## Determining the Stoichiometry of a Reaction by Continuous Variation

The stoichiometry of a chemical reaction can be determined experimentally, even if the identity of the products of the reaction are unknown, by a method called continuous variation. In this method, the ratio of reactants is varied while some physical characteristic of the reaction is monitored. The reaction will display the largest change in the physical characteristic when the "correct" reaction stoichiometry is reached. In this experiment, we will be studying a reaction that liberates heat; therefore, we will observe the temperature changes of a variety of mixtures of the two reactants, hypochlorite ion and thiosulfate ion.

$$x\ ClO^-(aq) + y\ S_2O_3^{2-}(aq) \rightarrow \text{products}$$

**Safety Concerns:** Hypochlorite ion is the active component in household bleach. Avoid contact with clothing and skin, rinse thoroughly with water if contact occurs. Some of the mixtures you test will liberate small amounts of vapor that may have an unpleasant odor; these fumes are not especially hazardous, they can be unpleasant.

### Procedure:

1. Open the Logger Pro program. The program should automatically detect the temperature probe. Set up the program to record temperature vs. time and adjust the data collection parameters to collect for 600 seconds.
2. Place a polystyrene cup in a beaker and add 25.0mL of hypochlorite ion solution to the cup. Place the temperature probe in the solution. Obtain 25.0mL of thiosulfate solution and click "Collect". Allow the program to collect 10-15 seconds of data to establish an initial temperature, then add the thiosulfate solution to the cup, continuously stirring the mixture with the temperature probe. Continue collecting data for at least 20 seconds after the temperature reaches a maximum. Record the initial temperature, the maximum temperature and the change in temperature. You do not need to save this graph.
3. Repeat the experiment using varying amounts of each reagent, but always keep the total volume of the reaction at 50.0mL. ***Collect at least 4-5 data points on each side of the ratio that gives you the largest change in temperature.*** Remember, you are looking for trends in the data, not a single "correct" point.

### Data Analysis:

Throughout this experiment, we are changing 2 variables (concentration of hypochlorite ion and concentration of thiosulfate ion). Normally, that would make data analysis difficult, but because of the nature of this reaction we can combine the 2 variables into a single quantity called mole fraction.

1. Calculate the moles of each reagent for each run. Mole fraction is defined as:

$$\text{Mol fraction of component "A"} = \frac{\text{mols of component "A"}}{\text{total mols of solute}}$$

   Calculate the mol fraction of $ClO^-(aq)$ and the mol fraction of $S_2O_3^{2-}(aq)$ for each of your data points.
   - ► Are these two values related? If so, how?
2. Prepare graphs of $\Delta T$ vs. {mol frac. $ClO^-(aq)$} and $\Delta T$ vs. {mol frac. $S_2O_3^{2-}(aq)$}.
   - ► How are these graphs related? Explain this relationship based upon your answer above.
3. You may not have taken a measurement at the "real" maximum value of $\Delta T$, but your data should be linear before and after this point in your graphs. Fit a line to the trends on either side of your maximum and determine the value of the mol fraction at the point of maximum $\Delta T$.

**Be sure that each person saves or prints a properly formatted and annotated Temperature vs. Mol Fraction graphs before you leave lab.** The easiest way to attach the graph to your hand-in is to use the Snipping Tool accessory and paste the graph directly into a Microsoft Word file.

### Questions for Analysis:

Address the following questions as you interpret your data and prepare your hand-in.

1. How are the trends and transitions in your graph(s) related to the limiting reagent in each experiment?
2. Describe any similarities or differences between this experiment and the Aluminum + HCl experiment. Could the method of continuous variation have been used to analyze the data from the Aluminum + HCl experiment? Could continuous variation have been used in the conductivity experiment? What modifications to the experimental procedure, if any, would have been necessary?
3. Based upon your results, what is the stoichiometric relationship between hypochlorite ions and thiosulfate ions in this reaction? {Notice that although we can balance the reactants side of the reaction using the data we have collected, we *still* don't know what the products of this reaction are.}