Counting Equilibrium and Le Chatelier's Principle

ND EPSCoR Lesson Plan

Lesson Title: Counting Equilibrium and Le Chatelier's Principle

Lesson Overview:
Equilibrium is a key principle in chemistry, biology, physics and a host of other disciplines. When a system is at equilibrium, no change in the state of the system occurs unless an external force is applied. Two types of equilibrium exist in nature, static and dynamic. In a static equilibrium, no change occurs to a system over time because all forces acting on the system cancel. In a dynamic equilibrium, the system is continually changing, but each of these changes cancel, leaving the system in the same state. Almost all equilibria in chemistry and biology are dynamic.

Lesson Objectives:

- Students will be able to define the scientific terms system, surroundings, and equilibrium.
- Students will be able to describe the difference between a static and dynamic equilibrium and identify examples of each of these types of equilibria.
- Students will be able to predict how external forces will affect systems at equilibrium.

NSF Subject Classification: Chemistry and Biology

National Next Gen Standards:
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
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.
HS-ESS3-3. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.

North Dakota Standards:
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
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.
HS-ESS3-3. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.

Grade or Grade Band:
High School

Time Needed (estimate)
20 - 30 minutes per lesson

Lesson Author: LeAnn Heid is an elementary teacher who has been teaching since 2004. She is currently working on her master's in education for leadership and will have this completed in 2021. LeAnn was recruited to do work for ND EPSCoR in 2016 and the work has continued to evolve since. She has a passion for learning and teaching students about the many opportunities that STEM careers can encompass.
Leann_heid@bismarckschools.org

Scientist/K12 Collaborator & University: Alex Parent

Scientist Bio: I'm Alex Parent, an Assistant Professor of Chemistry and Biochemistry at NDSU. I grew up on the east coast and attended Clark University in Massachusetts for my Bachelor of Arts degree in chemistry and Yale University in Connecticut for my Doctor of Philosophy degree in chemistry. I then spent two years working in Fukuoka Japan researching sustainable energy. I am an avid hiker, and love walking the many parks in Fargo and occasionally getting out to the Badlands and upstate Minnesota to experience more vertical trails. (The things I miss most about New England and Japan are the easy access to hills and mountains!) I am also an avid board gamer, with Uwe Rosenberg games being some of my favorites. My research focuses on methods of generating materials from renewable resources, particularly on using air in chemical synthesis. My current projects include developing new catalysts for activating oxygen from the air and studying the process by which current catalysts utilize air to effect chemical transformations in paints.

Summary of Research and/or Problem Being Studied
How do we keep a system at equilibrium? When a system is at equilibrium, no change in the state of the system occurs unless an external force is applied. Two types of equilibrium exist in nature, static and dynamic. In a static equilibrium, no change occurs to a system over time because all forces acting on the system cancel. In a dynamic equilibrium, the system is continually changing, but each of these changes cancel, leaving the system in the same state. Almost all equilibria in chemistry and biology are dynamic.

Preparation/Materials

Background knowledge students must have to be successful
Elements of the period table
Systems within the environment

Essential Terminology
System: a set of things working together as parts of a mechanism or an interconnecting network
Surroundings: the things and conditions around a person or thing
Equilibrium: a state in which opposing forces or influences are balanced

Websites:
http://www.shodor.org/interactivate/activities/RabbitsAndWolves/

Materials needed:
Lesson 1:

- PowerPoint slides 3-7
- 2-3 Sheets of Graphing Paper
- 1 Marker
- 2 Cups
- 40-50 Coins or Candies
- 1 Pencil

Lesson 2:

- PowerPoint slides 8-10
- Activity 1 materials

Lesson 3:

- PowerPoint slides 12-14
- 2-3 Sheets of Graphing Paper
- 1 Marker
- 3 Cups
- 40-50 Coins or Candies
- 1 Pencil or 3 Colored Pencils

Lesson 4:

- PowerPoint slides 15-25
- A computer with internet access

PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1:

1. Use PowerPoint slides 3-7 to discuss equilibrium and activity 1.
2. Directions for Activity 1 are below and also on slide 6.
3. Have students use Activity 1 worksheet to record results during the experiment.
4. Label one of your cups “liquid” and the other cup “gas” using your marker.
5. Place 24 coin or candy “water molecules” in the “liquid” cup.
6. Make three columns on one sheet of graphing paper.
7. Label the columns “Time Step”, “Liquid”, and “Gas”.
8. Following example 1 below, move your “water molecules” between the “Liquid” and “Gas” cups, recording the number of “molecules” in each cup at each time step.
9. Continue moving “molecules” until the system reaches equilibrium.
10. Make a line graph of your equilibrium data using the step # as the x-axis and the number of “molecules” in each cup as the y-axis.
11. Leave all “molecules” in their respective cups for the next activity.

