FLINN SCIENTIFIC

Name________________________________

Stoichiometry Worksheet

Questions and Calculations

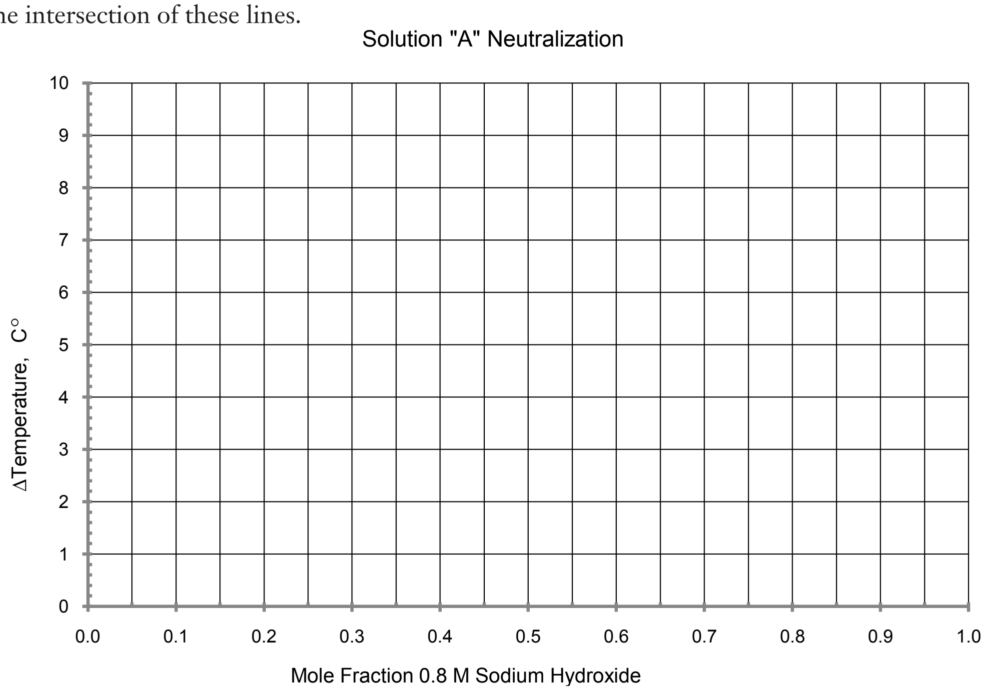
This demonstration uses the method of continuous variations to determine the mole ratio of two reactants in a chemical reaction. Several steps are involved. First, solutions of the reactants, an acid and a base, are prepared in which the concentrations are equal molar. Second, the solutions are mixed 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. In this case, it is the heat released when acid–base neutralization occurs. 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 generate the most heat and produce the maximum temperature change.

Reaction of 0.8 M Solution "A" with 0.8 M Sodium Hydroxide

Data Table

Volume 0.80 M Solution "A"	Acid solution $T_{initial}$ (°C)	Volume 0.80 M NaOH	Base solution $T_{initial}$ (°C)	T_{final} (°C)	ΔT (°C)	Mole Fraction 0.80 M NaOH
0	—	50	—	—	0.0	1.0
10		40				
20		30				
25		25				
30		20				
40		10				
50	—	0	—	—	0.0	0.0

1. Calculate the change in temperature and the mole fraction of sodium hydroxide for each determination, then plot on the graph the change in temperature values versus the mole fraction of sodium hydroxide. Use a ruler to draw two best-fitting straight lines through the increasing and decreasing data points. Determine the stoichiometry of the reaction from the intersection of these lines.



______ HxA(aq) + ______ NaOH(aq) → Products

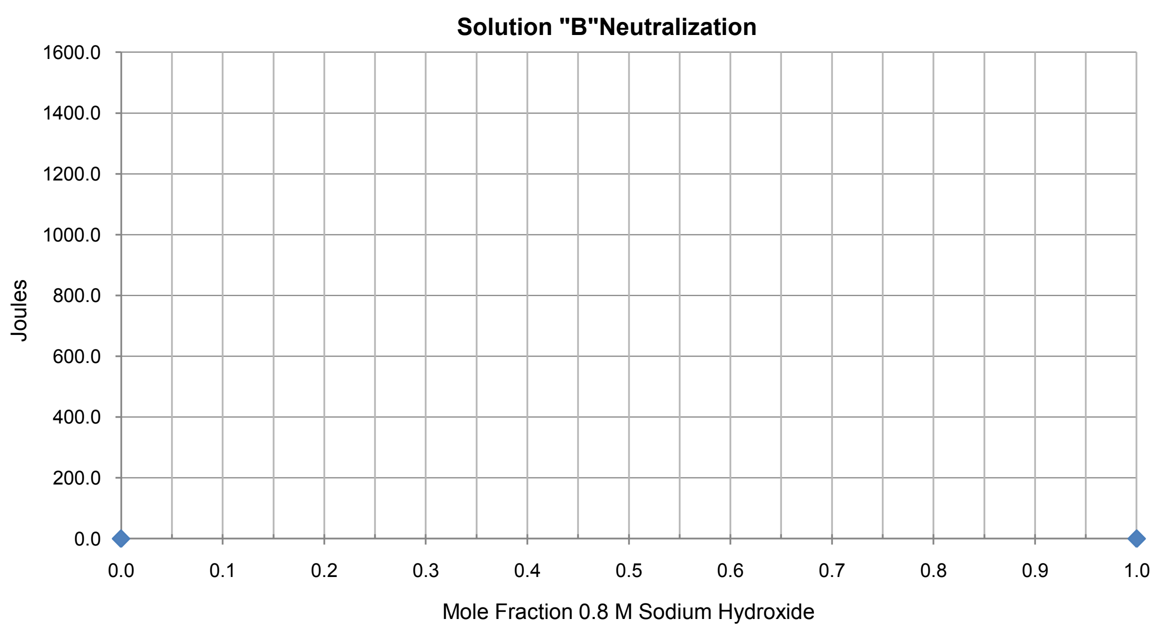
Reaction of 0.8 M Solution "B" with 0.8 M Sodium Hydroxide

