Finding the Ratio of Moles of Reactants in a Chemical Reaction

Introduction

A balanced chemical equation gives the mole ratios of reactants and products for a chemical reaction. If the formulas of all reactants and products are known, it is relatively easy to balance an equation to find out what these mole ratios are. When the formulas of the products are not known, experimental measurements must be made to determine the ratios.

Concepts

- Stoichiometry
- Mole ratio
- Oxidation–reduction reaction

Background

This experiment uses the method of continuous variations to determine the mole ratio of two reactants in a chemical reaction. Several steps are involved. First, solutions of the reactants are prepared in which the concentrations are known. Second, the solutions are mixed a number of times using different volume ratios of reactants. Third, some property of the reaction that depends on the amount of product formed or on the amount of reactant that remains is measured. This property may be the color intensity due to a reactant or product, the mass of a precipitate that forms, or the volume of a gas evolved.

In the method of continuous variations, the total number of moles of reactants is kept constant for the series of measurements. Each measurement is made with a different mole ratio of reactants. The optimum ratio, which is the stoichiometric ratio for the reactants in the balanced chemical equation, should consume the greatest amount of reactants, form the greatest amount of product, or generate the most heat and produce the maximum temperature change.

Sodium hypochlorite is an oxidizing agent and all the reactions tested in this experiment are oxidation–reduction reactions. The hypochlorite ion will be reduced as another substance is oxidized.

Experiment Overview

This experiment uses the *method of continuous variations* to determine the mole ratio of two reactants. The change of temperature is the property to be measured. The reactions are all exothermic, so the heat produced will be directly proportional to the amount of reaction that occurs. Since the experiment is designed so that the total volume of solutions is constant for all measurements, the temperature change will also be proportional to the total extent that the reaction occurs.

Pre-Lab Questions *(Use a separate sheet of paper to answer the following questions.)*

Review the procedure before answering questions.

1. The following values were obtained in a continuous variations experiment designed to find the mole ratio for the reaction between 0.5 M solutions of $AgNO_3$ and K_2CrO_4. One of the products is a precipitate.

Experiment	mL $AgNO_3$	mL K_2CrO_4	Grams Precipitate
1	5.0	45.0	1.7
2	15.0	35.0	5.0
3	25.0	25.0	8.3
4	30.0	20.0	10.0
5	35.0	15.0	9.9
6	40.0	10.0	6.6
7	45.0	5.0	3.3

Plot the data on graph paper as outlined in the procedure. Label axes and space the data so that the graph reflects the precision of the values given. Use a ruler to draw the best-fitting straight lines through the data points and determine the coefficients for the reactants in the balanced chemical equation.

_____ $AgNO_3$ + _____ K_2CrO_4 → Products

2. Is there enough data to make a valid conclusion? Why or why not?

Materials

Chemicals

Sodium hypochlorite, NaClO, 0.50 M, 175 mL

"Solution B", 0.5 M, 175 mL

Equipment

Styrofoam® cup

Thermometer

Beakers, 400-mL, 2

Graduated cylinders, 10-mL, 2

Graduated cylinder, 50-mL

Marker

Safety Precautions

Bleach is a 5% solution of sodium hypochlorite. This solution is a corrosive liquid; it causes skin burns. The solution reacts with acid to evolve chlorine gas; when heated it evolves chlorine gas. The solution is moderately toxic by ingestion and inhalation. Keep away from skin and clothing. Work in a fume hood or well-ventilated lab. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Obtain approximately 175 mL of the NaClO solution in a clean 400-mL beaker and 175 mL of "Solution B" to another clean 400-mL beaker. Label the beakers.
2. Measure the temperature of the NaClO solution and of "Solution B." Record the data in the Data Table. Use the same thermometer or a pair of calibrated thermometers. The solutions should be the same temperature. If they are not, you will need to make a correction for the temperature difference.
3. Using a clean 10-mL graduated cylinder, measure 5.0 mL of NaClO solution and pour the solution into a styrofoam cup. Using a clean 50-mL graduated cylinder, measure 45.0 mL of "Solution B" and add this to the Styrofoam cup.
4. Stir with a thermometer, and record the maximum temperature reached of the final solution in the Data Table.
5. Pour the solution out, rinse the cup and thermometer, and repeat steps 1–4 using a different ratio of the two substances, always keeping the total volume at 50.0 mL.
6. Continue testing various ratios until you have *at least three measurements on each side of the one that gave the greatest temperature difference [ΔT(°C)].*
7. Plot your data on a graph as shown in Figure 1.
8. Draw two straight lines that best fit your data, and determine where they intersect. Be sure to include the points at the 0:50 mL and 50:0 mL ratios. If any points do not fall close to the lines, you should repeat these measurements. Find the stoichiometric mole ratio of reactants from the point of intersection on your graph.

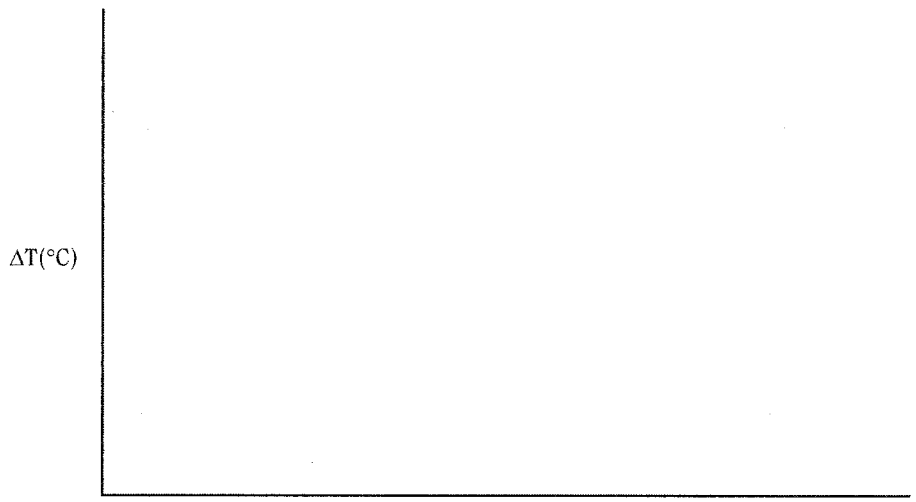

Figure 1. Graph of Experimental Data

Disposal and Cleanup

Your teacher will provide disposal and cleanup instructions.

Data Table

Initial Temperature _____

mL NaClO	mL _____	T_{final}(°C)	ΔT(°C)

mL NaClO	mL _____	T_{final}(°C)	ΔT(°C)

Post-Lab Calculations and Analysis

(Use a separate sheet of paper to answer the following questions.)

1. Explain how the method of continuous variations is used to determine the mole ratio of reactants in a chemical reaction.
2. Why was the total volume of solutions used kept constant in all trials?
3. Is it necessary that the concentrations of the two solutions be the same?
4. What is meant by the term limiting reagent?
5. Which measurement, temperature or volume, limits the precision of the data obtained in the experiment? Explain.
6. Which reactant is the limiting reagent along the upward sloping line of the graph? Which is the limiting reagent along the downward sloping line?
7. What other physical properties, other than temperature change, could be used in the method of continuous variations?
8. 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?
9. If the two solutions used are not at the same initial temperature, a correction must be made to find the correct change in temperature. How should this be done?