Hand warmer - Calorimetry

Introduction

Many physical changes involve release and absorption of heat. Examples include the dissolving of salts, known as heat of solution, changes in state (melting and freezing, evaporation and condensation), and the compression and expansion of gases.

Heat can be defined as energy transferred between matter because of differences in temperature. The ability of matter to transfer heat depends on its mass and temperature. A calorimeter is an instrument used to measure changes in heat energy. Two of the most common types of calorimeters are the coffee cup calorimeter and the bomb calorimeter. A coffee cup calorimeter is essentially a polystyrene (Styrofoam) cup with a lid. The cup is partially filled with a known volume of water and a thermometer is inserted through the lid of the cup so that its bulb is below the water surface. When a chemical reaction occurs in the coffee cup calorimeter, the heat of the reaction affects the temperature of the water inside the calorimeter. The change in the water temperature is used to calculate the amount of heat that has been absorbed (used to make products, so water temperature decreases) or evolved (lost to the water, so its temperature increases) in the reaction. The equation that can be used to calculate change in heat energy is

$$q = m \times Cp \times \Delta T$$

where q = heat absorbed or released (in J), ΔT = change in temperature (in °C), m = mass (in g), and C_p = specific heat capacity. The specific heat is the amount of heat required to raise the temperature of 1 gram of a substance 1 degree Celsius. The specific heat of water is 4.18 J/ (g °C). The joule (J) is the SI unit for heat energy.

Calorimetry is the basic chemistry behind instant cold packs and hand warmers. These devices consist of outer package of a solid ionic compound and an inner package of water. Upon activation, the solid dissolves in the water producing a large temperature change. An exothermic heat of solution will create a hand warmer; whereas, an endothermic heat of solution will create a cold pack. In this lab, you will investigate the heat of solution of different ionic compounds and the effect it has on its surroundings.

Engage

Materials

- LabQuest
- 2 Temperature Probes or digital thermometers
- 50-mL graduated cylinder
- 250-mL beaker
- weigh boats
- Styrofoam cup
- cold water
- warm water
- balance
- hot plate
- spatulas

Ionic solids:

- Ammonium nitrate
- Sodium chloride
- Lithium chloride
- Magnesium sulfate
- Calcium chloride
- Sodium acetate
- Sodium carbonate

Pre-Lab

Your instructor will perform a demonstration on how to use a calorimeter. Pay close attention to the demonstration. Collect data during the demonstration and calculate the heat of solution for magnesium sulfate with guidance from your teacher.

Determine the heat of solution of magnesium sulfate

Mass of water, m_{water}	grams
Mass of MgSO4, m_{MgSO4}	grams
Initial temperature, $T_{initial}$	˚C
Final temperature, T_{final}	˚C
Temperature change, ΔT	˚C

Molar heat of solution, q_{soln}	kJ/mole

Explore

Procedure

1. Obtain and wear goggles.
2. Connect the Temperature Probes to LabQuest and choose New from the File menu. If you have older sensors that do not auto-ID, manually set up the sensors.
3. On the Meter screen, tap Rate. Change the data-collection rate to 0.5 samples/second and data-collection length to 180 seconds. Select OK.
4. Place a Styrofoam cup into a 250 mL beaker as shown in Figure 1.

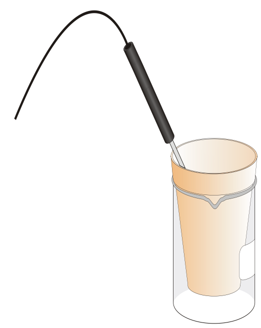

Figure 1

Your lab group will be assigned a maximum of 5.00 grams of an ionic solid. Using the general procedure from the pre-lab activity, design and perform experiment(s) to determine the heat of solutions for multiple solids. Be sure to review procedure and safety concerns with instructor before performing any experiments. Collaborative methods maybe required in order to adequately test multiple samples.

Post-Lab Questions

1. In contrast to a hand warmer, instant cold packs also work on the premise of heats of solutions. Review the data collected from all solids. Identify a solid that would best be suited for an ice pack. Explain your reasoning.

2. One type of cold pack has 100 g of water that mixes with 20 g of NH_4NO_3. If the heat of solution for NH_4NO_3 is 25.4 kJ/mole, what would be the final temperature of the bag in degrees Celsius if the initial temperature were 23°C? Given the specific heat of water is 4.18 J/g°C.

3. A 1.5886 g sample of glucose ($C_6H_{12}O_6$) was ignited in a bomb calorimeter. The temperature increased by 3.682°C. The calorimeter contained 1.000 kg of water. Find the molar heat of reaction (i.e., kJ/mole) for the given reaction.

$$C_6H_{12}O_6\ (s) + O_2\ (g) \rightarrow 6\ CO_2\ (g) + 6\ H_2O\ (l)$$

Elaborate

1. Collect data from other lab groups concerning the heat of solutions for each of the remaining solids. From the data collected, predict which solid could be used in an effective hand warmer. Your prediction must take into consideration the following:
    a. Your prediction must be the most cost effective for a hand warmer containing 10 grams of solid and 40 mL of water. A temperature change of 20˚C is expected. Cost information for each solid will be provided by your instructor.
    b. Your hand warmer must be nontoxic and the least harmful to the environment. Health and environmental concerns can be found on the MSDS for each solid.

2. In your experiments, it was assumed that the heat capacity of the calorimeter was 0 Joules/˚C. This typically isn't the case. If the heat capacity of the calorimeter is 3.43 Joules/˚C, would the heat of solution increase, decrease, or have no effect on your calculated heat of solution for your solid? Would your selection of solid change?