Investigation 4: Calorimetry of Neutralization Reactions

Focus Question: *What is the enthalpy change for neutralization reactions? How does it depend on the specific acids and bases used?*

Pre-lab required reading

Chemistry; an Atoms-Focused Approach: Sections 8.4, 10.3 – 10.6

Safety and Waste Disposal

- Eye protection should be worn at all times.
- Waste solutions produced in this investigation can be washed down the drain.

Background

Calorimetry is used to determine the amount of heat released or taken up during a chemical reaction. In this lab we will use simple solution calorimeters to determine the heat of reaction for several different acid-base reactions. We will use simple styrofoam coffee cups for a calorimeter. These cups have (to a very close approximation) a zero heat capacity. Thus no heat is transferred to the cups. However, the heat released by the reacting acid and base IS released to the surrounding aqueous solution. The aqueous solutions have a heat capacity of c_{sol} = 4.184 J/g·C and a density of 1.00g/mL. We can measure the increase in temperature of the solution (ΔT) and calculate the amount of heat gained by the solution (q_{sol}) using our model for heat transfer:

$$q_{sol} = m_{sol} \cdot c_{sol} \cdot \Delta T$$

Since the heat gained by the solution equals the heat lost by the reaction we find that the heat of the solution is related to the enthalpy change for the reaction:

$$q_{rxn} = -q_{sol} \quad \text{and} \quad \Delta H_{rxn} = \frac{q_{rxn}}{n}$$

Procedure

Wash and dry 7 beakers to gather appropriate amount of solutions. You will need to determine approximately how much of each solution to obtain based on the amounts needed below. Also obtain: a thermometer; two graduated cylinders (one marked "acid" and the other "base"); and a "coffee-cup" calorimeter (consisting of two nested styrofoam cups, a lid, and stirrer).

Your team will investigate the following combinations of solutions:

1. 23.0mL of 2.0 *M* HCl and 50.00mL of 2.0 *M* NaOH
2. 23.0mL of 2.0 *M* HNO_3 and 50.0mL of 2.0 *M* NaOH
3. 23.0 mL of H_2SO_4 and 50.0 mL of NaOH

4. 50.0 mL of H_2SO_4 and 40.0 mL of NaOH
5. 40.0 mL of $NaHSO_4$ and 50.0 mL of NaOH
6. 40.0 mL of Na_2SO_4 and 50 mL of HCl

7. 40.0 mL of NH_3 and 50.0 mL of HCl
8. 40.0 mL og NH_4Cl and 50.0 mL NaOH

Begin each trial by placing the volume of acid assigned for your first trial (measured with the “acid” graduated cylinder) into the calorimeter. Monitor the temperature of the acid. When the temperature of the acid has reached a constant value, record the temperature. Quickly add the assigned volume of base (measured with the “base” graduated cylinder) to the acid in the calorimeter and place the lid on the calorimeter. Stir the reaction mixture, recording the temperature at 30-second intervals until the temperature remains constant for a few minutes. Record the maximum or minimum temperature reached by the solution.

Dispose of the reaction mixture, rinse and dry the calorimeter, and repeat the procedure for the remaining trials.

Calculate the heat of reaction for each trial and determine the limiting reagent. Determine the enthalpy of the reaction per mole of limiting reagent for each reaction. Report these data to your instructor as needed. The average of the enthalpies determined by the class will be used to understand and apply Hess’s Law to the reactions under investigation.

References

Atkins, P.; Jones, L. “Chemical Principles: The Quest for Insight”, 5th ed.; Freeman: New York. **2010**.

Maloney, D. W.; Sweeney, J. A.; Davenport, D. A.; Ramette, R. W. *A Continuous Variation Study of Heats of Neutralization*. J. Chem. Ed., **58**, 9, **1981**, pp. 730 – 1.