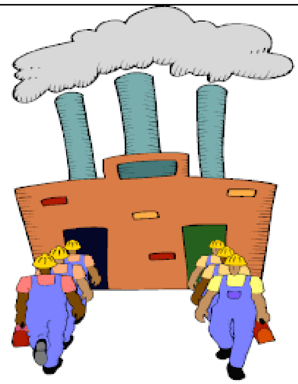
Activity: Dynamic Equilibrium

Model 1: Dynamic Equilibrium



Acme Manufacturing has been restricted to 100 employees in the building at one time. Throughout the day, twenty employees go on break each hour as twenty other employees return from break.

Chemical Equilibrium

$$2H_2\,(g) + O_2\,(g) \leftrightarrow 2H_2O\,(g) + \text{energy (heat)}$$

Questions

1. How many employees move in and out of the factory building during each hour? ________

2. Are the employees who move in and out of the building each hour the same people? Explain your answer.

3. Does the number of employees in the building change from hour to hour? Explain your answer.

4. Over the course of a day, the employees in the Acme Manufacturing Plant are said to be in a "dynamic equilibrium", Based on your understanding of how the staff move in and out of the plant, explain what is meant by the term "dynamic equilibrium".

A new faster and simpler check-in/check-out process has been proposed for workers at the Acme Manufacturing Plant. Some workers have said that this new process acts like a catalyst. (A catalyst is a substance that speeds up a chemical reaction without changing the outcome of the reaction and without being used up in the process.)

5. Would this new check-in/check-out process change the number of people in the building at any given time? Why or why not?

6. What would be the effect of the new check-in/check-out process on the workers at the factory? Support or refute the idea that the new check-in/check-out process is like a catalyst.

Like the Acme Manufacturing Plant, chemical reactions can also reach equilibrium. Answer the following questions about the chemical equation in Model 1 by applying the insight you gained from the Acme Manufacturing Plant questions.

7. When the reaction between hydrogen and oxygen **reaches equilibrium**:
   a. Does the number of molecules in the reaction vessel change? Explain.

   b. Is the reaction still proceeding in the forward direction? ___________________

   c. Is the reaction still proceeding in the reverse direction? ___________________

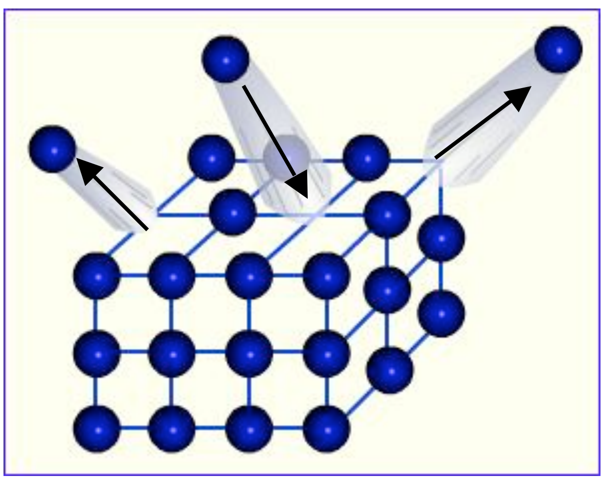
   d. Are the concentrations of the products and reactants changing? _______________

   e. Are the rates of the forward and reverse reactions the same? ________________

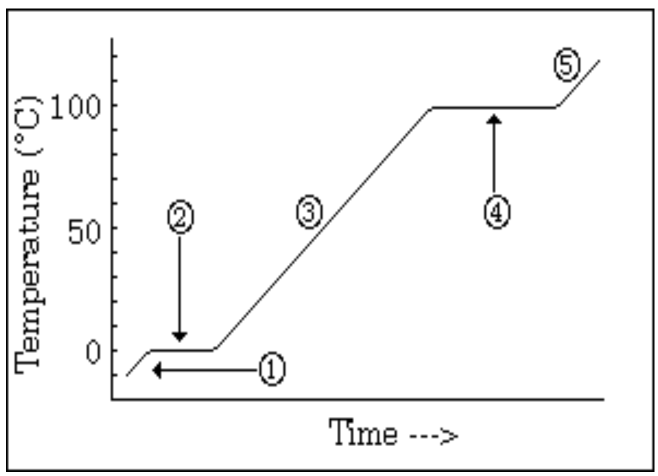
   f. Does the heat content of the system become constant? _________________

Model #2: Phase Change Equilbrium

An example of **phase equilibrium** is ice mixed with liquid water and held at 0 ^{o}C.



