

## An Equilibrium Analogy

The countries which have the greatest seasonal variations have the most diversified landscape, while in countries where the seasonal variations are slight the uniformity of landscape is at its maximum. Consideration will show that the same equations hold good for human nature.

.....- 5th century BC Hippocratean School of Medicine

### Introduction

Many chemical reactions are **reversible**. Both forward (toward products) and reverse (toward reactants) reactions occur. At any instant, even after equilibrium has been achieved, there is a conversion of reactants to products as well as of products to reactants. What then does equilibrium mean? To construct an analogy for equilibrium we consider the reaction,



where the concentrations of A and B are represented by the water levels in two graduated cylinders.

### Procedure

1. Obtain two 50.0 mL graduated cylinders labeled A and B. Then, obtain 2 pieces of glass tubing, one labeled A and one labeled B. Fill cylinder A with 50.0 mL of water. One partner is responsible for the A tube and the other partner is responsible for the B tube.
2. Lower tubes A and B into cylinders A and B, respectively. With the tubes touching the bottoms of the cylinders, place one index finger over the top end of each. Keeping your fingers over the ends of the tubes transfer the contents of tube A to cylinder B and the contents of tube B to cylinder A. Remove the empty tubes and record in your lab notebook the volumes of fluid in both graduated cylinders.
3. Repeat step 2 until you think **equilibrium** is reached. **Note:** Tube A is always returned to cylinder A for refilling and tube B is always returned to cylinder B for refilling. Consult your instructor when you feel equilibrium has been achieved. Then repeat step 2 a final time. **What is equal at equilibrium?**
4. Use a 10 ml graduated cylinder and measure the volume of water trapped in each glass tube when equilibrium has been established. Record these volumes in your lab notebook. **What is equal at equilibrium?**
5. Once equilibrium is established put an asterisk beside the entries in your data table. Now add a 10.0 ml "perturbation to cylinder A. Repeat the transfer process of part 2, above, until a new equilibrium is established. Again record the final volumes at equilibrium and the volumes trapped by each of the transfer tubes.

## Guided Discovery

Using Excel, plot the volume of water versus the number of transfers for each of A and B on the same graph (same axes). Join each set of points with a smooth curve. Use a different color for A and B. Continue the curves to include the 10 ml perturbation but do not try and smooth the new curve to the first. **Insert this plot and answer the following questions in your lab report.**

1. Think of the experiment above as an analogy for a simple chemical reaction in which a compound A is converted into a compound B. Identify what property of a chemical reaction system is being represented by the following:

- A) Volume of water in each cylinder
- B) Number of transfers
- C) Volumes of water transferred

2. How do you know when the experiment performed today reaches equilibrium?

And then, by analogy, when does a reaction system reach equilibrium?

3. What is equal at equilibrium for today's experiment and for a reaction system?

4. Compare the relative rates of the forward and backward reactions before and after the perturbation. That is, how were the transferred volumes affected by the perturbation?

5. How does the new equilibrium differ from the original equilibrium?

**In a reversible reaction the equilibrium state can be shifted either to the left (toward reactants) or to the right (toward products) by an alteration in the reaction conditions.** In our analogy the perturbation was made by adding reactants (cylinder A).

6. In which direction did the perturbation shift the reaction (look at the equilibrium position)?

7. What modification of this experiment would shift the equilibrium toward reactants?

8. What modification of this experiment would make the reaction irreversible?

**Conclusion:** What has this experiment helped you to learn? What questions still remain for you?