EXPERIMENT 13: Temperature Measurements and Heat of Dissolution

Materials:

- Beaker (100 mL)
- Thermometer
- Hot Plate
- Graduated Cylinder (50 mL)
- Ring Stand
- Thermometer Clamp
- Stirring Rod
- Balance
- Spatula
- Styrofoam Cups (2)
- Cardboard Square
- Sodium Chloride (NaCl)
- Calcium Chloride (CaCl₂)
- Ammonium Chloride (NH₄Cl)
- Ice

Objective:
To measure the enthalpy/heat flow as different solutes are dissolved in aqueous solution and determine the heat of solution.

INTRODUCTION

Temperature is a measure of how hot or cold an object is. Whenever there is a temperature difference, there will be a spontaneous heat flow from the object at higher temperature to the object at lower temperature. Thermometer is the instrument used to determine temperatures. Celcius and Kelvin scales are used for metric and SI units respectively while Fahrenheit scale is the choice for British units. These three scales are related by the following relationships:

\[
K = 0°C + 273 \quad 0°F = \frac{9}{5} (0°C) + 32 \quad 0°C = \frac{5}{9} (0°F - 32)
\]

Every change, physical or chemical, is associated with a change in energy, usually in the form of heat. The energy change of a reaction that occurs under a constant pressure is defined as the heat of the reaction or the enthalpy change. If heat is evolved during the change, the process is exothermic, and if heat is absorbed during the change, the process is considered to be endothermic. By convention, enthalpy changes for an exothermic process has a negative value while that of an endothermic process has a positive value.

We are familiar with different forms of energy. Heat energy, light energy, electrical energy, nuclear energy, chemical energy of the bonds in a molecule, are just a few examples of different forms of energy. From the Law of Conservation of energy, during any physical or chemical change.

\[\text{Energy lost} = \text{Energy gained}\]

In this experiment, you will become familiar with temperature measurements and record the temperature
changes that occur when ammonium chloride and calcium chloride are dissolved in water. From this data, you will be able to calculate the heat energy given off or absorbed during this dissolution process (heat of dissolution).

\[
\text{Heat absorbed/ evolved} = (\text{mass}) \times (\text{specific heat}) \times (\text{temperature change})
\]

The SI unit for heat is joule (J) while a non-SI unit calorie (cal) is widely used in scientific measurements. The relationship between these two units is:

\[1\ \text{cal} = 4.184\ \text{J}\]

Specific Heat is the amount of heat required to raise the temperature of one gram of a substance by one degree Celsius. It can be expressed in cal / g \(^0\)C or Joules / kg Kelvin.

Water has a relatively high specific heat of 1 cal / g \(^0\)C while metals usually have low specific heat. To calculate the heat of dissolution in water, specific heat of the aqueous solution will be considered to be that of pure water, 1 cal / g \(^0\)C.

Calorimeter is an instrument used to measure heat flow in and out of a system. In this experiment, the calorimeter will consist of two Styrofoam cups, one nesting in the other.
PROCEDURE

A. Temperature Measurement:

1. Using thermometer, measure the temperature of 50 mL of water in a 100 mL beaker. Be sure that the bulb is steady during the measurement and not touching the glassware. The bulb needs to be fully immersed in the liquid.

2. Place a 100 mL beaker with 50 mL water on a hot plate. Place a thermometer in the water with the help of a stand and clamp. Bring the water to a boil indicated by steady stream of bubble formation from within the liquid. Once water starts to boil temperature is going to be steady until all of the water boils off. Measure the boiling point of water.

3. Make about 30 mL of an ice-water mixture in a 100 mL beaker. Stir the ice slush and measure the temperature.

4. Add three tea spoon full of table salt, sodium chloride, to the slush and stir. Measure the temperature of the mixture.

B. Heat of Dissolution

1. Work in pairs for this section.

2. Weigh out about 10 grams of CaCl₂. Be sure to record the exact mass. Construct a calorimeter by nesting two Styrofoam cups, one inside the other. Add 50 mL of water to the calorimeter. Allow the water to stand for five minutes to reach a stable temperature.
   Place a small piece of card board to cover the cup. Make a small hole at the center of the card board and insert the thermometer through the hole. Make sure the thermometer bulb is under water. Measure the temperature of water. This is the initial temperature (Tᵢ).

