Finding the Ratio of Moles of Reactants in a Chemical Reaction

A balanced chemical equation gives the mole ratios of reactants and products for chemical reactions. 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.

This experiment uses the method of continuous variations to determine the mole ratio of two reactants. 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 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 of a reactant or product, the mass of a precipitate that forms, or the volume of the gas evolved. In this experiment 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 volume of solution is a constant for all measurements, the temperature change will also be proportional to the quantity of reactants consumed.

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 in the equation, should consume the greatest amounts of reactants, form the greatest amount of product, and generate the most heat and maximum temperature change.

Chemicals

Sodium hypochlorite, NaClO, 0.50 M
Sodium thiosulfate, $Na_2S_2O_3$, 0.50 M in NaOH, 0.20 M
or Potassium iodide, KI, 0.50 M in NaOH, 0.20 M
as "Solution B"

Equipment

Styrofoam cup
Thermometer
Graduated cylinders, 10-mL and 25- or 50-mL

Procedure

Safety Alert : NaClO is a bleach. Keep it off of clothing. All solutions are basic and harmful to skin and eyes. If you spill any, wash off with copious amounts of water. Work in a hodd or under a funnel attached to an aspirator since fumes may be given off. Wear chemical splash goggles and a chemical-resistant apron.

1. **Find your starting temperature**

Measure the temperature of the NaClO solution and of "Solution B", the second solution that you have chosen. Record your data in a 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.

2. **Mix solutions and measure temperature change**

Pour 5.0 mL of NaClO into the styrofoam cup, and then add 45.0 mL of the second solution. Stir with a thermometer, and record the highest temperature reached by the mixture. Pour the solution out, rinse the cup and thermometer, and repeat the process using a different ratio of the two substances, always keeping the total volume at 50.0 mL. Continue testing various ratios until you have at least three measurements on each side of the one that gave the maximum temperature.

3. **Plot the data**

Plot your data as shown in Figure 1. 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.

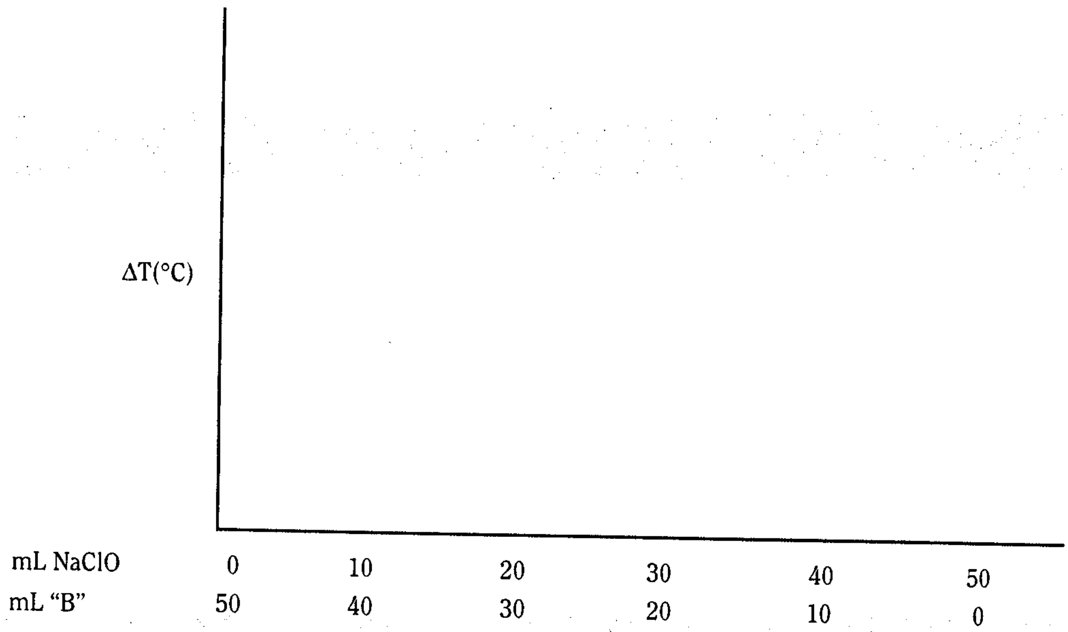

Figure 1. Graph of Experimental Data

Disposal

The solutions may be flushed down the drain with excess water.

Discussion

In your laboratory report include answers to the following:

1. Why must you keep a constant volume of reactants?
2. Is it necessary that the concentrations of the two solutions be the same?
3. Does the measurement of temperature or the measurement of volume limit the precision of your data? Explain.
4. Which reactant is the limiting reagent along the upward sloping line of your graph? Which is the limiting reagent along the downward sloping line?
5. What physical properties, other than the temperature change, could use the method of continuous variations?
6. 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?

References

Additional information on the continuous variations method may be found in the following:

Alexander, J. J.; Steffel, M. J. *Chemistry in the Laboratory*; Burgess International Group: Edina, MN, 1988; p 47.

Mahoney, D. W.; Sweeney, J. A.; Davenport, D. A.; Ramette, R. W.; *J. Chem. Educ.* 1981, 58, 730