Reaction Stoichiometry

Guided Inquiry Version

Stoichiometry is the study of quantitative relationships in chemical reactions. 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 can be conducted to help determine the mole ratios.

Acetic acid ($HC_2H_3O_2$) and sodium hydroxide (NaOH) are the reactants in the acid-base reaction to be investigated in the Preliminary Activity. Sodium hydroxide neutralizes acetic acid according to the unbalanced and incomplete equation:

$$A\ HC_2H_3O_2 + B\ NaOH \rightarrow \text{products}$$

It is possible to identify the coefficients of 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 reactants. You will use this mixture to establish the coefficients, and therefore the mole ratio of the reactants, for the reaction.

PROCEDURE

1. Obtain and wear goggles and gloves.

2. Connect the Temperature Probe to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer. (If you are using EasyTemp or Go!Temp, you do not need a data-collection interface.)

Figure 1

3. Obtain about 200 mL of each of the reactant solutions, NaOH and $HC_2H_3O_2$.

4. Measure out precisely 25.0 mL of the 1.0 M NaOH solution. Pour this solution into a Styrofoam cup and nest the cup in a beaker to help stabilize the cup (see Figure 1). **CAUTION:** *Sodium hydroxide solution is caustic. Wear gloves while handling it. Avoid spilling it on your skin or clothing.*

5. Immerse the tip of the Temperature Probe in the Styrofoam cup of NaOH solution.

6. Measure out precisely 25.0 mL of the 1.0 M $HC_2H_3O_2$ solution. **Note:** Do not mix the two solutions yet. **CAUTION:** *Use care when handling acetic acid solution. It can cause painful burns if it comes in contact with your skin or gets into your eyes.*

7. When everything is ready, start data collection (▶). Let the program gather and graph a few initial temperature readings, and then carefully add the $HC_2H_3O_2$ solution. Gently stir the reaction mixture with the Temperature Probe.
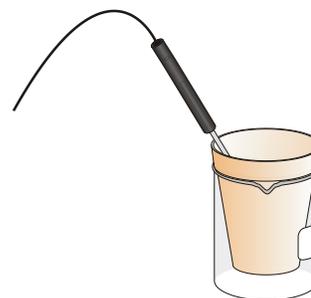
8. Data collection will stop after 180 seconds. You may stop data collection before 180 seconds have passed, if the temperature readings are no longer changing.

9. Determine and record the minimum and maximum temperatures.

   a. Choose Statistics from the Analyze menu to display statistics for the trial.
   b. Record the minimum and maximum temperatures in the Data Table that is provided. It may be necessary to examine the graph to determine the initial temperature, if the minimum temperature is not suitable.

10. Calculate the temperature change (Δt) by subtracting the minimum temperature from the maximum temperature. Record the result in the Data Table.

11. Dispose of the reaction mixture as directed. Rinse the Styrofoam cup with room temperature water and dry it.

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 both sides of the combination that produced the greatest temperature change.

DATA TABLE

Volume NaOH (mL)	Volume $HC_2H_3O_2$ (mL)	Temperature$_{min}$ (ºC)	Temperature$_{max}$ (ºC)	Δt (ºC)

QUESTIONS

1. Determine the whole number mole ratio of the two reactants.

   a. Plot a graph of temperature change (in °C) *vs.* volume of sodium hydroxide (in mL).
   b. Perform a linear fit through the linear region of the data that *precedes* the maximum temperature change.
   c. Perform a linear fit through the linear region of the data that *follows* the maximum temperature change.
   d. The point where the two lines intersect indicates the volume of sodium hydroxide component of the optimum $NaOH/C_2H_4O_2$ combination.
   e. Subtract the optimum NaOH volume from 50 mL to obtain the optimum $C_2H_4O_2$ volume.

    f.   Divide to obtain the $NaOH/HC_2H_3O_2$ volume ratio. **Note**: Since the NaOH and $HC_2H_3O_2$ solutions were each 1.00 M, the $NaOH/HC_2H_3O_2$ mole ratio will be the same as the $NaOH/HC_2H_3O_2$ volume ratio.

2.   What is the whole number ratio of moles of NaOH to moles of $HC_2H_3O_2$ in the reaction between sodium hydroxide and acetic acid?

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

4.   Acetic acid and sodium hydroxide react to form sodium acetate and water. Write a balanced chemical equation for this reaction.

5.   (Optional) Determine the enthalpy of reaction for the reaction between acetic acid and sodium hydroxide.