3. Holding the calorimeter steady, add all of the CaCl₂ to water, place the cover, and stir rapidly with a thermometer. Be careful with the bulb of the thermometer while stirring.

4. After mixing, time - temperature data should be recorded. One partner should record the temperature while other reads the time and keeps the record.

5. For five minutes, right from the start of mixing, take temperature at intervals of every 30 seconds. The highest temperature reached is the final temperature (Tᵢ) of water.

6. Print the temperature versus time plot using the graph paper provided in the lab book.

7. After recording your data, wash contents of the cup down the sink with lots of water.

8. Repeat steps 1 - 7 using approximately 10 grams of ammonium chloride. The minimum temperature reached in this case is the final temperature (Tᵢ).
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REPORT SHEET

Name ___________________________    Instructor ___________________________
Date _____________________________

Part A – Temperature Measurement

Water at room temperature: _______ °C
Boiling Water: _______ °C
Ice water: _______ °C
Ice water with salt: _______ °C

Part B – Heat of Dissolution

Heat gained by water during the dissolution of CaCl₂:

Mass of CaCl₂: _______ g
Mass of Water: _______ g
Total Mass of Solution: _______ g
T₁: _______ °C       T₂: _______ °C
Temperature change: _______ °C

Heat of dissolution per gram of solute: _______ cal/g.
(show calculation)

Dissolution of CaCl₂ is exothermic or endothermic? ________________________.
CaCl₂ can be used in hot packs or cold packs? ____________________________.
Heat lost by water during the dissolution of NH$_4$Cl:

Mass of NH$_4$Cl: ________ g

Mass of Water: ________ g

Total Mass of Solution: ________ g

T$_i$: ________ °C  T$_f$: ________ °C

Temperature change: ________ °C

Heat of dissolution per gram of solute: ________ cal/g.

(show calculation)

Dissolution of NH$_4$Cl is exothermic or endothermic? _______________________.

NH$_4$Cl can be used in hot packs or cold packs? _______________________.

<table>
<thead>
<tr>
<th>Time/ Temperature Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CaCl$_2$</strong></td>
</tr>
<tr>
<td>Time (sec)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
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Pre-Laboratory Questions and Exercises
Due before lab begins. Answer in the space provided.

1. Express the heat of dissolution of CaCl$_2$ and NH$_4$Cl in joules per gram of the compound.

2. Indicate whether the following processes will have a positive (+) or negative (-) value for enthalpy change.
   
   a) boiling of water ______
   b) freezing of water ________
   c) cooling effect during perspiration ______
   d) burning charcoal on a grill ______
   e) evaporation of rubbing alcohol from skin ______

3. Calculate the specific heat of 10.0 g an unknown metal whose temperature rose by 22.5 Celsius degrees when 63.5 J of heat energy was absorbed by the metal.

4. When a 3.25 g sample of solid ammonium nitrate dissolves in 60.0 g of water in a coffee- cup calorimeter, the temperature drops from 22.0$^\circ$C to 16.5$^\circ$C. Calculate the heat of dissolution. Assume the specific heat of the solution as the same as pure water. Is this dissolution process endothermic or exothermic?
**EXPERIMENT 13: Temperature Measurements and Heat of Dissolution**

Name: ____________________________

*Post-Laboratory Questions and Exercises*

*Due after* completing the lab. Answer in the space provided.

1) What is the **specific heat** of a substance that absorbs $2.5 \times 10^3$ joules of heat when a sample of $1.0 \times 10^4$ g of the substance increases in temperature from 10.0°C to 70.0°C?


2) A 1.0 kg sample of metal with a specific heat of 0.50 kJ/kg°C is heated to 100.0°C and then placed in a 50.0 g sample of water at 20.0°C. What is the **final temperature** of the metal and the water?


3) How much **heat is absorbed** when 500.0 g of water (sp. heat = 4.184 J/g. °C) goes from 25.0 °C to 35.0 °C?


4) The temperature of a silver coin (C =0.24 J/g.°C) falls by 353 °C as it releases 5,550 Joules of heat. What is the **mass** of the coin?