Your Name: ________________________

Lab Partner's Name: ________________________

Matter & Energy: Temperature & Heat in Physical Processes

Objectives: 1) To observe changes in temperature and heat energy which occur during physical processes such as freezing and dissolving. 2) To become familiar with the use of a simple calorimeter. 3) To calculate the specific heat of a metal and to compare the result with a known value.

Background: Read the section on matter and energy in your lecture textbook.

Equations:

Equation (1)

$$\text{Heat (Absorbed or Released, J)} = \text{specific heat (J/g}\bullet{}^\circ\text{C)} \times \text{mass (g)} \times \Delta T\ (^\circ\text{C})$$

Equation (2)

$$\Delta T = (T_{final} - T_{initial})$$

Equation (3)

$$\%\ \text{error} = \frac{|(\text{true value} - \text{experimental value})|}{\text{true value}} \times 100$$

Conversions:

1 calorie = 4.184 Joules

specific heat of water = 4.184 J/g•°C

Equipment Needed:

- Alcohol thermometer
- Beaker (400-mL)
- Graduated cylinder (100-mL)
- Hot plate
- Iron ring
- Laboratory balance
- Styrofoam cup with lid
- Test tubes (2, 25 x 150 mm)
- Utility clamp
- Weighing boat (plastic)
- Wire stirrer

Chemicals Needed:

- Calcium chloride, $CaCl_2$ (appx. 10 g)
- Potassium nitrate, KNO_3 (appx. 10 g)
- Metal with unknown specific heat (appx. 20 g)

Lab Report:

Turn in all 8 pages, in numerical order, with your names on the front page.

Pre-lab activity:

1. Define the following terms in your own words:

    a. melting point

    b. calorimeter

    c. change of state

    d. specific heat

    e. endothermic

    f. exothermic

2. When a solid substance was dissolved in water originally at room temperature (approximately 20 °C), the resulting mixture had a final temperature of 30°C. Was the dissolving process endothermic or exothermic? Explain.

3. A certain physical process requires 32.0 kilojoules (kJ) of heat. Convert this quantity to calories.

Procedure

Part A: Dissolving: An Endothermic or Exothermic Process?

1. Dissolving Potassium Nitrate

Weigh approximately 10 grams of potassium nitrate (KNO_3) and record the actual mass in grams (to the nearest milligram) in your data table.

Using a 100-mL graduated cylinder, obtain 100.0 mL of de-ionized (DI) water and transfer it into a Styrofoam cup.

Measure the initial temperature of the water using your alcohol thermometer and record this temperature in your data table as the initial temperature.

Quickly add all of the potassium nitrate to the water and place the lid on the Styrofoam cup with the thermometer through the hole in the lid so that it is immersed in the water.

Swirl gently to dissolve the solid, stopping periodically to record the temperature of the mixture. When the temperature has reached either a minimum or maximum, record that temperature extreme in your data table as the final temperature.

Calculate the change in temperature (ΔT) for the dissolving process using equation (2).

Repeat the process, starting with a fresh batch of water, for Trial 2.

2. Dissolving Calcium Chloride

Do two more trials, using the same procedure as above, substituting calcium chloride ($CaCl_2$) for the potassium nitrate.

Data and Calculations

Part A: Dissolving: An Endothermic or Exothermic Process?

1. Dissolving Potassium Nitrate

	Trial 1	Trial 2
Mass of KNO_3	____________	____________
$T_{initial}$	____________	____________
T_{final}	____________	____________
ΔT	____________	____________

Show your calculation for ΔT.

Is the dissolving of potassium nitrate in water an endothermic or exothermic process? Explain.

2. Dissolving Calcium Chloride

	Trial 1	Trial 2
Mass of $CaCl_2$	____________	____________
$T_{initial}$	____________	____________
T_{final}	____________	____________
ΔT	____________	____________

Show your calculation for ΔT.

Is the dissolving of calcium chloride in water an endothermic or exothermic process? Explain.

Part B: Specific Heat of a Metal

Fill a 400-mL beaker approximately half full with tap water and bring the water to a boil on a hot plate.

While waiting for the water to boil, do the following:

> Weigh approximately twenty grams of your assigned metal into a plastic weigh boat that has been tared (i.e. the mass of the weigh boat has been "zeroed out" by pressing the tare button). Accurately record the mass of metal in the data table.

Add the metal to a 25 x 150 mm test tube and place in the boiling water bath for ten minutes.

While your metal sample is being heated, do the following:

> Using a graduated cylinder, obtain 25.0 mL of de-ionized (DI) water and transfer it into a Styrofoam cup.
>
> Measure the initial temperature of the water in the cup using your alcohol thermometer and record this temperature in your data table as the initial temperature for water.

After the metal has been heated in the boiling water bath for ten minutes, record the temperature of the boiling water bath as the initial temperature for metal.

Using a test tube holder, very quickly add all of the metal sample to the water in the Styrofoam cup and place the lid on the Styrofoam cup with the thermometer through the hole in the lid so that it is immersed in the water.

Swirl gently, stopping periodically to check the temperature. When the temperature has reached either a minimum or maximum, record that temperature extreme in your data table as the final temperature for both the water and the metal. (*Note that the temperature of everything in your calorimeter would eventually settle back to room temperature if you waited long enough. Fortunately, the heat transfer between the metal and water is far more rapid than the loss of heat from the calorimeter. Therefore, the temperature change should stop, or slow down considerably, at an equilibrium temperature somewhere between the two initial temperatures.*)

Calculate the change in temperature (ΔT) for the metal and for the water, using equation (2).

Repeat this procedure and record your data in the column for Trial 2.

Part B: Specific Heat of a Metal Sample # ______

	Trial 1	Trial 2
Volume of water	____________	____________
Mass of metal	____________	____________
$T_{initial}$ for metal	____________	____________
$T_{initial}$ for water	____________	____________
T_{final} for metal & water	____________	____________
ΔT for metal	____________	____________
ΔT for water	____________	____________

Show your calculations for ΔT for the water and for the metal.

Use equation (1) to calculate the heat energy absorbed by the water. (Assume that the density of water is 1.00 g/mL.) Show your calculations below.

Assume that no heat is lost to the calorimeter. Therefore, the heat energy that is absorbed by the water should be equivalent to the heat energy that is released by the metal. Heat is neither gained nor lost.

(Heat absorbed by water) + (Heat released by metal) = 0

Calculate the specific heat of the metal by rearranging equation (1) to solve for specific heat.
Show your calculations below.

Obtain the true value for the specific heat of your metal and calculate your percent error using equation (3).

Post-lab questions:

1. A student performed Part B and did not allow the metal to heat long enough, so that it did not attain the temperature of the boiling water bath. Would this result in a calculated specific heat that is erroneously low or erroneously high compared to the true value? Explain.

2. A student performed Part B and did not wait for the water and metal mixture to reach a temperature minimum. Would this result in a calculated specific heat that erroneously low or erroneously high compared to the true value? Explain.

3. If the heat transfer for dissolving one gram of calcium chloride is reported to be 670 joules, how many joules of heat energy was transferred when you dissolved the calcium chloride sample in Part A2? (Show supporting calculations below. *Note: This does not involve Equation 1*.)

4. Use three sentences or less to summarize the results of this experiment.

5. A 25.000 g metal sample is cooled from 100.0 °C to 25.0 °C. If the heat energy released by the metal is calculated to be 2.50 kJ, what is the specific heat of the metal in J/g•°C? Show calculations below.