MOLE:MOLE RATIO LAB

How Can We Determine the Mole:Mole Relationships in a Chemical Reaction?

A balanced chemical 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.

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

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 since the concentrations of the reactants are equimolar, the same *total number* of moles of reactants. The reaction is exothermic, thus the mixture generating the most heat energy will be the reaction that completely consumes both the hypochlorite and the thiosulfate ions leaving no excess reactant. You will collect maximum temperatures for each trial, determine the total temperature change for each trial, and then graph your data in order to establish the optimum mole to mole ratio and thus establish the coefficients for the reaction.

Objectives

In this experiment, you will:

• Measure the enthalpy change of a series of reactions using the method of continuous variations.

• Determine the stoichiometry of an oxidation-reduction reaction in which the reactants are known but the products are unknown.

Materials

- Data collection apparatus
- Ring stand with utility clamp
- Temperature probe
- 0.50 M NaOCl solution (200 mL per lab group)
- 0.50 M $Na_2S_2O_3$ solution in 0.2 M NaOH
- 3 - 250 mL beakers or other containers
- 2 - polystyrene cups with lid

Figure 1

Procedure

1. Obtain and wear goggles.

2. Set up the data collection system. Connect an interface to the computer or handheld with the proper cable.

    a. Connect a temperature probe to the interface.

    b. Start the data collection program.

    c. The default time graph and preset run time are sufficient for this experiment.

3. Obtain about 200 mL of each of the reactant solutions.

4. Measure out precisely 25.0 mL of the 0.50 M NaOCl solution into a polystyrene cup.

    If you miss the 25.0 mL mark, just record your volume exactly and take extra care with the next measurement since you need to obtain the same total volume (50.0 mL) for each trial. Nest the cup in a beaker to help stabilize the cup (see Figure 1).

5. Immerse the tip of the temperature probe in the polystyrene cup of NaOCl solution.

6. Measure out precisely 25.0 mL of the 0.50 M $Na_2S_2O_3$ solution into a beaker. **Do not mix the two solutions yet.**

7. Start the 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.

8. Examine the data to calculate and record the maximum temperature change.

9. Rinse out and dispose of the reaction mixture as directed.

10. Continue testing various ratios of the two solutions, keeping the total volume constant, until you have 3 measurements on either side of the ratio that produced the greatest temperature difference.

Data Table

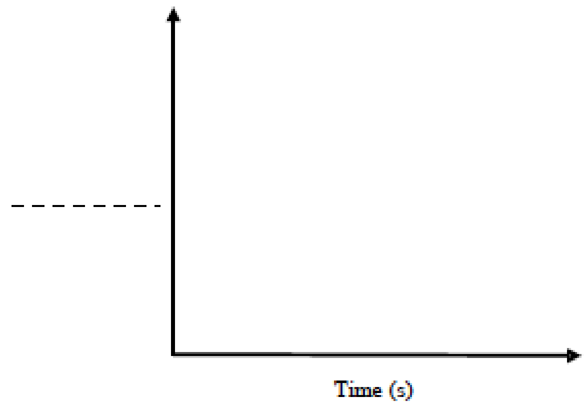
Trial	Volume OCl^{-} (mL)	Volume $S_2O_3^{2-}$ (mL)	Maximum Temperature Change (°C)
1			
2			
3			
4			
5			
6			
7			

Pre-Lab Questions

1. What is the total reaction volume for this procedure?

2. Predict the sign of ΔH for this reaction. Justify your prediction.

3. Using the set of axes provided on the right, properly label the y-axis and sketch the curve that you expect to see at the end of a given trial. Explain how you will use the graph to determine the maximum temperature change.



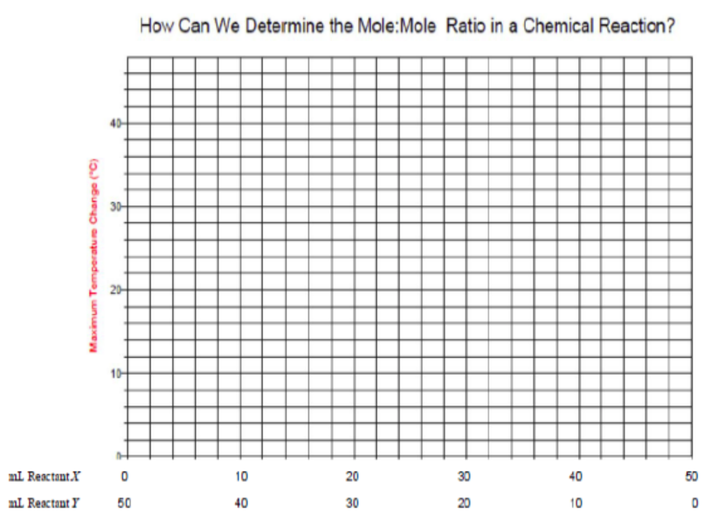
4. Explain how you will use this curve to determine the maximum temperature change for a given trial.

5. A student conducts this experiment using two equimolar reactants, X &Y, and obtains the data shown in the table below. The optimum mole-to-mole ratio requires that you plot the maximum temperature change recorded for each trial vs. the volume of X reacting.

To determine the optimum ratio, perform two linear regressions for the temperature change vs. volume of reactant X data. One regression will have a positive slope, while the other will have a negative slope. Both regressions will involve all the points on the portion of the graph that approaches the maximum. The optimum volume for reactant X is obtained by interpreting the point where the two regression lines intersect. Once you've established the simplest whole number optimum ratio for the reactants, write the moles of reactant X that react completely with reactant Y in the space provided below the table.

Volume Reactant *X* (mL)	Volume Reactant *Y* (mL)	Temperature Change (°C)
25.0	25.0	24.9
30.0	20.0	33.0
20.0	30.0	19.8
40.0	10.0	22.3
10.0	40.0	7.8
45.0	5.0	14.1
43.0	7.0	18.0

___moles of *X* react with___moles of *Y*



Post-Lab Questions and Data Analysis

1. Use graphical methods to determine the whole number mole ratio of the two reactants in this experiment, based on your data.

2. Why must the total volume of the solution mixture be kept constant in all trials?

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

4. Identify the limiting reactant for each trial that you performed.

5. Write the balanced oxidation-reduction reaction for the reaction of OCl^{-} and $S_2O_3^{2-}$ in basic solution. Does the mole ratio that you determined in your experiment match the actual reaction equation's coefficients?

6. Suggest a measurement (other than the temperature change) that could be used in an experiment involving the method of continuous variations that could be used to determine the mole ratios for a pair of reactants.

7. Why is it more accurate to use the point of intersection of the two lines to find the mole ratio rather than the ratio associated with the greatest temperature change?

8. A student mixes two solutions that are not at the same initial temperature. If, 20 mL of Solution A at 23°C is mixed with 30 mL of Solution B at 30°C, suggest a method for making a correction so that the student does not have to repeat the experiment.

Adapted from:
Advanced Chemistry with Vernier & Laboratory Experiments for Advanced Placement Chemistry by Jack Randall, PhD