Pop-Bead Equilibrium

Overview

This activity uses large pop beads to simulate the behavior of a chemical reaction that eventually reaches equilibrium.

Key Concepts

- chemical equations
- chemical reactions
- equilibrium
- models

National Science Education Standards

Science as Inquiry

Abilities Necessary to Do Scientific Inquiry

- *Students use the pop-bead model to develop descriptions and explanations for a chemical reaction in equilibrium. (5–8)*
- *Students use the pop-bead model to develop chemical equations and charts to improve understanding of chemical reactions that are in equilibrium. (9–12)*

Physical Science

Properties and Changes of Properties in Matter

- *Students observe the pop-bead model to develop understandings about how substances combine to form new substances. (5–8)*

Structures and Properties of Matter

- *Students observe the pop-bead model to develop understandings about how a compound is formed when two atoms bind together chemically. (9–12)*

Chemical Reactions

- *Students observe forward and reverse reactions and chemical equilibrium through the pop-bead model. (9–12)*

Whole-Class Activity

Simulate a chemical reaction with pop beads to model how equilibrium is achieved.

Materials

- about 200 large pop beads
- large, shallow box or box lid
- blindfold
- graph paper
- timer or stopwatch

Procedure

1. Pour the pop beads into the box. Make sure the beads are separated and spread out in a single layer. Even though the beads are a variety of colors and shapes, all beads represent the reactant (A).

2. Assign students to the following roles:
   - The forward-reaction person will connect beads into pairs.
   - The reverse-reaction person will disconnect beads. This person will be blindfolded during the activity.
   - Two shakers will move the box back and forth at a regular pace.
   - Two counters will count the number of connected and unconnected beads at the end of each time interval.
   - The timer will use the stopwatch to measure 1-minute time intervals.

3. Have the shakers begin moving the box and the timer start the stopwatch.

4. As soon as timing begins, have the forward-reaction person connect the beads together into pairs as fast as possible to produce the product (A_2). (See Figure 1.) Have the blindfolded, reverse-reaction person try to find the connected beads and disconnect them as fast as possible. Shake the box for 1 minute. *What does the shaking simulate?*

Figure 1: Forward reaction

5. At the end of the 1-minute time interval, stop the process while the counters count the number of connected beads and the number of unconnected beads. Record these numbers in a table for each time interval.

6. Do not take apart any of the pop-bead pairs. Repeat steps 3–5 eight or nine more times to ensure equilibrium is reached.

7. Graph each of your data points on the same set of axes, with time on the horizontal (x) axis and the number of reactants and products on the vertical (y) axis. First, plot the number of products over time. Then on the same graph, plot the number of reactants over time. Label each appropriately. *What trend do you notice in the graph? Write a simulated chemical equation for the reaction of the pop beads.*

Instructor Notes

Tips and Instructional Strategies

- Large pop beads are typically marketed for babies and toddlers and are available online and at stores that carry children's toys and supplies. Sets come in a variety of shapes and colors. Tell students that all pop beads represent the reactant (A).
- It is best to have multiple setups so that all students in a class can participate as part of a group at the same time.
- Since equilibrium for a reaction can be approached from both the forward and reverse directions, students can also run the reverse reaction ($A_2 \rightarrow 2A$). For the reverse reaction, begin with all the pop beads connected in pairs as A_2 and measure how much A is formed and A_2 remains for the same time intervals and reaction conditions. To maintain the same reaction conditions, the same student must wear the blindfold as in the forward reaction and the beads should be shaken as in the forward reaction.

Explanation

The "reaction" being studied is:

$$2A \underset{blindfolded}{\overset{sighted}{\rightleftarrows}} A_2$$

At time zero, only reactants (A) are present in the system. As the forward reaction proceeds, the product (A_2) forms by the joining of two reactants ($2A \rightarrow A_2$). As more reactants are used up, their number decreases. As more products are produced, their number increases. (See Figure 2.)

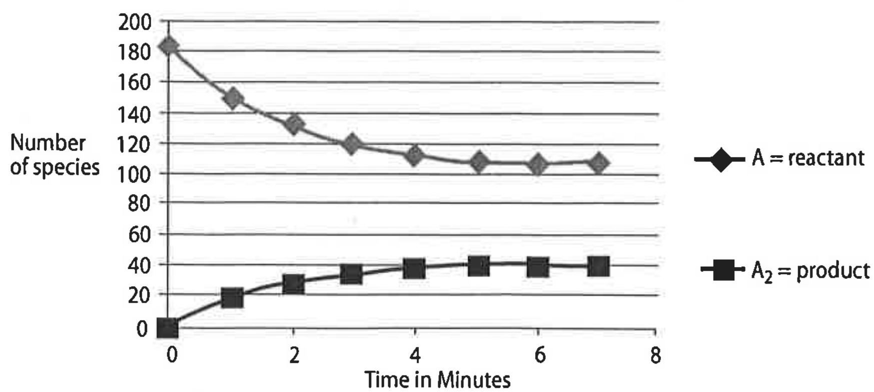

Figure 2: Equilibrium simulation

The reverse reaction ($A_2 \rightarrow 2A$) also occurs but is slow initially because not many product molecules are present and because the reverse-reaction person is blindfolded. As more product molecules become available in the mixture, the rate of the reverse reaction increases. Eventually, the rates of the forward reaction and the reverse reaction become equal and an equilibrium is established.

This activity models a chemical system in which the rate constant of the forward reaction (k_f) is greater than the rate constant of the reverse reaction (k_r). k_r is smaller because the reverse-reaction person is blindfolded and must disconnect the beads by the sense of touch, while the forward-reaction person can both see and feel the beads in order to connect them and so "reacts" at a faster rate.

As with any model, this one has limitations. Students should understand that the numbers of reactants and products that are counted and graphed in this activity are different than the concentrations that are used to calculate an equilibrium constant. In an actual chemical reaction, concentrations would be measured and plotted on the vertical axis of the graph and time on the horizontal axis. Concentration is not a number of items alone, but a ratio of the amount of substance in a given volume (for example, moles/liter). In this activity, concentration is modeled by the number of the specific species, A and A_2.

Answers to Student Questions

Step 4

The shaking simulates the random motion of the reactants and products in the reaction container (box).

Step 7

a. *Both lines will tend toward a horizontal line, which is the point at which the forward and reverse reactions are occurring at the same rate.*

b. $2A \leftrightarrows A_2$

Reference

Escudero, E. Summit Country Day High School, Cincinnati, OH. Personal communication, 2009.