Particle Diagram for H_2O (S) ←→ H_2O (l)



Heating Curve for Water

1. For true equilibrium to occur, how many particles would be leaving the crystal lattice and becoming a liquid particle, for every one that is returning?

2. Which segment on the heating curve where this equilibrium COULD occur:

   H_2O (l) ←→ H_2O (g)

3. If this system is to ACTUALLY be kept in a state of solid ←→ liquid equilibrium, at what temperature would the glass of water need to be kept?

4. When solid ←→ liquid equilibrium is reached:
   will any ice be melting?
   will any ice be forming?

5. Why doesn't an ice/water system achieve a state of equilibrium when it sits out on the table during meal time?

6. Write an equilibrium equation for the phase equilibrium that occurs in a sealed bottle of bromine at 25°C. Use Table S to determine the state of Br_2.

Model #3: Chemical Equilibrium

The reaction below is reversible, so some of all three substances were put in the container to begin with. The gases are sealed in a vessel and held at a constant temperature. A probe is used every minute to measure the concentration of each gas, as shown in the chart below.

$$H_2\,(g) + I_2\,(g) \rightleftharpoons 2\,HI\,(g)$$

Time (min)	$[H_2]$	$[I_2]$	$[HI]$
0	0.22	0.22	0.04
1	0.18	0.18	0.12
2	0.16	0.16	0.16
3	0.15	0.15	0.18
4	0.15	0.15	0.18

1. What is happening to the concentrations of H_2 and I_2 as time goes by?

2. What is happening to the concentration of HI as time goes by?

3. Based on questions #1 and #2, which reaction is proceeding more rapidly at first, the forward one or the reverse one? How do you know?

4. Notice that the concentration of H_2 and I_2 diminished by 0.4 going from 0 to 1 minute. Simultaneously, the concentration of HI increased by twice as much, or 0.8. Can you determine why this is so? (HINT! Look at the coefficients in the balanced equation…)

5. Was equilibrium achieved at 2 minutes, or at 3 minutes? Explain!

Practice:

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.

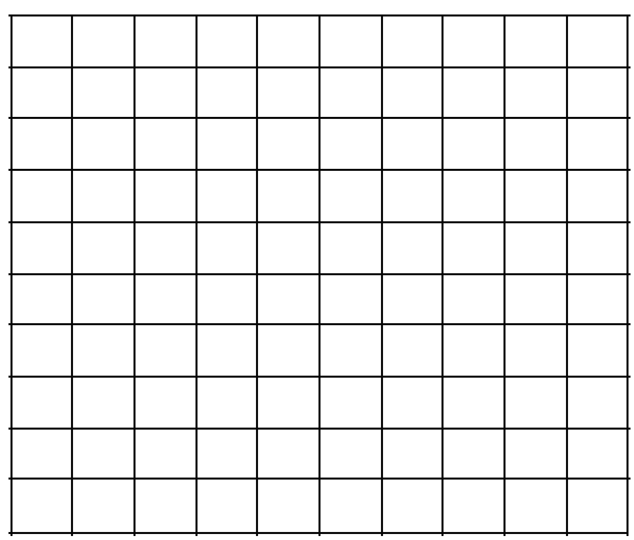
$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 91.8\ kJ$$

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

1. 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.

<u>Concentrations of reactants and products</u>
<u>in the Haber process versus time</u>



2. At what time does the system in question 4 reach equilibrium? How do you know?