Data Table

Volume 0.80 M Solution "B"	Acid Solution $T_{initial}$ (°C)	Volume 0.80 M NaOH	Base solution $T_{initial}$ (°C)	T_{final} (°C)	ΔT (°C)	Mole Fraction 0.80 M NaOH	Heat Released (J)
0	—	50	—	—	0.0	1.00	0.0
10		40				0.80	
20		30				0.60	
25		25				0.50	
30		20				0.40	
40		10				0.20	
50	—	0	—	—	0.0	0.00	0.0

1. Calculate the heat released (q) for each determination. Assume the specific heat capacity of the solution is 4.18 Jg/°C and the density of the solution is 1.00 g/mL.

2. Plot on the graph the heat released values versus the mole fraction of sodium hydroxide. Use a ruler to draw two best-fitting straight lines through the increasing and decreasing data points. Determine the stoichiometry of the reaction from the intersection of these lines.



______ HxA(aq) + ______ NaOH(aq) → Products

3. What is the limiting reactant when the mole fraction value of sodium hydroxide is somewhere on the ascending line? On the descending line?

Reaction of 0.8 M Solution "C" with 0.8 M Sodium Hydroxide

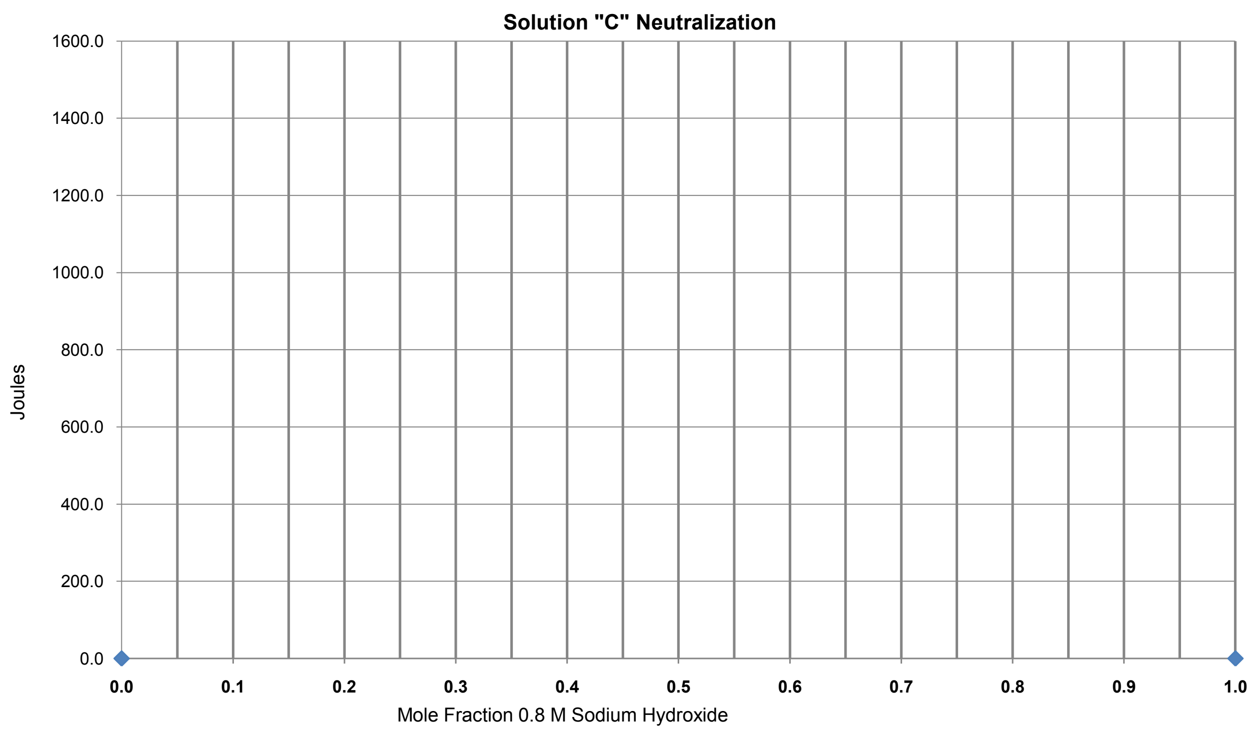
Data Table

Volume 0.80 M Solution "C"	Acid Solution $T_{initial}$ (°C)	Volume 0.80 M NaOH	Base Solution $T_{initial}$ (°C)	T_{final} (°C)	ΔT (°C)	Mole Fraction 0.80 M NaOH	Heat Released (J)
0	—	50	—	—	0.0	1.0	0.0
10		40				0.8	
20		30				0.6	
25		25				0.5	
30		20				0.4	
40		10				0.2	
50	—	0	—	—	0.0	0.0	0.0

