Ice calorimeter

Science, Physics

Abstract: This report is a description of an experimental determination of the enthalpy of reaction of sulfuric acid in a reaction with magnesium to produce magnesium sulfate. Through the use of an ice calorimeter, the rxn H° D for this reaction is determined to be 1 360kJ mol â ̂' â ̂' Ã— . Introduction: This report details an experiment in thermochemistry. Included are the methods, results, and interpretation of results of an experimental determination of an enthalpy of reaction. The reaction being studied is between sulfuric acid, and magnesium metal. ( ) (H2SO4 aq +Mg s)®H2 (g)+MgSO4 (s) This reaction is run as an isothermal reaction, where the enthalpy change is measured by the change in volume of melting ice. Published values for the density of water, and ice, as well as the heat of fusion of water will be used to determine the amount of heat energy that is released by the reaction. The relationship between the changing volume of the calorimeter, and the amount of ice that is melted by the reaction can be expressed mathematically by the following expression. uantity of ice melted uantity of ice melted olume before rxn olume after rxn ensity of ice ensity of water Q Q V V D D â ̂' = â ̂' In order to account for the natural melting of ice at room temperature, the data will be plotted on a coordinate system. A leastsquares linear regression will then be used to identify the equations of two lines, one representing the rate of ice melting prior to the addition of the sulfuric acid, and one representing the rate of ice melting after the reaction has reached completion. These equations will enable the determination of the volume change due to the heat produced by the reaction by use of basic analytic geometry. Experimental: Methods An ice calorimeter is used to determine the change in volume of the water and ice. This consists of a beaker with a modified stopper. The stopper has holes in which a test tube, a graduated pipette stem, and a fill tube with petcock are firmly seated. The beaker is packed full of ice and water, the stopper is securely installed, and the entire assembly is packed in a bucket of ice. At this time 5 mL of chilled 1. 00 M sulfuric acid is measured using a 5. 00 mL pipet, and placed into the test tube installed in the calorimeter lid. Once theses preparations have been made, the 3 assembly is observed for a couple of minutes to ensure there are no apparent leaks. Once satisfied that the assembly is water tight, the stopwatch is started, and the initial pipet reading is recorded. Throughout the run, the pipet reading is recorded every 30 seconds. The volume is observed for 3 minutes to establish the normal melting rate of the ice. At this time, 0. 209 g Mg(s) is added to the calorimeter in the form of solid ribbon cut into very small pieces. The reaction is allowed to run to completion while recording the pipet reading every 30 seconds. Once the change in volume over several consecutive time intervals is changing at the same rate as during the initial 3 minutes of monitoring, the reaction is assumed to be complete. Data Table 1. Change in calorimeter volume over time time(s) pipette reading(mL) 0 0. 750 30 0. 735 60 0. 730 90 0. 715 120 0. 710 150 0. 700 180 0. 690 210 0. 685 240 0. 675 270 0. 670 300 0. 615 330 0. 525 360 0. 450 390 0. 385 420 0. 325 450 0. 270 480 0. 230 510 0. 185 540 0. 150 570 0. 125 600 0. 100 630 0. 080 660 0. 060 690 0. 045 720 0. 035 750 0. 020 780 0. 010 810 0. 000 4 Figure 1. change in calorimeter volume over time 0. 000 0. 100 0. 200 0. 300 0. 400 0. 500 0. 600 0. 700 0. 800 0 100 200 300 400 500 600 700 800 900 time (s) pipet reading (mL) Figure 2. Projection of normal volume change y = -0. 0003x + 0. 7463 R2 = 0. 9901 y

= -0. 0004x + 0. 3095 R2 = 0. 9944 -0. 100 0. 000 0. 100 0. 200 0. 300 0. 400 0. 500 0. 600 0. 700 0. 800 0 100 200 300 400 500 600 700 800 900 time(s) pipet reading(mL) Results: The heat of the reaction in the test tube caused some of the ice in the calorimeter to melt. This resulted in a decrease in the total volume of ice and water. The change in volume is shown in the figure 1, plotted against the elapsed time at each reading. The data points occurring before the magnesium strips were added to the acid, as well as the last 5 points, which represent the normal rate of ice melting after completion of the reaction, are evaluated using a least-squares linear regression. This yields the equations of two lines. The slopes of these lines represent the rate of ice melting before and after the reaction, as shown in figure 2. 5 These equations are now evaluated at the approximate midpoint of the reaction. For these calculations, time= 500 seconds will be used. The volume change will be the difference in y between the two equations. ( ) ( ) ( ) 1 1 . 0003 500 . 7463 . 5963 Where 500 . 0004 500 . 3095 . 1095 br ar y mL s s mL x s y mL s s mL âˆ' âˆ' = âˆ' Ã— + = = = âˆ' Ã— + = Now subtract to find the change in volume caused by the reaction. . 5963 . 1095 . 487 br ar y âˆ' y = mL âˆ' mL = mL Now, the quantity of ice that was melted can be determined using the formula given in the introduction. The values for the densities of ice and water will be required for this calculation. These were found in the CRC Handbook1, and are as follows: ( ) 1 2 H O l @0 C=. 99987g mLâˆ' Ã— ( ) 1 2 H O s @0 C=. 917g ml âˆ' Ã— Now these values will be applied to the equation. uantity of ice melted uantity of ice melted olume before rxn olume after rxn ensity of ice ensity of water Q Q V V D D âˆ' = âˆ' 1 1 . 487 . 917 . 99987 Q Q mL g mL g mL âˆ' âˆ' = âˆ' Ã— Ã— 1 1 1 . 99987 . 917 . 08287 .

