Dynamic Equilibrium: Which Way Do We Go?

Why?

The word dynamic means that a system is in motion. The word equilibrium means that the system is stable and does not change. How can one have a system that's in motion and in equilibrium at the same time?

Success criteria

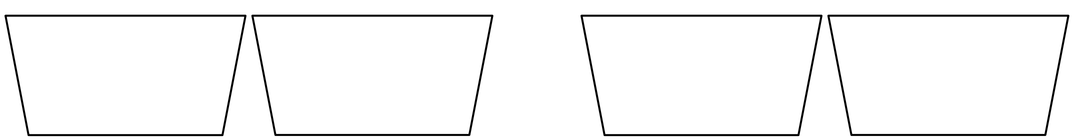
- Define dynamic equilibrium.
- Describe a system at equilibrium in terms of the equilibrium equation and by using particle model diagrams.
- Interpret an equilibrium system from a graph of concentration versus time.

Task

Participate in the demonstration about equilibrium with two clear containers (4L fish tanks work well) of water (or watch closely as the demonstration is being shown.) Predict how the system will look once equilibrium is reached.

Key Questions

1. Draw a line in each container to show the initial water level and the water level when the system is at equilibrium.



Initial Equilibrium

2. Once the system has reached equilibrium, what do you think would happen to the water levels if we continue the demonstration for 24 hours?

3. Why is this demonstration an example of a system at equilibrium?

4. Why is this equilibrium system dynamic?

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5. What are two limitations of the “container” demonstration that was used at the start of this activity to illustrate a physical or chemical equilibrium?

6. Suggest another analogy for a dynamic equilibrium system other than the container demonstration.

Exercises

1. An example of phase equilibrium is ice in liquid water at $0^{o}C$ as shown in the photo.

(http://www.raynewater.com/Glass%20with%20ice%20and%20lemon.GIF)

In the space below, draw a particle model diagram that shows ice and water as a dynamic equilibrium between the solid phase and liquid phase of water.

2. A saturated solution that contains some of the solid solute at the bottom of the container is called a solution equilibrium system. An example of solution equilibrium with table sugar (sucrose) is shown by the equation below.

$$C_{12}H_{22}O_{11}(s) \xleftrightarrow{water} C_{12}H_{22}O_{11}(aq)$$

What do you see in this equation that indicates this is a dynamic equilibrium system?

3. In the space below, draw a particle model diagram for this solution equilibrium system.

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An example of a chemical equilibrium can be found in the production of ammonia by the Haber process. In this reaction, nitrogen and hydrogen react to form ammonia as shown in the equation below.

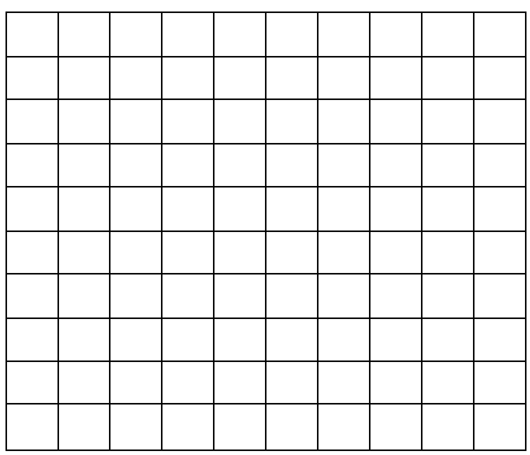
$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + 91.8\ kJ$$

The data table below shows measured amounts of nitrogen, hydrogen, and ammonia over a period of time in a system that starts out containing only nitrogen and hydrogen.

Time (min.)	Concentration of nitrogen (M)	Concentration of hydrogen (M)	Concentration of ammonia (M)
0	1.00	1.00	0
1	0.97	0.91	0.06
2	0.94	0.82	0.12
3	0.92	0.76	0.16
4	0.92	0.76	0.16
5	0.92	0.76	0.16

Label and mark appropriate scales on the axes and plot the data from the table. Label the x-axis "time" and the y-axis "concentration." Use a different symbol for each of the components in the reaction.

Concentrations of reactants and products
in the Haber process versus time



5. At what time does the system in question 4 reach equilibrium? Explain.

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Applications

1. Write an equilibrium equation for the phase equilibrium that occurs in a sealed bottle of bromine at 25°C.

2. Go to the Website for the "Mission to Mars" www.sasked.gov.sk.ca/docs/chemistry/mission2mars/

   Copy the equilibrium equation found on the first page of the website. This equation shows the production of methane and water.

3. On the "Mission to Mars" site click on the link, "single user logon". Look in the menu on the left and click on "Changing Equilibrium". Look in the menu on the left again and click on "Methane for nothing?"

   Is this process endothermic or exothermic?

4. Rewrite the equation from answer #2 with the energy term written on the correct side of the equation.

   For the Mission to Mars, it says, "*Methane for nothing and the oxygen is free*." Explain, in terms of materials and energy, why neither the methane nor the oxygen is really free.

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