Equilibrium Water Games

Introduction

Set up two water reservoirs containing different amounts of water and start bailing, swapping water from one container to another. Will the water level in each container keep changing? Will the water level eventually be the same in each container?

Concepts

- Reversible reactions
- Equilibrium
- Equilibrium constant

Materials

Beakers or large containers, 2-L, 2

Beakers, 50-mL and 100-mL, or other small containers, such as medicine cups

Water

Safety Precautions

Although this activity is considered nonhazardous, please observe all normal laboratory safety guidelines.

Procedure

1. Fill one large beaker ***(A)*** about 2/3-full with water. Leave the other beaker ***(B)*** empty. These will serve as water reservoirs in this activity.
2. Ask for two volunteers, one to measure the amount of water in each large beaker, the other to record results.
3. Measure and record the initial volume of water in beakers ***A*** and ***B***.
4. Recruit two additional volunteers to transfer water from beaker ***A*** to beaker ***B*** and vice versa. Volunteer ***A*** will use a 100-mL beaker, volunteer ***B*** will use a 50-mL beaker.
5. Instruct the two "water" volunteers to transfer water from one reservoir to another. They should fill their small beakers as full as possible without tipping the large beakers ***A*** and ***B***. Each student then pours the water into the other large beaker. Water cannot be "caught" during the pouring.
6. This is a partnership, not a race, and the students should work cooperatively to ensure that the water is transferred smoothly without spilling. *Note:* In the first cycle, only the student working from beaker ***A*** will be able to transfer any water.
7. Continue pouring water from one reservoir to another. Measure and record the volume or level of water in beakers ***A*** and ***B*** at the end of each pouring cycle.
8. As the demonstration proceeds, ask the class to predict what will happen to the level of water in the two reservoirs. Revise the predictions as needed.
9. When no further changes are observed in the level of water in beakers ***A*** and ***B***, introduce the term *equilibrium* to describe the results.
10. Using the transfer of water from beaker ***A*** to beaker ***B*** as an analogy, ask students to define the term equilibrium for a *reversible reaction* of the type A B. The definition should include both the properties of the system at equilibrium and how it is achieved.
11. *(Optional)* Why are the water levels different in the two beakers at equilibrium? Are there any conditions where the water level would be the same in each $\rightleftarrows$ beaker at equilibrium? Try the activity with two small beakers that are the same size.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (19960:

Unifying Concepts and Processes: Grades K–12
Constacy, change, and measurement
Evolution and equilibrium

Content Standards: Grade 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure of atoms, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder, interactions of energy and matter

Tips

- Use the largest beakers possible for the water reservoirs. Some teachers like to use aquariums for the reservoirs, and a variety of different size beakers to swap the water back and forth.
- One misconception with this activity is that the two reactions occur in an orderly fashion. A better physical analogy of a chemical reaction would be to have 30 students surrounding the two beakers and all of them transferring liquid as fast as they can—unfortunately, this would lead to complete mayhem and a mess.
- The following false ideas represent typical student misconceptions about the nature of chemical equilibrium. The concentrations of reactants and products must be equal at equilibrium. *(Having equal amounts of water in the two reservoirs at equilibrium is a special-case scenario that will be observed only if the small containers used to transfer the water are exactly identical.)* Reversible reactions occur in one direction only until all the reactants are depleted, then the reverse reaction begins to take place—think of this as the windshield wiper analogy. *(Both reactions take place simultaneously and reach a state of dynamic equilibrium when the amount of water being removed from each cylinder is the same.)* Use the results of this activity to ask students leading questions that will help them build more accurate models of chemical equilibrium.
- The physical analogy between this demonstration and chemical reactions is only a model. The most obvious place where the analogy breaks down is in the physical separation of reactants and products in separate beakers or graduated cylinders. In reality, of course, there is no “left side” or “right side” in a reaction mixture.

Discussion

This activity demonstrates by physical analogy many important concepts concerning chemical equilibrium. (1) At equilibrium, the rate of the forward reaction equals the rate of the reverse reaction. In the water games analogy, this is evident when the amount of water being removed from the container is the same as the amount being added. (2) The fact that the amounts of reactants and products remain constant once equilibrium is reached is the net result of a dynamic series of events, not a static condition. In the water games analogy, students should continue to transfer water for a few cycles even after the water levels become constant—there is no reason the process cannot continue indefinitely. (3) Equilibrium can be approached from either direction (from the reactant or product side). This is easy to demonstrate in the water games analogy by having different groups start with water in either the reactant or product reservoir.

The application of equilibrium to chemical reactions requires a closed system in which reactants and products are neither being added nor removed from the system. If reactants and products are somehow added or removed from the closed system, then the equilibrium condition is disturbed. LeChâtelier’s Principle predicts what will happen when the process continues and equilibrium is re-established. In the water games analogy, the amount of water present in the two reservoirs will be different after additional water is added and a new equilibrium position is achieved, but the ratio of water in the two reservoirs should be the same.

Graphing the results in Parts A and B—volume of water in each reservoir versus the number of times water has been swapped—is a valuable exercise. Students should be able to generate the same types of graphs that their textbooks show for the concentrations of reactants and products as a function of time in the approach to equilibrium.