

Heat of Reaction

Some Like It Hot

Recommended grades level(s) 11-12

Overview: - Provide a brief description and recommendations for use.

Time Duration: - 50 minutes

Objective(s):

The learner will observe the temperature changes of two reactions, one exothermic and one endothermic.

The learner will calculate the heat of reaction for each of the two reactions using data gathered in the investigation.

Materials and/or Resources:

Styrofoam cup

3 large test tube

Thermometer

Water

Bleach (5.25 solutions of sodium hypochloride

Sodium sulfate

3 stoppers

Graduated cylinder

20 g of barium hydroxide octahydrate crystals

10 g of ammonium nitrate

500 ml beaker

10 % sodium sulfate

Fine filter paper

Background Information:

During a chemical reaction, energy is needed to break the bonds between atoms. As new bonds form, energy is produced. The difference between the energy required and the energy produced is called the heat of reaction. That energy difference is usually manifested in a temperature change.

If, as is the usual case, more energy is produced than is required, the excess energy is given off as heat. This heat causes the temperature of the chemicals, container, and surroundings to increase. A reaction of this type is called exothermic.

There are some reactions that will proceed even though more energy is required than is produced. This type of reaction is called endothermic and is characterized by a decrease in the temperature of the chemicals, container, and surroundings.

Chemists measure the heat of reactions with calorimeters. The energy, as heat, is absorbed by water in the calorimeter. The difference in the temperature of the water

before and after the reaction is used to calculate the heat of reaction. The calorimeter is insulated to prevent heat exchange with the surroundings. The heat of the reaction is then equal to the heat absorbed by water and the calorimeter.

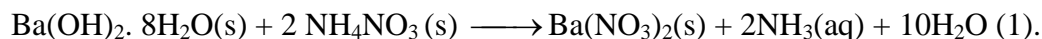
Chemists measure the heat of reactions with calorimeters. The energy, as heat, is absorbed by water in the calorimeter. The difference in the temperature of the water before and after the reaction is used to calculate the heat of reaction. The calorimeter is insulated to prevent heat exchange with the surroundings. The heat of the reaction is then equal to the heat absorbed by water and the calorimeter.

The heat absorbed is calculated by $\Delta H = m_{(H_2O)}Cp_{(H_2O)}\Delta T + m_{(calorimeter)}Cp_{(calorimeter)}\Delta T$, where $m_{(H_2O)}$ is the mass of the water, $Cp_{(H_2O)}$ is the specific heat of water, $m_{(calorimeter)}$ is the mass of the calorimeter, $Cp_{(calorimeter)}$ is the specific heat of the calorimeter, and ΔT is the change in temperature. The product $m_{(calorimeter)} Cp_{(calorimeter)}$ is often called the heat capacity. The term heat capacity is also used for the term Cp . The heat can be calculated by calculating the heat absorbed by the water. In place of the complex calculations, a calibration experiment determines the amount of heat absorbed by the calorimeter is known and can be used to calculate the experimental heat of reaction.

In this investigation the assumption is made that the calorimeter, Styrofoam cups, thermometer and test tube are not going to absorb any heat. That is a fairly good assumption for Styrofoam and fortunately the test tube and thermometer are not large and don't absorb much energy.

In this investigation, both endothermic and exothermic reactions will be examined using a simple calorimeter and making some simplifications in the calculations.

The reaction of sodium hypochlorite and sodium sulfite is exothermic. It is also an oxidation reduction reaction. Sulfite is oxidized to sulfate while hypochlorite is reduced to chloride. $ClO^- + SO_3^{2-} \longrightarrow Cl^- + SO_4^{2-}$. The endothermic reaction of barium hydroxide octahydrate and ammonium nitrate starts with two powders and produces a solution. The products include ammonia, which can probably be smelled, and barium nitrate, which is of limited solubility. The reaction is both an acid base neutralization and precipitation reaction:



The barium hydroxide octahydrate must be the octahydrate form so that there will be enough water to dissolve the two powders. The ammonium nitrate and barium hydroxide octahydrate are added one and then the other, alternately so that an intimate mixture can occur.