Lesson 2:

1. Use PowerPoint slides 8-10 to discuss perturbing a dynamic equilibrium and activity 2.
2. Directions for Activity 2 are below and also on slide 8.
3. Add an additional 20 “molecules” to the cup labeled “Gas”.
4. Record the number of “molecules” in each cup in your chart as before, and put an asterisk next to that time point.
5. Following the example above, move your “water molecules” between the “Liquid” and “Gas” cups, recording the number of “molecules” in each cup at each time point.
6. Continue moving “molecules” until the system reaches equilibrium.
7. Extend the line graph of your equilibrium data using your new data, marking on the graph the time point when the additional molecules were added.
8. Questions to ask students after the experiment.
   What happened to the number of “Liquid” molecules at equilibrium when you added more “Gas” molecules?
   What is the relationship between the equilibrium values before you added extra “Gas” molecules and the equilibrium values after you added the “Gas” molecules?

Lesson 3

1. Use PowerPoint slides 12-14 to discuss how to model a three point equilibrium and activity 3.
2. Directions for Activity 3 are below and also on slide 13.
3. Have students use Activity 3 worksheet to record results during the experiment.
4. Label one of your cups “Solid”, one cup “Liquid”, and the final cup “Gas”.
5. Place 40 coin or candy “molecules” into the “Solid” cup.
6. Make four columns on one sheet of graphing paper.
7. Label the columns “Time point”, “Solid”, “Liquid”, and “Gas”.

8. Following example 2 below, move your “molecules” between each cup, and record the number of molecules in each cup at each time point.
9. Continue moving “molecules” until the system reaches equilibrium.
10. Make a line graph of your equilibrium data using the time point as the x-axis and the number of “molecules” in each cup as the y-axis.
11. Once you have reached equilibrium, continue to example 3 below, which contains an irreversible reaction.

Lesson 4

1. Use PowerPoint slides 15 – 25 to discuss equilibria in the environment for directions to activity 4 or follow the steps below.
2. Navigate to http://www.shodor.org/interactivate/activities/RabbitsAndWolves/
3. Observe the simulation screen, zoom in if it is too small to see well
4. Identify what icons indicate wolves, rabbits, and grass
5. Click the button labeled “View Population Graph” to bring up a graph of the number of wolves and rabbits at each time point, as well as the percentage of grass at each time point.
6. Click the button labeled “Start Simulation” to begin the simulation of this food chain.
7. After the simulation reaches an equilibrium, or after 500 iterations, click the “Pause Simulation” button.
8. Record the results of your simulation in the questions below.
9. Click the button labeled “View/Modify Parameters”, then click the button labeled “View/Modify Start-Up Parameters” in the box that appears.
10. Modify the amount of starting grass, rabbits or wolves.
11. Predict what effect this will have on the simulated ecosystem.
12. Click the “Return to Simulator” button.
13. Click the “Reset Simulation” button.
14. Click the “Start Simulation” button.
15. Observe the population graph for your modified starting numbers and answer the questions below.
16. Try to find starting parameters that lead to a stable equilibrium population of rabbits and wolves.
17. If you find starting parameters that lead to a stable equilibrium, try running the simulation again with those parameters.

Extensions for above average students:

Higher level of balancing equations (equilibrium)

More in depth system

Mediation/Support for students that need it:

Peer to peer partnership

Lesson Outline (for research-based lessons)

Lesson 1:
- Intro to equilibrium
- Modeling a dynamic equilibrium activity

Lesson 2:
- Perturbing a dynamic equilibrium
- Le Chatelier's Principle

Lesson 3:
- Modeling a three-component equilibrium

Lesson 4:
- Equilibria and the environment
- Modeling a simple food chain

Standards Alignment

ND Science Standard(s):
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
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.
HS-ESS3-3. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.

Disciplinary Core Idea: e.g.

Life Science – changes to an ecosystem
Physical Science – change in a system to create equilibrium
Engineering – computational simulation

North Dakota DPI Standards:
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
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.
HS-ESS3-3. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.

Next Gen Standards:
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
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.
HS-ESS3-3. Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.

Science and Engineering Practices
Developing and Using Models
Analyzing and interpreting data
Using mathematics and computational thinking

Cross Cutting Concepts
- Stability and Change

Unit Objectives
- Students will be able to define the scientific terms system, surroundings, and equilibrium.

- Students will be able to describe the difference between a static and dynamic equilibrium and identify examples of each of these types of equilibria.
- Students will be able to predict how external forces will affect systems at equilibrium.

Assessment: Create a model (draw, on computer, written, etc) of a more complicated food web using what you learned about equilibrium.

Daily Plans and Assessments

Learning Target for each day/activity

Lesson 1 – Students will model dynamic chemical equilibria using candies or coins.

Lesson 2 - Students will predict and model what happens to dynamic equilibria when they are perturbed by an external factor. They will then discuss the theory used to predict changes in equilibria when they are perturbed.

Lesson 3 – Students will model a three-component system, and observe how adding a third component affects the nature of an equilibrium.

Lesson 4 – Students will model equilibrium in a more complex system, a simplified food chain, and predict how different external influences will affect the balance of this system.

Criteria for Success/Assessment for each activity

Completion of the activity worksheets and final assessment.

Additional Lesson Resources / Materials

References:

Websites for purchasing materials

All materials can be purchased at the dollar store or Walmart.