91688079 . 91688079 . 91688079 Q Q Q g mL g mL g mL âˆ’ âˆ’ âˆ’ = âˆ’ = Ã— Ã— Ã— ( ) 1 . 487mL . 91688079g mL . 08287Q âˆ’ Ã— = . 4465209447 5. 39 . 08287 g Q = = g Now, the heat of fusion of water will be used to determine the amount of heat that is released by the reaction. 2 79. 72 H O = fusion cal H g D Now convert to Joules per gram. 6 79. 72 cal 4. 184 1 J g cal Ã— 1 2 333. 5 of H O fusion J g H âˆ’ = Ã— = D This reaction transferred heat to the surroundings. This makes the reaction exothermic, so the enthalpy change will have a negative sign. 5. 39 g 333. 5 1 J g âˆ’ Ã— = âˆ’1. 80Ã—103 J Now the chemical equation is presented for the reaction of sulfuric acid and magnesium to produce magnesium sulfate. This will be the first step to calculating rxn DH for this reaction. ( ) ( ) ( ) ( ) 2 4 2 4 H SO aq +Mg s ®H g +MgSO s The equation is balanced with all coefficients equal to 1, therefore, 1 mol of reactant will produce 1 mol of product. The molar mass of magnesium is now used to determine the amount of Mg available for the reaction. 1 . 209 Mg= 24. 31g mol g mmass âˆ’ Ã— 1 1 24. 31 mol g Ã— 3 8. 60 10 mol âˆ’ = Ã— Now, the volume and molarity of sulfuric acid is used to determine the amount available for the reaction. 1mol L 1L Ã— 1000 mL 5mL Ã— 3 5. 00 10 1 mol âˆ’ = Ã— It is now apparent that magnesium is in excess, and there are 3 5. 00 10 mol âˆ’ Ã— of the limiting reactant. Due to the 1 to 1 ratio of reactant to product, there should also be 3 5. 00 10 mol âˆ’ Ã— product. This quantity will enable us to establish rxn DH for the reaction. 3 1. 80 10 rxn J H âˆ’ Ã— D = 3 1 1 1 5. 00 10 1000 kJ mol J âˆ’ Ã— Ã— Ã— 1 360kJ J âˆ’ = âˆ’ Ã— Discussion: Recall that the purpose of this experiment was to attempt to measure the reaction enthalpy of a given reaction. In this case, by measuring the amount of heat absorbed by the ice in the chamber, we can determine the amount of heat that was released in the reaction. By measuring precisely, we can measure the heat given off by a small amount of reactants, and use that information to determine the heat of the reaction in the standard units. The results of this experiment determined the rxn DH of the reaction of magnesium and sulfuric acid to form magnesium sulfate and hydrogen gas to be 1 360kJ mol âˆ’ âˆ’ Ã— . 7 Published data could also be used to determine the heat of this reaction. In this case, though, this data will be used to check the accuracy of experimental results. This is simply done by using the published values2 for the DHF of sulfuric acid and magnesium sulfate to determine the standard heat of reaction. Remember that water and hydrogen gas are in their standard states and have F DH values of 0. ( ) ( ) ( ) 2 4 2 tan H SO 814 MgSO 1278. 2 1278. 2 814 464. 2 f f rxn f f H products H reac ts H H kJ mol H kJ mol kJ mol D âˆ’ D = D D = âˆ’ D = âˆ’ âˆ’ âˆ’ âˆ’ = âˆ’ Here we can see that by using published values for the standard heats of formation of the compounds used in the experiment, we can calculate the standard state heat of reaction for this reaction. Compared with these values, the results of this experiment deviate from the calculated book values by 22. 45%.