

# Determination of the enthalpy for decomposition of hydrogen peroxide assignment



## Determination of the Enthalpy for Decomposition of Hydrogen Peroxide

**Objective:** To construct a coffee cup calorimeter, measure its calorimeter constant, and determine the enthalpy of decomposition and formation of hydrogen peroxide. **Background:** This experiment is a classic thermodynamics lab. In it, we attempt to measure the enthalpy ( $\Delta H$ ) of a chemical reaction. The main obstacle is that this is a quantity that cannot be measured directly. It instead is observed as heat from one substance is transferred to another while being monitored with a thermometer.

A temperature change in a known substance (such as water) can be related to a certain amount of heat ( $q$ ).  $q = \text{mass} \times \Delta T = \text{mass} \times (T_f - T_i)$  Specific heat Our calorimeter is going to be a set of Styrofoam coffee cups. These cups are well known insulators, and they should keep most heat inside themselves. They are not perfect, however, and they will absorb some of the heat from the process, so we need to determine the calorimeter constant. For any process, the first law of thermodynamics must be followed.  $\Delta E = 0 = q_{\text{system}} + q_{\text{surroundings}}$  However, if the calorimeter itself is going to absorb some energy, it must be accounted for as well.  $\Delta E = 0 = q_{\text{system}} + q_{\text{surroundings}} + q_{\text{calorimeter}}$  In the first portion of our experiment, a known mass of water with a known temperature will be used to determine how much energy is being absorbed by the calorimeter. Once this is known, the change in enthalpy from the decomposition of hydrogen peroxide can be determined.  $2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$  A solution of hydrogen peroxide will be added to the calorimeter and its temperature will be monitored for a short time.

A small amount of iron nitrate will be added to catalyze the reaction and produce a measureable temperature change. This temperature change will

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be plotted over time. Using this plot, the mass of solution, its specific heat, the calorimeter constant, and the temperature change, we will be able to determine the enthalpy for the reaction. Procedure Week One ???

Determination of the calorimeter constant Objective ??? To measure the amount of energy absorbed by the calorimeter while observing a change in temperature. 1. Using a top loading balance, determine the mass of Styrofoam cup and a stir bar. . Place about 100mL of warm deionized water in the cup. Monitor its temperature for 3-4 minutes. Record the temperature every minute. 3. Using a top loading balance, determine the mass of a second Styrofoam cup and a stir bar. 4. Place about 100mL of room temperature water in the cup. Monitor its temperature for 34 minutes. Record the temperature every minute. 5. When the temperature of the warm water is about 20° C above the room temperature water, quickly pour it into the room temperature water. Continue monitoring the temperature and recording it every minute. . After several minutes, when the temperature is no longer changing quickly, record the mass of the combined water. 7.

Repeat this procedure at least one more time. Week One ??? Preparation of a standard potassium permanganate solution Objective: To prepare a potassium permanganate solution with a known concentration. This will be used in a second week to standardize a hydrogen peroxide solution. 1. Obtain enough potassium permanganate to make 250. 0mL of a 0. 02M solution. NOTE: Use the analytical balance for this operation.

It is NOT necessary to get exactly the amount you calculated. It is only important to be close to this amount, and to record the amount you took accurately. 2. Dissolve this in a small amount of water before diluting it to a

final volume of 250.0 mL in a volumetric flask. 3. Transfer this to a clean dry bottle, and store it for use next week.

Week Two ??? Determination of the Concentration of hydrogen peroxide. Objective: Determine the concentration of hydrogen peroxide and use this result to know how many moles are being decomposed.

1. Pipet 2.0 mL of hydrogen peroxide into a small Erlenmeyer flask. Add about 10 mL of 4.0 M H<sub>2</sub>SO<sub>4</sub> and 50 mL of deionized water.
2. Rinse and fill a buret with the potassium permanganate solution that was prepared last week.
3. Start to titrate the solution. It should stay clear until the endpoint is reached. The endpoint is the lightest permanent pink color that persists.
4. Repeat so that you have three precise trials.
5. Calculate the concentration of the hydrogen peroxide solution. The balanced chemical equation is written below.

$$2\text{MnO}_4^-(\text{aq}) + 5\text{H}_2\text{O}_2(\text{aq}) + 6\text{H}^+(\text{aq}) \rightarrow 2\text{Mn}^{2+}(\text{aq}) + 5\text{O}_2(\text{g}) + 8\text{H}_2\text{O}(\text{l})$$

Week Two ??? Enthalpy of Decomposition of Hydrogen Peroxide Objective: Use the calorimeter from last week to determine the enthalpy of decomposition of hydrogen peroxide.

