EXPERIMENT 4
THE EQUILIBRIUM GAME

PURPOSE:

To use a physical model system to illustrate the approach to chemical equilibrium.
This is a model for understanding how the concentration of reactants (A) and products (B) change with time as equilibrium is achieved.

$$\mathbf{A} \rightleftarrows \mathbf{B}$$

PRINCIPLES:

Two students making simultaneous transfers of water from one cylinder to another will accomplish this study of the approach to equilibrium. The transfer of water from cylinder A to cylinder B is analogous to the forward reaction in a chemical change, which results in a decrease in the amount of reactants as they form products.
Likewise, the transfer of water from cylinder B to cylinder A is analogous to the reverse reaction, which results in a decrease in the amount of products, as they form reactants.
The number of transfers that occur is analogous to the time course for the reaction.
Both the forward reaction and the reverse reaction are occurring at the same time throughout the attainment of equilibrium. The degree of change in the volume in the cylinders is analogous to the rate of change in the concentrations of reactants and products as equilibrium is approached. These rates, or degrees of change, become constant and equal to each other when equilibrium is reached.
There is a significant difference, however, between this physical model and a chemical reaction approaching equilibrium. Among other differences, in chemical systems the forward reaction and the reverse reaction are occurring in a **single container** rather than two.

PROCEDURE:

1. Working in pairs, label a 25 mL graduated cylinder “A” and fill it to the 25.0 mL mark with water.
   Label a second 25 mL graduated cylinder “B” ; rinse it out and shake as much water out as possible. Leave it empty.
2. Rinse two glass tubes of **different diameters** withwater and drain as much as possible. **Use the larger diameter tube with cylinder A.**
3. Simultaneously (at exactly the same time as) with your partner, lower a glass tube into each of the two cylinders, **without blocking the open ends of the tubes**.
   After the tube reaches the **bottom** of the cylinder, place your index finger over the top end of the glass tube and hold down tightly.
   Carefully transfer the contents of the tubing to the other graduated cylinder and allow to drain.
   Read the volumes in the cylinders (nearest 0.1 mL) only after both transfer tubes have drained completely.
4. Record the volume in both cylinders after the transfer. Use a table in your notebook with the following headings:

Number of Transfers	Volume in A (mL)	Volume in B (mL)

   Expect about 20-30 rows of entries.

5. Repeat steps #3 and #4 five more times after equilibrium has been reached.

NOTES: Consult with your instructor if you are not sure when equilibrium has been reached.

Always return the same glass tubing to the same cylinder !

Record the total volume in each cylinder (A and B) after every transfer!

ANALYSIS:

1. Construct a graph by recording the data for both cylinders on the same graph. Plot the 'Volume of Water" on the Y axis versus the "Number of Transfers" on the X axis. Label each axis and join each set of points with a **smooth curve.** Label the two smooth curves "A" and "B" respectively.

2. The change in the volume (ΔV) in each of the cylinders is analogous to the change in concentration (ΔC) of the reactants and products during a chemical reaction. The change in the number of transfers (Δ # transfers) is analogous to the change in the time (Δt) during a chemical reaction. It follows:

$$\frac{\Delta V}{\Delta \#\ \text{transfers}} = \frac{\Delta C}{\Delta t}$$

Note that the ratio ΔV/ Δ # transfers is the slope of the plot of any given transfer. Note also that this slope is decreasing as the number of transfers increases. After a large number of transfers have occurred, the slope is very small, or zero (the smooth curve is almost flat). This situation is analogous to the approach to equilibrium where the rate of change of the concentrations of the reactants and products is very large at the beginning, but becomes less and less as the reaction proceeds. After long times, the rate of change of the concentration of both reactants and products becomes zero; at this point the reaction has reached chemical equilibrium.

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NAME: ___________________________
PARTNER: ________________________

REPORT FORM

Enter your readings into the table below and construct a graph.
Enter volumes to the nearest 0.1 mL

Number of transfers	Volume in A (mL)	Volume in B (mL
0	25.0	0.0
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
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1. (a) From your graph, how many transfers are required before the volumes in the cylinders are equal to each other ? __________

   (b) At this point, is the physical system at equilibrium ? ____________

   (c) Why or Why not ?

   ____

   ____

   ____

2 (a) From your graph, determine the approximate number of transfers needed to reach equilibrium: _________ Indicate this clearly on your graph.

   (b) For both A and B, what is the degree to which the volume changes with additional transfers past this point ?

   ____

   ____

3. (a) If the tubing with the narrower inside diameter was used to remove volume from cylinder A, which cylinder, A or B, will have the larger volume at equilibrium ? _____

   Why ?

   ____

   ____

   ____

4. (a) If the situation above in 3(a) represented reactants A and products B, is the equilibrium constant, K_{eq}, greater or less than 1 ? ______________________ Explain your answer

   ____

   ____

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