# Investigation 3: Calorimetry and Designing a Heat Pack

***Focus Question:*** *How much heat is absorbed or lost when solids are dissolved in water? How would you design and test a heat pack?*

## Pre-lab required reading

Chemistry; an Atoms-Focused Approach: Sections 9.3 – 9.6

## Safety and Waste Disposal

- Eye protection should be worn at all times.
- Salt water waste solutions produced in this investigation can be washed down the drain.
- Ethylene glycol cannot go down the drawn and should be reused or placed into a waste container.

## Background

Calorimetry is used to determine the amount of heat released or taken up during a chemical reaction or physical process. In this lab we will use simple solution calorimeters to determine the heat of reaction for three different solids dissolving, sodium chloride, potassium chloride and calcium chloride. Note that when these ionic solids dissolve they dissociate into ions. For example:

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)} \quad (1)$$

We will use simple polystyrene 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 or absorbed by the process of the solid dissolving IS released to the surrounding aqueous solution. We will assume that the aqueous solutions have the same heat capacity and density of pure water (i.e. $c_{sol}$ = 4.184 J/g·C and a density of 1.00g/mL). We can measure the increase in temperature of the solution ($\Delta T$) and calculate the amount of heat gained by the solution ($q_{sol}$) using our model for heat transfer:

$$q_{sol} = m_{sol} \cdot c_{sol} \cdot \Delta T \quad (2)$$

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 (i.e. the process of the solid dissolving):

$$q_{rxn} = -q_{sol} \quad (3)$$

And

$$\Delta H_{rxn} = \frac{q_{rxn}}{n} \quad (4)$$

## Procedure

Obtain a beaker with about 500 mL of distilled water, a thermometer and a "coffee-cup" calorimeter (consisting of two nested polystyrene cups, a lid, and stirrer).

Begin each trial by placing 50.0mL of water into the calorimeter. Record the temperature of the water. Precisely weigh 4-6 g of one of the salts (sodium chloride, potassium chloride or calcium chloride). Add the salt to the water in the calorimeter and place the lid on the calorimeter. Gently stir the reaction mixture, recording the temperature at 5-second intervals until the temperature reaches a plateau. 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 two salts.

Determine which salt would be most useful in a hot pack. For this salt, you will more accurately determine the heat produced when it dissolves. First place 100mL of water into the calorimeter. Record the temperature of the water. Precisely weigh 10 g of the salt. Add the salt to the water in the calorimeter and place the lid on the calorimeter. Gently stir the reaction mixture, recording the temperature at 5-second intervals until the temperature reaches a plateau. Dispose of the reaction mixture, rinse and dry the calorimeter. Repeat the procedure two more times. For the second sample, use 70 mL of water. For the third sample, use 50 mL of water. You should use approximately the same mass of salt for each trial. Use this information to determine the heat of the reaction and the mass ratio of salt/water for each trial.

Your goal for this part of the lab is to design and test a heat pack for maintenance workers on the Alaskan pipeline. Your heat pack must be able to treat frostbite in a worker's hand. Consider that the hand was cooled from normal body temperature of 37 ºC down to a dangerous 15 ºC, at profound risk of frostbite. Determine how much salt should be in the heat pack, and how much water should be added to activate it and a way to test the heat output of the pack. Use the generally accepted value for the human body's specific heat of 3.47 J/g ºC and an estimate for the mass of one hand of 200.00g. A 50/50 mixture of ethylene glycol and water has specific heat capacity of 3.46 J/g ºC.

## References

Atkins, P.; Jones, L. "Chemical Principles: The Quest for Insight", 6th ed.; Freeman: New York. **2013**.
Vannatta, M. W.; Richards-Babb, M.; Sweeney, R. J. *J. Chem. Ed*., 87, 11, **2010**, pp. 1222 – 1224.
Davidovits, P. *Physics in Biology and Medicine*, 3rd ed.; Elsevier, Inc.; Oxford, UK, **2008**; pp 119.