7.2 Coffee Cup Calorimetry I – Heat of Neutralization

Subjects: Thermodynamics, enthalpy, calorimetry

Description: Using a coffee cup calorimeter, the heat of neutralization of HCl and NaOH is measured. From this, the enthalpy change for the neutralization of one mole of HCl can be calculated.

Materials:
Two Styrofoam coffee cups – nested
Lid or parafilm (w/ rubberband to secure parafilm)
Thermometer or thermocouple – preferably with USB interface for transfer of data to computer*
50 mL 0.1 M HCl‡
50 mL 0.1 M NaOH‡
2 100 mL graduated cylinders

‡NaOH and HCl are located in the cabinets under the hood.
*Shared items. Located in the drawers opposite the storage shelves.

Procedure:
1. Set up calorimeter apparatus.
2. Measure temperature of solutions before mixing.
3. Simultaneously add HCl and NaOH to coffee cup
4. Measure temperature change after mixing
5. Calculate enthalpy change

Discussion:
Calorimetry is the process by which the heat in a chemical or physical process can be measured. The apparatus is the calorimeter. A coffee cup calorimeter made of styrofoam is not technologically advanced but it is fairly effective in preventing heat transfer between the system and the environment. Because the cup is open to the atmosphere, this is a constant pressure measurement.

The neutralization reaction of hydrochloric acid with sodium hydroxide is given below:

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) + heat$

What is the energy as heat lost or gained by the solution? First assume that the densities of the solutions and the specific heat capacities are approximately those of water – 1g/ml and 4.20 J/g.K, respectively.

Also assume that no energy is lost to the surroundings.

$q_{solution} = C*m*\Delta T \qquad \Delta T = T_f - T_i$

$q_{solution}$ = (50g HCl + 50g NaOH)(4.2 J/g K)(ΔT) = 420(ΔT) J

The energy absorbed or evolved for the reaction is qr. By conservation of energy:

$q_r + q_{solution} = 0$ therefore $q_r = -q_{solution} = -420(\Delta T)$ J

What is the enthalpy change when one mole of acid is neutralized?

$\Delta_r H$= (-420ΔT J / 50 g HCl)(36.4 g/mol HCl) = -305.7ΔT J/mol HCl

Once the change in temperature is measured, the $q_{solution}$ and the change in enthalpy for the reaction can be calculated.

Safety: HCl is corrosive. NaOH is caustic. Both can cause burns. Use gloves and eye protection while performing the experiments.

Disposal: Neutral solutions can be washed down the drain.

References:

1. J. Kotz, P. Treichel, J. Townsend; *Chemistry & Chemical Reactivity* 7th ed. Instructors Edition; Brooks/Cole; 2009