Name: _____ Date:_____ Experiment # _____

LAB: VALIDATION OF HESS'S LAW

Instructions

1. Complete the pre-lab day before the actual lab is performed
2. No lab report is needed; complete the calculations and discussion questions that are provided on the sheet provided. Complete the Lab Journal, include the prelab in your journal too.
3. Use goggles while performing the lab and cleaning up the lab. Goggles should only be taken off when all the students are done with the lab activities and you are working of the calculations. You may use aprons and gloves if you so desire and you need to bring your own.
4. If you come in contact with any of the chemicals wash with cold running water for 10 to 15 minutes. Tell your partner and inform you teacher ASAP. All chemicals used are dilute, follow procedures while handling solid NaOH pellets.
5. All chemicals can be disposed of in the sink but make sure you wash the sink down with running water. This instruction is valid only for this experiment.
6. If any member in a group refuses to wear goggles all members of the group will be awarded a mark of 'zero' for you experiment.
7. Record your observations in your observation book and get the teachers signature in the appropriate spots on the lab sheet after filling up the data.
8. If in doubt always ask your teacher
9. All instructions provided are for the current lab only. Other labs may have additional safety requirements.

Pre lab: Heat of Reaction

1. The specific heat of water is 4.18 J/g^{o}C. How many joules of heat will be required to raise the temperature of 150 g of water by 40 ^{o}C?

2. A calorimeter containing 1 liter of water at 23^{o}C is warmed to 68^{o}C when 5 g of butter is burned. Calculate

   a) the total number of joules absorbed by water

   b) the number of joules/g given off by the oxidation of butter fat.

   c) the number of kJ / g given off by the oxidation of the butter fat

3. Why must the sodium hydroxide be weighed as quickly as possible in this experiment?

4. 5.61 g of KOH is dissolved in 200 ml of water in a Styrofoam calorimeter. The temperature rise is 9^{o}C. Calculate

   a) the number of joules absorbed by the water due to the dissolving of the KOH

   b) the number of moles of KOH dissolved in the reaction

   c) the heat of the reaction in kJ/mol for the dissolving of potassium hydroxide in water (heat of solution)

Experiment # 2: Hess's Law Validation

Introduction:

The principle of heat exchange states that in a calorimetric determination Heat lost = Heat gained provided that there are no exchanges with the environment resulting from conduction, convection or radiation. A calorimeter is an insulating vessel designed to minimize energy exchanges with the surroundings. The heat transferred whether gained or lost is given by the formula.

$$\text{Heat Transfer } (q) = \text{Mass } (g) \times \text{Specific heat } (c) \times \text{Temperature change } \Delta T$$

$$q = mc\Delta T$$

The unit of heat are calories, kilocalories or kilo joules. When incorporated into the Enthalpy Change notation ΔH = q / mol of reactant or product.

In this experiment, the heat lost by an exothermic reaction is determined by the heat gained by the water in a Styrofoam calorimeter or the Styrofoam calorimeter. From the calculation of the heat absorbed by the water, the HEAT OF REACTION can be calculated. The three related reactions are studied in this manner. The second purpose for this experiment is to verify Hess's Law – The principle of additivity of heats of reaction. One of the reactions studied is the algebraic sum of the other two reactions.

General Instructions:

1. The experiment should be done in groups of 3 unless instructed otherwise
2. Do not touch NaOH with your hands. If a spill occurs, pick the solid pellets up with paper towel and dispose of the pellets (not the towel) into the container placed in the lab for disposal of chemicals. Wash your skin with plenty of water if contact is made – if irritation persists, consult your teacher.
3. For rapid weighing tare the balance with the stoppered weighing bottle or weighing boat available on the pan. Then add the NaOH to approximately 2.0 g. Record the weight.
4. Use the Styrofoam calorimeter provided for the experiment. Steel thermometers are inserted through the hole in the lid. When mixing the contents keep the lid closed as much as possible to avoid heat loss to the surroundings. Stir gently with circular metal stirrer placed in the calorimeter until an uniform high or low temperature is attained.
5. Make sure to rinse out the calorimeters after each experiment
6. Check your final temperature changes for each experiment with the teacher.

