

CHEMICAL EQUILIBRIUM SIMULATION

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MATERIALS NEEDED

2 clear or translucent, rectangular storage containers, approximately 11 x 16 inches square (10 L volume), such as Rubbermaid storage containers, small aquariums, etc.

Water

Food color

Beakers:

2 400-mL

1 250-mL

1 100-mL

1 50-mL

2 Graduated cylinders, 500-mL

SAFETY PRECAUTIONS

There may be water splashed on the table and floor during this experiment. Clean up spills to prevent someone from slipping and falling.

DISPOSAL

There are no disposal hazards in this experiment.

PROCEDURE

Fill one of the containers at least half-full of water. Add food color to increase visibility of the water.

Place the two containers, side-by-side, on a desk or large table in the front of the room. The container containing the water should be on the left, as viewed by the class. Place the graduated cylinders next to each of the containers.

Select two volunteers. Give each volunteer a 400-mL beaker, (Beakers should be the same size.) and have each of them stand behind one of the containers.

Ask each volunteer to scoop out a beaker full of the contents of their container and pour it into the large graduated cylinder. Note the volume of liquid. Pour the liquid back into the containers.

Ask each volunteer to scoop out beakers full of the contents of their container and pour it into the other container. They should continue to do this at their own rates. Ask the class what will happen to the liquid in the containers as the volunteers continue scoop the contents of their containers.

After the volunteers have transferred a few scoops of liquid to the other containers, stop them. Ask each volunteer to scoop out a beaker full of the contents of their container and pour it into the large graduated cylinder. Note the volume of liquids. Pour the liquid back into the containers.

Have the volunteers continue to scoop out beakers full of the contents of their container and pour it into the other container.

After the volunteers have transferred a few more scoops of liquid to the other containers, stop them. Ask each volunteer to scoop out a beaker full of the contents of their container and pour it into the large graduated cylinder. Note the volume of liquids. Ask the class "How is the amount of liquid being scooped out of each container changing?" Pour the liquid back into the containers.

Continue to have the volunteers to scoop out beakers full of the contents of their container and pour it into the other container. Continue to stop every few scoops to measure the amount of water being transferred. Note the volume of liquids. How is the amount of liquid being scooped out of each container changing? Pour the liquid back into the containers.

Eventually, both volunteers will be scooping the same amount of water from one container to the other. When this happens, a state of equilibrium has been reached. Show that the reaction does not stop, even though the same amount of material is present in each container, water is still being transferred in each direction. (Note: Equilibrium is a dynamic process and is characterized by the equal rates. The fact that the liquid remains equal in both containers is a macroscopic indicator that the system is at equilibrium, but it is not the equilibrium condition.)

Stop the simulation. Leave the water in the containers.

Select two new volunteers. This time give one volunteer a large beaker, such as a 400-mL beaker, and the second volunteer a small beaker, such as a 100-mL beaker.

Ask each volunteer to scoop out a beaker full of the contents of their container and pour it into the large graduated cylinder. Note the volumes of the liquids. Pour the liquids back into the containers.

Ask the class what will happen if the previous procedure of having the volunteers scoop water into the other containers is followed as before.

Have the volunteers scoop out beakers full of the contents of their container and pour it into the other container. Stop every few scoops to measure the amount of water being transferred. Note the volume of liquids. How is the amount of liquid being scooped out of each container changing? Pour the liquid back into the containers.

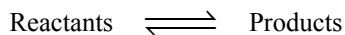
Eventually, both volunteers will be scooping the same amount of water from one container to the other. When this happens, a state of equilibrium has been reached. Show that the reaction does not stop, even though the same amount of material is being transferred in each direction. (Note: As indicated previously, equilibrium is a dynamic process and is characterized by the equal rates. In this part of the demonstration, the liquid levels are different in the two containers, but the rates remains equal. This reflects the kinetics of the reactions as the large beaker, which represents a faster initial reaction rate, is limited by the concentration of available reactant to the same rate as the smaller beaker. Unequal levels of water in the two containers is a truer reflection of the position of an equilibrium system.)

If desired, the demonstration can be continued using different size beakers.

After the equilibrium is established, and while the volunteers are scooping water back and forth, disturb the equilibrium by adding a liter or more of water (using a different color in the water) to one of the containers. What has happened to the equilibrium? What will happen as the volunteers continue to scoop the water between the two containers? This will illustrate the effect of a volume change on a system according to Le Châtelier's principle.

EXPLANATION

Equilibrium is a dynamic process. There are two reactions taking place simultaneously, the reaction of the reactants to form products and the reaction of products to form reactants.



In the first simulation, both the initial forward reaction rate and the initial backward reaction rate were the same (i.e., both beakers were the same size). As a result, both containers ended up with the same amount of water in them. But, be sure to emphasize that equilibrium occurs when the forward and backward rates are equal and that the reactions do not stop at equilibrium, they both continue at equal rates. The constant amount of water in each container is a macroscopic property of the equilibrium system.

In the second simulation, the forward reaction rate and the backward reaction rate were different (i.e., the beakers were different sizes). As a result, both containers ended up with different amounts of water in them, but, the rates of reaction were still equal (i.e., the same amount of liquid was being transferred in each direction). Again, the reactions do not stop at equilibrium, they both continue at equal rates which are limited by the amount of reacting material available to each specific reaction.

Le Châtelier's principle states that if a system in equilibrium is disturbed by a stress, then, as long as the equilibrium system is not destroyed beyond recovery, the system will counteract that stress and return to an equilibrium state. The effect of the additional colored water is the stress applied to the equilibrium system.