VISUALIZING CHEMICAL EQUILIBRIUM

David A. Katz
Chemist, Educator, Science Communicator, and Consultant
133 N Desert Stream Dr., Tucson, AZ 85745, USA
Voice/fax: 520-624-2207 Email: dakatz45@msn.com

Materials Needed

2 large, clear or translucent, rectangular containers, at least 28 x 40 cm (11 x 16 inches) square, such as Rubbermaid storage containers, small aquariums, etc.
beakers, 400-mL, 250-mL, 100-mL, and 50-mL
2 graduated cylinders, 500-mL
water
food color

Safety

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

Experimental 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. (See Figure 1)

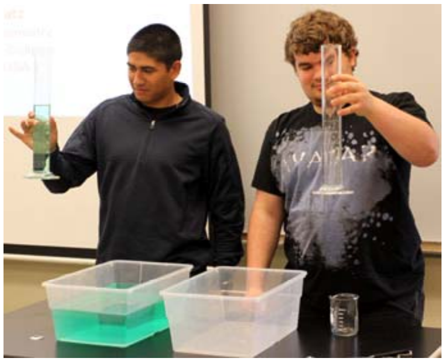

Figure 1. Students compare one "scoop" of material from each container

Ask each volunteer to scoop out a beaker full of the contents of their container and pour it into the other container. Ask the class what will happen to the liquid in the 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. (See Figures 2 and 3)

Have the volunteers continue to scoop out a beaker 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. How is the amount of liquid being scooped out of each container changing? Pour the liquid back into the containers.

Figure 2. Students scoop liquid between two containers

Continue to have the volunteers to 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.

Figure 3. After transferring some liquid, students measure volumes being transferred.

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 and that the same amount of material is being transferred in each direction. (See Figure 4)

Stop the simulation. Leave the water in the containers.

Continue the process with the same students or with 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.

Figure 4. Eventually, an equilibrium state is reached, where students are transferring equal volumes of liquid between the two 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. (See Figure 5)

Eventually, both volunteers will be scooping the same amount of water from one container to the other. When this happens, a new 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. (See Figure 6)

After the equilibrium is established, and while the volunteers are scooping water back and forth, disturb the equilibrium by adding a few liters of water (using a different color in the water) to one of the containers. What will happen as the volunteers continue to scoop the water between the two containers? This will illustrate Le Châtelier's principle.

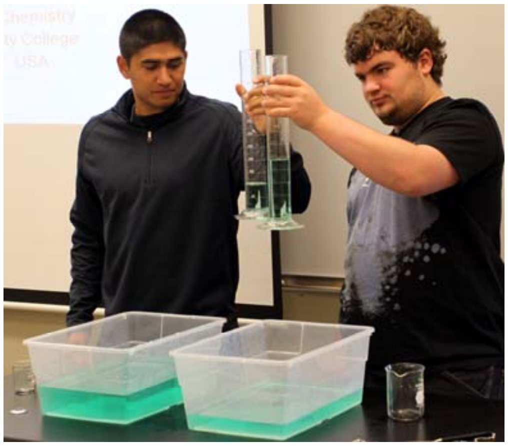

Figure 5. One student (on the left) now has a 100 mL beaker while the other has a 400 mL beaker

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.

$$\text{Reactants} \leftrightarrows \text{Products}$$

In the first simulation, both the forward reaction rate and the 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. Be sure to emphasize the reactions do not stop at equilibrium, they both continue at equal rates as illustrated by the students continuing to scoop water between the two containers.

Figure 6. A new equilibrium condition has been reached.

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, 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. After continued transfer of water between the two containers, equilibrium will be reestablished.