1. Calculate the heat released (q) for each determination. Assume the specific heat capacity of the solution is 4.18 Jg/°C and the density of the solution is 1.00 g/mL.

Example: For mole fraction equal to 0.5; q = m × °C × ΔT = 50 g × 4.18 J/g °C × 4.7 °C = 980 J

2. Plot on the graph the heat released values versus the mole fraction of sodium hydroxide. Use a ruler to draw two best-fitting straight lines through the increasing and decreasing data points. Determine the stoichiometry of the reaction from the intersection of these lines.



______ HxA(aq) + ______ NaOH(aq) → Products

3. It is found that 42.00 mL of 0.800 M NaOH is needed to titrate 2.153 g of citric acid to its final end point. Calculate the equivalent mass of the acid. Based on this value and the answer to question 2, calculate the molar mass of citric acid.

4. The citric acid molecule can be written as

$H_2C—COOH$

$HO—C—COOH$ or $C_3H_4OH(COO)_3H_3$

$H_2C—COOH$

Write the net ionic equation for the neutralization reaction of citric acid and sodium hydroxide.

Supplement

Sodium Hydroxide Standardization

Materials

Phenolphthalein indicator solution, 1%, 1 mL	Erlenmeyer flask, 125-mL
Potassium hydrogen phthalate, $KHC_8H_4O_4$, 2 g*	Oven and desiccator
Sodium hydroxide solution, NaOH, 0.8 *M*, 150 mL*	Spatula
Balance, 0.01-g precision	Support stand and buret clamp
Beakers, 150-mL, 2	Wash bottle
Buret, 50-mL	Weighing dish

**Materials included in kit.*

Safety Precautions

Sodium hydroxide solution is corrosive to skin and eyes; skin burns are possible; very dangerous to eyes. Acetic acid solution is toxic and corrosive. Avoid contact with skin and eyes. Phenolphthalein solution is flammable and is moderately toxic. Wear heat-resistant gloves or use tongs when handling the hot flask. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Pre-Lab Standardization

1. Obtain a sample of potassium hydrogen phthalate (KHP) that has been previously dried in an oven and stored in a desiccator.
2. On an analytical balance, accurately weigh 0.4 to 0.6 g of KHP in a previously tared weighing dish. Record the mass of the KHP in the Standardization Data Table on page 5.
3. Transfer the KHP into an Erlenmeyer flask—pour the solid through a funnel into the flask. Use water from a wash bottle to rinse all of the remaining solid in the weighing dish and in the funnel into the flask.
4. Add about 40 mL of distilled water to the flask and swirl until all the KHP dissolves.
5. Obtain about 75 mL of the sodium hydroxide solution, NaOH, approximately 0.8 molar in a 150-mL beaker.
6. Clean a 50-mL buret, then rinse it with three small portions (about 7 mL each) of the NaOH solution.
7. Fill the buret to above the zero mark with the NaOH solution. Place an empty beaker under the buret.
8. Open the buret stopcock to allow any air bubbles to escape from the tip. Close the stopcock when the liquid level is between the 0- and 10-mL marks.
9. Measure the precise volume of the solution in the buret and record this value in the Standardization Data Table as the "initial volume." *Note:* Volumes are read from the top down in a buret. Always read from the bottom of the meniscus, remembering to include the appropriate number of significant figures.
10. Position the buret over the Erlenmeyer flask so that the tip of the buret is within the flask but at least 2 cm above the liquid surface.
11. Add three drops of phenolphthalein solution to the KHP solution in the flask.
12. Begin the titration by adding 1.0 mL of NaOH solution to the Erlenmeyer flask, then closing the buret stopcock and swirling the flask.
13. Repeat step 12 until 15 mL of the NaOH solution have been added to the flask. Be sure to continuously swirl the flask.
14. Reduce the incremental volumes of NaOH solution to 0.5 mL until the pink color starts to persist. Reduce the rate of addition of NaOH solution to drop by drop until the pink color persists for 15 seconds. *Note:* Remember to constantly swirl the flask and to rinse the walls of the flask with distilled water before the endpoint is reached.

15. Measure the volume of NaOH remaining in the buret, estimating to the nearest 0.01 mL. Record this value as the " final volume" in the Standardization Data Table.

16. Repeat the standardization titration two more times. Rinse the Erlenmeyer flask thoroughly between trials with deionized water.

Standardization Data Table

	Trial 1	Trial 2	Trial 3
Mass KHP, g			
Final Volume, mL			
Initial Volume, mL			
Volume of NaOH Added, mL			