The Enthalpy Change for a Reaction that can be Carried out in a Series of Steps in a Styrofoam Cup Calorimeter

Introduction

When all of the energy change of a reaction appears as heat and the pressure of the reacting system remains constant, then the change in enthalpy ,ΔH equals the heat of reaction (q).

In this investigation you will be examining three separate but related reactions in which $\Delta H = q$. By making the appropriate measurements and calculations, you will determine ΔH for each reaction. The relationship between the three ΔH values will then be examined using Hess's Law.

Procedure

The class lab partners will perform part of the lab (ie. Part A, Part B, or Part C) as described in the lab.

NOTE: Measure all volumes in graduated cylinders. Record to the nearest 0.1 cm^3.
Measure all masses to the nearest 0.01 g.
Record all temperatures to the nearest $0.1^{O}C$

Calculations

1.Complete all calculations required to fill in the data table. Show the steps of your calculations clearly on a separate sheet of paper and include units throughout your calculations. Round off all final answers to the appropriate number of sig figs.

Assume:
a) The specific heat capacity of all solutions = the specific heat capacity of water ($4.18\ Jg^{-1}\ {}^{O}C^{-1}$)
b)The density of all solutions = density of water ($1.00\ g\ cm^{-3}$)

2. Write out the thermochemical equations for the three parts of this investigation. Arrange them to indicate their relationship in terms of Hess's Law.

3.Calculate the percentage error using:

% difference = $|\Delta Ha + \Delta Hb + \Delta Hc| \ / \ |\Delta Hc| \quad X\ 100$

Discussion

1. Discuss at least two possible sources of error in this investigation, that would explain the difference above.

2. a) Write the ionic equation for Part A and Part B.
   b) Write and compare the result with the ionic equation for Part C.

3. Suppose you had used 8 g of sodium hydroxide in Part A.

   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 calculations of the heat of reaction for Part A?

4. Write the net ionic equation for the reaction between solutions of potassium hydroxide, KOH, and sulphuric acid, H_2SO_4. Compare the net ionic equations for this with that of Part B. What does the heat of reaction for Part B of this experiment represent? Write the thermochemical equation for Part B of the experiment.

5. Predict the heat of reaction for NaOH and HNO_3. Explain your answer.

6. A student performed the experiment for the calorimetric determination of the molar heat of neutralization of KOH with H_2SO_4. 100 mL of 1.00 mol dm^{-3} KOH was reacted with 50.0 mL of 1.00 mol dm^{-3} H_2SO_4 , a temperature rise of 10.2 ^{O}C was observed.

   a) What is the molar heat of neutralization for KOH, calculated by the student?
   b) How will the students calculated value differ from the accepted value for this reaction? Explain your answer.
   c) If the student used ethanoic acid, $CH_3COOH_{(aq)}$, instead of sulphuric acid, $H_2SO_{4(aq)}$, how will his value differ from the value obtained by the reaction of $H_2SO_{4(aq)}$ + $KOH_{(aq)}$
   Explain your answer.

Results and Observations

Part A: Dissolving $NaOH_{(s)}$ in H_2O **Steps:** 1.Add 200 mL of room temperature water to a Styrofoam cup. Record the temperature 2.Measure out a sample of NaOH(s) with a mass between 3.9 g and 4.1 g. Record mass to 0.01 g. 3.Add NaOH(s) to the water. Stir gently until dissolved. Record maximum temperature reached. NaOH(s) ----> NaOH(aq)	**Part B: Neutralizing $NaOH_{(aq)}$ with $HCl_{(aq)}$** **Steps:** 1.Add 100 mL of 1.00 mol dm^{-3} HCl to a Styrofoam cup and record the temp. 2.Measure 100 mL of 1.00 mol dm^{-3} NaOH in a graduated cylinder and record its temperature. 3.Pour the NaOH into the HCl in the Styrofoam sup. Stir and record the maximum temperature. NaOH(aq) + HCl (aq) ---> NaCl(aq) + H_2O(l)	**Part C: Dissolving and Neutralizing $NaOH_{(s)}$ in $HCl_{(aq)}$** **Steps:** 1.Add 200 mL of 0.5 $moldm^{-3}$ HCl to a styrofoam cup and record the temperature of the solution. 2.Measure out a sample of NaOH(s) with a mass between 3.9 and 4.1 g. Record the mass to the nearest 0.01 g. 3.Add the NaOH(s) to the acid solution. Stir gently with a thermometer until all the NaOH is dissolved. Record the maximum temp. reached.
Mass of NaOH(s) Volume of Water initial Temp of water Final Temp of solution endo- or exo-	Temp of 1 mol dm^{-3} HCl Volume of 1 $moldm^{-3}$ HCl Temp. of 1 mol dm^{-3} NaOH Volume of 1 mol dm^{-3} NaOH Highest temp. reached Endo or Exo?	Mass of NaOH(s) Volume of 0.5 $moldm^{-3}$ HCl Final temp. of solution Endo- or Exo-
RESULTS	**RESULTS**	**RESULTS**
Change in Temp. Mass of Solution Heat associated with reaction (q) # moles NaOH(s) used Heat produced per mole of NaOH(s) ΔH_a in kJ per mol of NaOH used	Change in temp Mass of solution Heat associated with reaction (q) # moles of NaOH used (n=CV) Heat produced per mole of NaOH ΔH_b in kJ per mol of NaOH used	Change in temp. Mass of the final solution Heat associated with the reaction (q) # moles NaOH used Heat produced per mole of NaOH ΔH_c in kJ per mol of NaOH used
$\Delta H_a + \Delta H_b$ =		ΔH_c