Determining the Mole Ratios in a Chemical Reaction

A balanced chemical reaction equation gives the mole ratios of the reactants and the products as coefficients. When some of the chemical formulas are not known, an experiment must be conducted to help determine the mole ratios.

This experiment uses two common substances as the reactants: hypochlorite ion (OCl^-) from household bleach and thiosulfate ion ($S_2O_3^{2-}$), the active ingredient in a photographic "fixer" solution used to develop film. In the reaction, hypochlorite ions oxidize the thiosulfate ions according to the unbalanced and incomplete reaction equation below.

$$A\ OCl^- + B\ S_2O_3^{2-} \rightarrow \text{products}$$

It is possible to identify the coefficients, *A* and *B*, for the reactants, without knowing the products of the reaction. The process that you will use to determine the coefficients is called *continuous variations*. You will prepare a series of mixtures of the two reactants. Each mixture will have the same total volume and the same total number of moles of reactants. The reaction is exothermic, thus the mixture that generates the most heat energy will be the reaction that completely consumes both the hypochlorite and the thiosulfate ions. You will use this mixture to establish the coefficients, and therefore the mole ratio, for the reaction.

OBJECTIVES

In this experiment, you will

- Measure the enthalpy change of a series of reactions.
- Determine the stoichiometry of an oxidation-reduction reaction in which the reactants are known but the products are unknown.

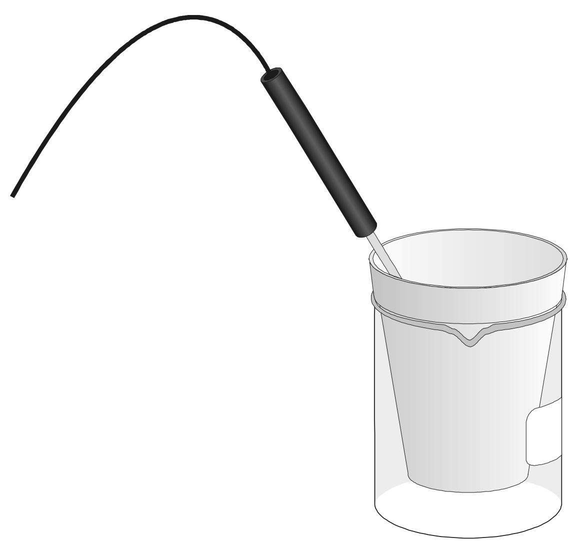

Figure 1

MATERIALS

Vernier computer interface
computer
Temperature Probe
two 10 mL graduated cylinders
two 25 mL graduated cylinders
two 50 mL graduated cylinders
three 250 mL beakers
0.50 M sodium hypochlorite, NaOCl, solution
0.50 M sodium thiosulfate, $Na_2S_2O_3$, solution in 0.2 M sodium hydroxide, NaOH
Styrofoam® cups

PROCEDURE

1. Obtain and wear goggles.
2. Connect a Temperature Probe to Channel 1 of the Vernier computer interface. Connect the interface to the computer with the proper cable.
3. Start the Logger *Pro* program on your computer. Open the file "09 Mole Ratio" from the *Advanced Chemistry with Vernier* folder.
4. Obtain about 200 mL of each of the reactant solutions, NaOCl and $Na_2S_2O_3$.
5. Measure out precisely 25.0 mL of the 0.50 M NaOCl solution. Pour this solution into a Styrofoam cup and nest the cup in a beaker to help stabilize the cup (see Figure 1).
6. Immerse the tip of the Temperature Probe in the Styrofoam cup of NaOCl solution.
7. Measure out precisely 25.0 mL of the 0.50 M $Na_2S_2O_3$ solution. **Note:** Do not mix the two solutions yet.
8. Click 

 to begin data collection. Let the program gather and graph a few initial temperature readings, and then add the $Na_2S_2O_3$ solution. Gently stir the reaction mixture with the Temperature Probe.
9. Data collection will stop after 3 minutes. You may click 