Table 1

Reaction	Mass of NaOH	Volume NaOH	Volume HCl	Moles NaOH	ΔT Temp ^{o}C	'q' joules	Heat of reaction ΔH
1							
2							
3							

Calculations

Show all formulae and arithmetic

1. **Reaction 1**

   $NaOH_{(s)} \longrightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

   Heat transfer q =

   Moles of NaOH reacted =

   ΔH_1 =

2. **Reaction 2**

   $NaOH_{(s)} + H^{+}_{(aq)} + Cl^{-}_{(aq)} \longrightarrow H_2O + Na^{+}_{(aq)} + Cl^{-}_{(aq)}$

   Heat transfer 'q' =

   Moles of NaOH reacted =

   ΔH_2 =

3. **Reaction 3**

   $Na^{+}_{(aq)} + OH^{-}_{(aq)} + H^{+}_{(aq)} + Cl^{-}_{(aq)} \longrightarrow H_2O + Na^{+}_{(aq)} + Cl^{-}_{(aq)}$

   Heat transfer `q` =

   Moles of NaOH reacted =

   ΔH_3 =

Questions

1. Using NET IONIC equations for the reactions 1,2 and 3 prove that

   Reaction 2 = Reaction 1 + Reaction 3

2. (a) Define Hess`s Law

   (b) What mathematical relationship exists between ΔH_1, ΔH_2 and ΔH_3 according to Hess`s Law?

3. Compare the ΔH_2 value determined in the experiment 2 with the ΔH_2 value calculated using the relationship in 2b using the formula

   % Difference

   $$\%\ Difference = \frac{\Delta H_{2(Hess)} - \Delta H_{2(expt)}}{\Delta H_{2(Hess)}} x100\%$$

   =

   (b) Is Hess's Law validated by your results? Explain.

4. List at least 4 assumptions made in the calorimetric calculations throughout the experiment.

5. Suppose you performed another experiment and used 4 g of solid NaOH in reaction # 1
   (a) How would this effect the change in temperature? Be specific.

   (b) What would have been the number of joules evolved from your experiment?

   (c) What effect would this have on your resulting value of ΔH_1?

Procedure

Apparatus and chemicals required:

- Styrofoam Calorimeter
- Thermometer or temperature probes (either works well)
- 3, 250 ml dry and clean beakers
- Distilled water
- $NaOH_{(s)}$ in small plastic containers (do not leave it open or it will become moist and your results will be skewed)
- Measuring jars
- 1 M NaOH solution about 100 ml
- 1 M HCl about 150 mL. Take 50 ml of 1 M HCl and add 50 ml of distilled water to obtain 100 mL 0.5 M HCl in part II.
- In part III use 50 ml of 1 M HCl with 50 ml 1 NaOH.

Part I : Determination of the heat of reaction 1.

Caution: *Sodium hydroxide is extremely corrosive to the skin and causes blindness. So handle with care, respect all chemicals. Follow protocol and instructions provided before the lab. If in doubt ask your teacher.*

a. Put 100 ml of cool tap water into a styrofoam calorimeter. Stir carefully until a constant temperature is reached (about room temperature). Measure this temperature as precisely as possible and record it in your observation book. You may use a lab quest / phone and a steel temperature probe to record your temperature.

b. Weigh out about 2 g of solid sodium hydroxide, $NaOH_{(s)}$, as precisely as possible. Since sodium hydroxide becomes moist as it is being weighed in the open-air. If you need help ask. The weight of NaOH can be anyway between 1.95 and 2.05 grams.

c. Transfer the massed $NaOH_{(s)}$ into the water in the calorimeter. Place the thermometer into the solution and stir gently but continuously until the sodium hydroxide is dissolved. Record the highest temperature reached. Before proceeding to reaction 2 discard the solution in the container provided for you in the lab and rinse the calorimeter thoroughly with water before you start part ii.

Part II: Determination of the heat or reaction 2.

a. Repeat steps a, b and c of part I, but substitute the water with 100 ml of 0.5 M HCl for tap water in step a. Measure temperature changes and proceed to b. (Add 50 mL 1 M HCl to 50 mL distilled water to prepare 0.5 M HCl solution).

b. Discard the solution and rinse the calorimeter before proceeding to reaction 3.

Part III: Determination of the heat of reaction 3.

a. Measure 50 ml of 1.0 M HCl into the calorimeter record the temperature now measure 50 ml of 1.0 M NaOH measure its temperature and add it to the acid in the calorimeter. Measure the rise in temperature