Procedures:

1. Prepare a calorimeter out of two small Styrofoam cups by cutting two holes in the bottom of the 6.4 oz. cup. One hole should be just large enough for the large test tube. The other hole is just large enough for a thermometer.
2. Fill the 8.5 oz. cup with water to within $\frac{1}{2}$ cm of the top with the large test tube in the cup.
3. Place the top cup (6.4 oz) on the calorimeter. It should fit snugly just inside the rim of the bottom (8.5 oz) cup. Place the test tube through the hole and set it against the bottom of the calorimeter. Insert the thermometer into the calorimeter.
4. Place 15 mL of bleach (a 5.25% solution of sodium hypochlorite, NaClO) into the test tube. Measure and record the temperature.
5. Add 15 mL of 0.5 M sodium sulfite (Na_2SO_3). Stopper the test tube.
6. Gently swirl the cups to mix the water. The mixing transfers the heat of the water evenly.
7. Record the temperature each minute until the temperature reaches a maximum and begins to decrease or reaches a plateau.
8. Remove the test tube and thermometer. Using a graduated cylinder measure the amount of water in the calorimeter. Also measure the volume of the reaction solution.
9. Prepare the calorimeter for another experiment by placing the same amount of room temperature water in the cup as measured in Step 8.
10. In a clean dry test tube put about 20 g of barium hydroxide octahydrate crystals ($\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$). Record the temperature of the water.
11. Weigh out about 20 grams of barium hydroxide octahydrate crystals ($\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$) onto a watch glass.
12. Weigh out about 10g of ammonium nitrate (NH_4NO_3) onto a second watch glass. Add the barium hydroxide octahydrate and the ammonium nitrate to a clean dry test tube by adding small amounts of one and then the other until all has been added. Stopper lightly and shake the test tube until the solids become a solution. Place the test tube in the calorimeter.
13. Record the temperature each minute until it reaches a minimum and begins to rise or reaches a plateau.
14. Measure the volume of the test tube contents.

15. BARIUM DISPOSAL Pour the test tube contents into a 500mL beaker. Add 100 mL of 10% sodium sulfate. Stir well. Allow to settle.
16. Filter the precipitate (BaSO_4) onto fine filter paper. Fold a piece of filter paper in half and in half again. Tear off the outside corner. Open the paper up between the first and second sheet to form a cone. Place the precipitate and filter to dry. Discard in the designated receptacle to be buried in a secure toxic waster landfill.
17. The sulfite hypochlorite solution can be flushed down the drain with plenty of water.

Development Resources:

Hassell, Alton C, Marshall P., Hill J. (1998) Chemical Investigations for Changing Times. 8th ed New Jersey: Prentice Hall Upper Saddle River.

HEAT OF REACTION REPORT SHEET

Name: _____

Lab Partner: _____

Section: _____

Date: _____

I. SODIUM SULFITE AND BLEACH

1. Initial Temp.	_____	6	_____	12	_____
1 (minutes)	_____	7	_____	13	_____
2	_____	8	_____	14	_____
3	_____	9	_____	15	_____
4	_____	10	_____		
5	_____	11	_____		

2. Temperature Difference $\Delta T =$ _____ $^{\circ}\text{C}$ - _____ $^{\circ}\text{C}$ = _____ $^{\circ}\text{C}$
Final Initial

3. Water Volume _____ mL

 Reaction Solution Volume _____ mL

4. Heat of Reaction

$$\Delta H = (\text{_____ mL} + \text{_____ mL}) \frac{1 \text{ g}}{\text{mL}} \frac{1.0 \text{ calorie}}{\text{g} \cdot ^{\circ}\text{C}} \times \text{_____ } ^{\circ}\text{C} = \text{_____ calories}$$

Volume:	Reaction	Cp(H ₂ O)	ΔT
Water	Solution		

The 1 g/mL is a conversion factor. Cp(H₂O) equals 1.0 calorie per gram degree.

II. BARIUM HYDROXIDE AND AMMONIUM NITRATE

1. Initial Temp.	_____	6	_____	12	_____
1 (minutes)	_____	7	_____	13	_____
2	_____	8	_____	14	_____
3	_____	9	_____	15	_____
4	_____	10	_____		
5	_____	11	_____		

2. Temperature Difference $\Delta T = \frac{\text{Final}}{\text{Initial}} \text{ } ^\circ\text{C} - \text{ } ^\circ\text{C} = \text{ } ^\circ\text{C}$

3. Water Volume _____ mL
 Reaction Solution Volume _____ mL

4. Heat of Reaction

$$\Delta H = (\text{Volume: Water} \text{ mL} + \text{Reaction Solution} \text{ mL}) \frac{1 \text{ g}}{\text{mL}} \frac{1.0 \text{ calorie}}{\text{g} \cdot ^\circ\text{C}} \times \Delta T \text{ } ^\circ\text{C} = \text{ } \text{calories}$$

III. QUESTIONS:

1. How would ignoring the heat absorbed by the Styrofoam cup, the thermometer and the glass test tube affect the heat of reaction measured?
2. Do the reaction solutions actually have the same heat capacity as water?
3. Which reaction is exothermic?
4. Could the barium-ammonium reaction freeze two drops of water? If the drops were between a beaker and a piece of cardboard, would the cardboard be frozen to the beaker? (Try it sometime.)
5. Why did we go to the extra trouble to dispose of the barium?