# Thermochemistry Lab #2 - Heat of Reaction - Hess's Law

http://www2.ucdsb.on.ca/tiss/stretton/chem2/enthlab2.htm

https://chemdemos.uoregon.edu/demos/Heat-of-Neutralization-HClaq-NaOHaq

The foundation of the study of thermochemistry was laid by the chemist Germain Hess, who investigated heat in chemical reactions during the last century. One statement of the law that bears Hess's name says:

> The enthalpy change for any reaction depends on the products and reactants and is independent of the pathway or the number of steps between the reactant and product.

In this experiment, you will measure and compare the quantity of heat involved in three reactions. These heats of reaction will be measured using a styrofoam calorimeter. The three reaction are shown below.

Reaction 1: The dissolving of solid sodium hydroxide in water.

$$NaOH(s) \text{ ---> } Na^{+}(aq) + OH^{-}(aq)$$

Reaction 2: The reaction of solid sodium hydroxide with dilute hydrochloric acid.

$$NaOH(s) + H^{+}(aq) + Cl^{-}(aq) \text{ ---> } Na^{+}(aq) + Cl^{-}(aq) + H_2O\ (l)$$

Reaction 3: The reaction of sodium hydroxide solution with dilute hydrochloric acid solution.

$$Na^{+}(aq) + OH^{-}(aq) + H^{+}(aq) + Cl^{-}(aq) \text{ ---> } Na^{+}(aq) + Cl^{-}(aq) + H_2O\ (l)$$

**Objectives:**

To measure and compare the amount of heat involved in three separate but related reactions.
To provide experimental verification of Hess's Law.

**Apparatus and Materials:**

2 large styrofoam cups w/lid
graduated cylinders
solid sodium hydroxide, NaOH
0.50 M sodium hydroxide solution (record exact molarity determined)
0.25 M hydrochloric acid solution (record exact molarity determined)
0.50 M hydrochloric acid solution (record exact molarity determined)
Vernier temperature probe linked to Logger Pro
balance
250 mL beaker

**Safety:**

Hydrochloric acid and sodium hydroxide are corrosive. Avoid direct contact. If any touches your skin, wash it off immediately. Solid sodium hydroxide is especially dangerous because it absorbs moisture rapidly from the air, forming an extremely corrosive liquid. Avoid spilling this solid, and if a spill occurs, clean it up immediately. Be sure to close the lids of bottles of sodium hydroxide securely, immediately after using.
Dispose of solutions in appropriate beakers under the fume hood. A lab apron, goggles, and closed-toe shoes are required.

## Procedure:

**Standardizing NaOH solution using KHP and standardizing HCl**
Your group will need three solutions of known molarity:
0.50 M sodium hydroxide solution
0.25 M Hydrochloric acid solution
0.50 M Hydrochloric acid solution

Use KHP to standardize 500mL of NaOH. Use this solution to standardize 500mL of .50M HCl and dilute part of this to make 250mL of .25M HCl.

**Part One: The Dissolving of Solid Sodium Hydroxide in Water**
Use 200.mL of distilled water. Water has a density of 1.00g/mL.
Use around 2 grams of NaOH, precisely measured.
Discard the solution in the appropriate beaker under the fume hood.

**Part Two: The Reaction of Solid Sodium Hydroxide with Hydrochloric Acid**
Repeat steps Part One, but replace the 200. mL of distilled water with 200. mL of 0.25 M hydrochloric acid.

Discard the solution in the appropriate beaker under the fume hood.

**Part Three: The Reaction of Sodium Hydroxide Solution with Hydrochloric Acid**
Accurately measure 100 mL of 0.50 M hydrochloric acid solution into your calorimeter and 100 mL of 0.50 M sodium hydroxide into a 250 mL beaker. Both solutions should be at or near room temperature. Record the temperatures and volumes of each solution.

Add the sodium hydroxide solution to the acid solution in the styrofoam cup. Stir the mixture with the temperature probe and record the highest temperature reached.

Discard the solution in the appropriate beaker under the fume hood.

## Questions:

1. Add the ionic equations given in the introductions for Parts One and Three. Compare the result with the ionic equation for Part Two.

2. Compare the sum of the heats of reaction for Parts One and Three with that obtained for Part Two. In the light of your answer to Question 1, explain your results here.

3. Discuss Hess's law in terms of the law of conservation of energy and in terms of the three parts of this experiment.

4. Suppose you had used 8 g of sodium hydroxide in Part One.
   a) How would this have affected the change in temperature?
   b) What quantity of heat would have been evolved in your reaction?
   c) What effect would this have had on your calculation of the heat of reaction for Part One?

5. Write the net ionic equation for Part Three of this experiment. Write the net ionic equation for the reaction between solutions of potassium hydroxide and sulfuric acid. Compare the two net ionic equations. What does the heat of reaction for Part Three of this Experiment represent.

## Data and calculations

| | |
|---|---|
| **Standardizing solutions** | |
| **NaOH data** | |
| mass of KHP used | g |
| Starting volume on NaOH buret | mL |
| Ending volume on buret | mL |
| **NaOH calculations** | |
| moles of KHP | mol |
| mol of NaOH used | mol |
| volume of NaOH used | mL |
| molarity of NaOH | M |
| **HCl data** | |
| volume of HCL | mL |
| Starting volume on NaOH buret | mL |
| Ending volume on buret | mL |
| **HCl calculations** | |
| volume of NaOH used | mL |
| mol of NaOH used | mol |
| molarity of HCl | M |
| | |
| **Part 1** | |
| **Data** | |
| Volume of water used | mL |
| Initial temperature | $^oC$ |
| Final temperature | $^oC$ |
| Mass of NaOH | g |
| **Calculations** | |
| Mass of $H_2O$ used | g |
| Temperature change | $^oC$ |
| Molar mass of NaOH | g/mole |
| Moles of NaOH | mole |
| Energy released ($\Delta$ E) | kJ |
| $\Delta H_{dissolution}$ of NaOH | kJ/mol |
| Accepted $\Delta H_{dissolution}$ of NaOH | kJ/mol |
| % error | % |

| **Part 2** | |
|---|---|
| **Data** | |
| Volume of .25M HCl used (enter your M of HCl) | mL |
| Initial temperature | ºC |
| Final temperature | ºC |
| Mass of NaOH | g |
| **Calculations** | |
| Mass of 0.25 M HCl used (enter your M of HCl)<br><br>Assume the density is 1.00g/mL | g |
| Moles of HCl | mol |
| Temperature change | ºC |
| Molar mass of NaOH | g/mol |
| Moles of NaOH | mol |
| Energy released (Δ E)<br><br>Assume that the value of *c* for 0.25 M HCl is the same as that for water. (4.184 J/gºC) | kJ |
| $\Delta H_{rxn}$ | kJ/mol |
| | |
| **Part 3** | |
| **Data** | |
| Volume of 0.50 M HCl solution (enter your M of HCl) | mL |
| Volume of 0.50 M NaOH (enter your M of NaOH) | mL |
| Initial temperature of HCl solution | ºC |
| Initial temperature of the NaOH solution | ºC |
| Highest final temperature of mixture | ºC |
| **Calculations** | |
| Change in temperature | ºC |
| Moles of HCl used | mol |
| Moles of NaOH used | mol |
| $\Delta H_{rxn}$ (/mol of limiting reactant) | kJ/mol |
| Accepted $\Delta H_{rxn}$ | kJ/mol |
| % error | % |