 to end data collection before three minutes have passed, if the temperature readings are no longer changing.
10. Examine the graph to calculate and record the maximum temperature change.
    a. To determine the highest temperature, click the Statistics button, . The minimum and maximum temperatures are listed in the statistics box on the graph. It may be necessary to examine the graph to determine the initial temperature, if the minimum temperature is not suitable.
    b. Open Page 2 of this experiment file by clicking on the Next Page button, . The table in this file is already set up for you to enter data. In the first line in the table, enter the volume of hypochlorite for the trial you just completed, as well as the temperature change, in °C.
    c. Return to Page 1 of the experiment file.
11. Rinse out and dispose of the reaction mixture as directed.
12. Repeat the necessary steps to continue testing various ratios of the two solutions, keeping the total volume at 50.0 mL, until you have three measurements on either side of the ratio that produced the greatest temperature change.

13. Print a copy of your final Page 2 graph (change in temperature *vs.* volume of hypochlorite).

DATA TABLE

Volume OCl^{-} (mL)	Volume $S_2O_3^{2-}$ (mL)	Temperature change (°C)

DATA ANALYSIS

1. Determine the whole number mole ratio of the two reactants. Use the information in the graph you created on Page 2 of the experiment file (temperature change *vs.* volume of hypochlorite).

2. The molarities of the reactant solutions were equal in this experiment. Is this necessary, or even important, for the success of the experiment?

3. Which solution was the limiting reactant in each trial?

4. Find the actual balanced chemical equation for the reaction between OCl^{-} and $S_2O_3^{2-}$. Does the mole ratio that you determined in your experiment match the actual reaction equation's coefficients for the two reactants? Explain, especially if your mole ratios do not match the coefficients.

Determining the Mole Ratios in a Chemical Reaction

1. This experiment conforms to the guidelines for the ninth laboratory experiment listed in the College Board AP Chemistry guide (the Acorn book).

2. The method used in this experiment is called continuous variations, in which a series of reactions is conducted using various ratios of the reactants. The temperature change of the exothermic reaction is measured and recorded for each ratio. The optimum ratio produces the greatest amount of heat energy, thus the greatest change in temperature.

3. The solution volumes are measured with a graduated cylinder. The solutions are mixed in a Styrofoam® cup and the temperature change is measured with the precision allowed by the Stainless Steel Temperature Probe (±0.1°C).

4. One 50-minute lab period is sufficient to complete the experiment. It is a good idea for your students to plot their results on a graph as they complete each trial, in case they need to conduct additional trials. This can be done quite easily when collecting data using Logger *Pro* on a computer; data can be manually entered into the data table and graph of temperature *vs.* volume of hypochlorite on Page 2 of this experiment file.

5. Prepare the 0.50 M NaClO solution by diluting 745 mL of fresh bleach with distilled water to a total volume of 1.0 L. Grocery store laundry bleach works well, but do not use bleach labeled "color safe". Most commercial bleaches are labeled as 5.25% NaClO by mass, which is approximately 0.67 M. Note: If you use bleach labeled "Ultra", the NaClO concentration is 6%. Prepare the 0.50 M NaClO solution by diluting 653 mL of Ultra bleach with distilled water to a total volume of 1.0 L.

6. Prepare the 0.50 M $Na_2S_2O_3$ solution in three steps. To make 1.0 L of solution, first dissolve 124 grams of $Na_2S_2O_3{\bullet}5H_2O$ (or 79.1 g of anhydrous $Na_2S_2O_3$) in 500 mL of distilled water. Then add 8 g of solid NaOH and stir the mixture to dissolve the NaOH. Lastly, add distilled water to make 1.0 L of solution.

7. If your students analyze the Page-2 graph (temperature change *vs.* volume of hypochlorite) with Logger *Pro* software, they can determine the mole ratio with intersecting lines.
   a. Drag the mouse cursor across the linear region of data that *precedes* the maximum change in temperature, then click on the Linear Fit button, . Repeat this for the data that *follows* the maximum change in temperature, then click on the Linear Fit button, .
   b. Choose Interpolate from the Analyze menu. Then move the mouse cursor to the volume reading where both linear fits display the same temperature change value.

HAZARD ALERTS

Sodium thiosulfate: Slightly toxic by ingestion; body tissue irritant. Hazard code: C—Somewhat hazardous.