be modeling the reaction: \( P + P \rightleftharpoons P_2 \)
by putting paper clips together (forward reaction) and taking them apart (reverse reaction). This simulation allows you to “stop” the reaction after a certain amount of time so that you can monitor the “concentrations” of the reactants and products. This is much more difficult to do with a real chemical reaction, so it is up to you to think about how the paper clips relate to a real chemical reaction.

To demonstrate equilibrium, you will need to simulate the forward reaction and the reverse reaction.

Prelab Questions
1. Why do you need to simulate the reverse reaction? (Explain using collision theory).
2. Why is it necessary for the person putting paper clips together to do so at a constant rate?
3. If you put paper clips together faster, what does that represent?
4. How will you know when equilibrium is established?
5. Challenge: How could you simulate adding a catalyst? How could you simulate increasing temperature?

Purpose:
1. To understand how and why equilibrium is established.
2. To understand equilibrium position and equilibrium constant.
3. To identify factors that affect the equilibrium constant, the equilibrium position, and the time it takes to reach equilibrium.

Procedure
PART I: ESTABLISHING DYNAMIC EQUILIBRIUM
1. Make a group of four people. Two people will put paper clips together (forward reaction), one person will take paper clips apart (reverse reaction), and one person will be the timer and record data. Clip the small ends together.
   *One variation*: Use a cover (box) and do all assemble/disassemble under the cover (box). Make a note whether you used a cover or not.
2. You need ~60 loose paper clips. The three reactors should do their part of the reaction as soon as the timer starts. After 60 seconds, count and record the number of loose paper clips (P) and the number of joined paper clips (P_2).
3. Continue for another 60 seconds, stop, and count and record the number of P and P_2. Continue these 60 second intervals until the RATIO of P and P_2 no longer changes (changes of 1–2 paper clips differences are okay).

PART II: FACTORS THAT AFFECT EQUILIBRIUM
Repeat part I twice, each time using one of the following options:
- Have two reverse reactors and one forward reactor
- Combine with another group (only one counter) and use new ratio of assemblers/disssemblers (not 2:1)
- Have reactors react as fast as they can (What does this simulate?)
- Have someone constantly removing P_2 as it gets made
Start with only $P_2$ molecules
Have someone arbitrarily start adding more P atoms
Have someone arbitrarily start adding more $P_2$ molecules
Clip the “big” ends together

Results
Data tables will differ based on number of trials, and chosen factors to investigate. Make your own data tables that will hold your data.

Calculations
Graph your three sets of data ($P$ and $P_2$ vs. time).
Find $K_{eq}$ for your three sets of data.

Analysis
1. How does the rate at which the paper clips are put together change with time? Explain in terms of collision theory.
2. How does the rate at which the paper clips are taken apart change with time? Why?
3. Define dynamic equilibrium. Does equilibrium mean that there are the same amounts of reactant and product?
4. Share your group’s data with all the other groups to analyze. You should share and compare your $K_{eq}$ from part I. Talk about the rate at which equilibrium was reached or if it was reached. Offer suggestions for the differences (make sure to indicate if they were using a cover box or not).
5. Share and collect data for part II with all the other groups to analyze. Again, share and compare your $K_{eq}$.
6. Assume that $P$ is red, and $P_2$ is blue. What color are the equilibrium solutions for any trial from part II? (ignore any that didn't reach equilibrium)
7. Why do you need to simulate the reverse reaction? (Explain using collision theory)
8. Why is it necessary for the person putting paper clips together to do so at a constant rate?
9. What would it represent if the person putting paper clips started putting them together faster?
10. How do you know that equilibrium has been established?
11. Challenge: How would you simulate adding a catalyst? How would you simulate increasing temperature?