1. Add 50.0 mL of hydrogen peroxide to the tared Styrofoam cup using a graduated cylinder.
2. Obtain 10.0 mL of 0.5 M iron(III) nitrate in a graduated cylinder.
3. Start recording the temperature of the hydrogen peroxide solution. At the five minute mark, quickly add the iron nitrate, but do not record the temperature.
4. At the six minute mark start recording temperatures again until you reach the 12 minute mark. . Dump out the solution, and repeat if time permits.

Calorimeter Constant Calculations It is very straightforward to determine the energy that is gained or lost when a known mass of water is heated or cooled.

$$q_{\text{system}} = -q_{\text{surroundings}} = q_{\text{calorimeter}}$$

From the data above, you will need to plot the temperature of the room temperature water and extrapolate that line out a bit. That will be its initial temperature (T<sub>1</sub>).

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Extrapolate through the points after mixing, and this will be its final temperature ( $T_2$ ). From this the heat gained by the room temperature water can be calculated.  $q_{\text{room}} = \text{mass} \cdot (T_2 - T_1) \cdot C_{\text{water}}$ . This is repeated for the warm water. Extrapolate the warm water's temperature through the time when it is mixed. This will be its initial temperature ( $T_3$ ). Extrapolate through the points after mixing and this will be its final temperature ( $T_2$ ). From this the heat lost by the warm water can be calculated.  $q_{\text{warm}} = \text{mass} \cdot (T_3 - T_2) \cdot C_{\text{water}}$ . The Calorimeter constant will be the difference between these two. Whatever energy lost by the warm water should have been gained by the room temperature water, except for what was gained by the cup.  $q_{\text{room}} = q_{\text{warm}} + q_{\text{cup}}$ .  $T_2 - T_1 = C_{\text{cup}}$ . A sample for the plot is below. The vertical line is the time when the two water samples were mixed.

Time (min)	Room Temp Water Temp (C)	Warm Water Temp (C)
2	22	
4	27	
6	32	
8	37	42
10		
12		

Mixing Curve for Water

Calculations for the Enthalpy of Decomposition of Hydrogen Peroxide The solution here is mostly water, and it is assumed to have a specific heat of  $4.184 \text{ J/g} \cdot \text{C}$ . There are two things that would absorb the energy lost by hydrogen peroxide: the solution, and the cup.  $q_{\text{H}_2\text{O}_2} = q_{\text{solution}} + q_{\text{cup}}$ . The 'q' of the solution is calculated in a way similar to that of water.

The time and temperature information will have to be plotted. The only thing that is different here, is that the temperature of just one thing is being recorded. There will only be two temperatures,  $T_1$  and  $T_2$ .  $q_{\text{solution}} = \text{mass} \cdot (T_2 - T_1) \cdot 4.184 \text{ J/g} \cdot \text{C}$ .  $q_{\text{cup}} = C_{\text{cup}} \cdot (T_2 - T_1)$ . Here  $C_{\text{cup}}$  was determined last week. To determine the  $\Delta H$  in terms of joules per mole, one will have to divide the energy by the number of moles in the solution.

moles ? M H ? 2 O<sub>2</sub> ? ? Volume ? H<sub>2</sub>O<sub>2</sub> Report Information taken from this lab included the following. Week One ?

Mass of room temperature water ? Mass of cup(s) and stirring bar(s) ? Mass of warm water ? Mass of combined water ? Initial temperatures for water ? Post mixing temperatures for water ? Time ? Mass of potassium permanganate ? Volume of potassium permanganate solution Week Two ? Volume of hydrogen peroxide solution titrated. ? Volume of potassium permanganate used. ? Mass of cup and stirring bar. ? Mass of hydrogen peroxide ? Mass of mixed peroxide and iron ? Temperature prior to mixing. ? Temperature after mixing. ? Time From this, one will need to calculate: ? ? ? ?

The concentration of potassium permanganate The concentration of hydrogen peroxide (averaged) The calorimeter constant (averaged) The enthalpy of decomposition of hydrogen peroxide (averaged) In a 1 ??? 2 page typed report please give the following: ? ? ? A brief 2-3 sentence abstract describing the experiment and the final result. Work detailing how quantities were determined. A brief one paragraph discussion dealing with the comparison of the result to the literature value of (-94. 6 kJ/mole). What specific sources of error might account for a difference between your result and the literature value.