Calorimetry Lab

Purpose: Students will measure latent heat and specific heat.

PLEASE READ the entire handout before starting. You won't know what to do unless you understand how it works!

Introduction: Calorimetry is the art of measuring energy. For example, determining how many calories are in a cheeseburger is done with a device called a "bomb calorimeter." A sample of the food is burned in a closed container that is surrounded by water. The energy content of the food is determined from the temperature increase of the water jacket that surrounds the combustion chamber.

In this lab, you will do two classic calorimetry experiments: measuring the latent heat of fusion of water, and measuring the specific heat capacities of two different metals. Both experiments will use the same apparatus.

Apparatus:

Fig. 1 shows the construction of the basic calorimeter. The calorimeter is designed to minimize heat flow between the inner cup and the outside world.

Conduction of heat is eliminated by supporting the inner cup only by the thin, insulating phenolic (a type of plastic) ring, and by providing an insulating air space around the cup.

Convection is eliminated by blocking air circulation with the solid ring and the lid.

Radiation is eliminated by making the inner cup and outer jacket out of aluminum, which is mirror-bright to infrared radiation.
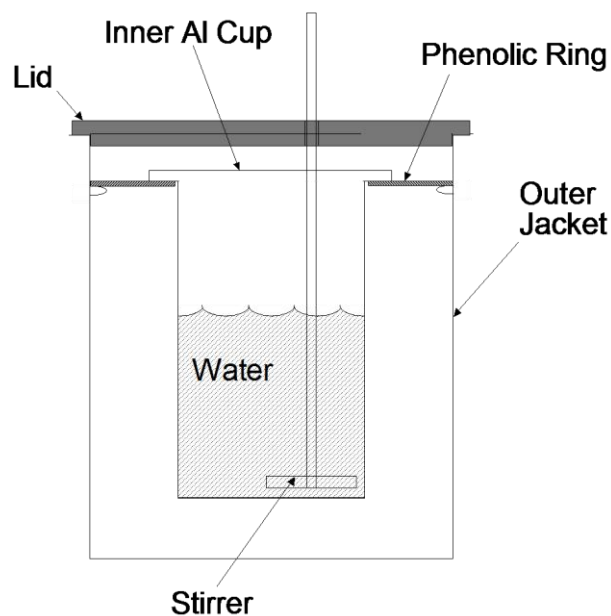

Fig. 1: The calorimeter.

To use the calorimeter, the inner cup is half filled with a known mass of water, and the temperature is measured. The sample is added, the temperature is measured again, and the desired quantity (latent heat or specific heat) is calculated.

SAFETY CONCERNS:

- **Use tongs and wear goggles** when removing the samples from the pot of boiling water. Protect your eyes against accidental splashes!

Experiment 1: Specific heat of a metal

A sample of metal (or anything else) is heated to 100°C (or other known temperature) in a bath of boiling water. The temperature of the water in the calorimeter is measured before and after adding the sample. The specific heat capacity of the metal can be determined from the maximum temperature achieved by the water in the calorimeter.

We must create an equation that describes this process for our particular situation, as follows:

(Heat lost by the sample) =
$\quad$ *(Heat gained by the cup) + (Heat gained by the stirrer) + (Heat gained by the water)* $\qquad$ (1)

Next, we will express equation (1) in a more conventional style. Recall that in general, heat gained or lost in changing the temperature of a substance is given by the equation

$$Q = mc\Delta T \qquad (2)$$

where m is the mass of the substance, c is the specific heat capacity, and ΔT the temperature change. Substituting this into the various parts of equation (1) gives us

$$m_{sample}c_{sample}\Delta T_{sample} = m_{cup}c_{cup}\Delta T_{cup} + m_{stirrer}c_{stirrer}\Delta T_{stirrer} + m_{water}c_{water}\Delta T_{water}$$

$$\qquad (3)$$

Equation (3) describes the situation at hand. It looks daunting, but it can usually be simplified considerably. You will only have one "unknown" (c_{sample}), and it will not be difficult to do the algebra to solve for it. You might also note that the cup and stirrer are both made of aluminum and experience the same ΔT, so these two terms can be combined. Or you might choose to leave out the stirrer, and stir the water in the calorimeter with the thermometer instead. It's your choice.

- The specific heat of water is, by definition, 1.00 cal/g/°C.

Experiment Question 1a: What is the specific heat of aluminum?

Experiment Question 1b: What is the specific heat of copper (brass)? (pick <u>one</u>)

In each case, determine the specific heat and its error, and discuss the agreement of your results to the accepted values. Do not look up the "accepted values" until the end of each experiment.

Keep track of what you did, and attach your notes and calculations to the data sheet.

Apparatus Tips:

- Measure the mass and temperature of the water in the calorimeter cup before adding the sample.
- Use distilled water to prevent hard-water mineral buildups on the apparatus.
- Fill the cup only halfway with water, as you'll need room for the sample.
- The samples lose heat quickly when removed from the boiling water. When you are ready to add the sample, take the entire calorimeter over to the pot of water, quickly place the sample in the calorimeter, and take the assembled calorimeter back over to your table.

- You're interested in the maximum final temperature reached by the water in the calorimeter. Make sure that you stir the water, and make sure that the thermometer is not touching the cup, stirrer, or sample.
- **Please do not return used samples to the pot**, as your classmates don't want to accidentally get a cold sample. Return used samples to the table <u>next to the pot</u> so the TA can reheat them all at once.

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Experiment Question 2: What is the Latent Heat of Fusion of Water?

- Determine the latent heat of fusion and its error, and discuss the agreement of your results to the accepted value.   Do not look up the "accepted value" until the end of the experiment.
- Keep track of what you did, and attach your notes and calculations to the data sheet.

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In this context, "fusion" means "melting."   Phase changes, such as going from solid to liquid or liquid to gas, require energy. Phase changes can also release heat energy, which is why Florida citrus farmers turn on the sprinklers in their orange groves when the temperature approaches freezing. The heat released by the ice forming on the trees protects the fruit.

Your job: Measure the amount of heat required to melt a gram of ice. This result is called "The Latent Heat of Fusion" of water.

Again, we must create an equation that describes the process for our particular situation, as follows:

(Heat that enters the ice) + (Heat that enters the ice water) =

(Heat lost by the cup) + (Heat lost by the stirrer) + (Heat lost by the cup water)   (4)

Note that we have two "kinds" of water. First, we have the warm water that we initially put into the calorimeter cup. The "cup water" is the source of the thermal energy that melts the ice. Second, we have the liquid water that entered the calorimeter in the form of ice. The ice melts, and then the ice water warms up from 0°C to the final equilibrium temperature of the calorimeter. Even though the cup water and ice water are mixed together in the calorimeter, we must treat them separately in our equation.

Next, we will express equation (4) in a more conventional style. The general equation for latent heat is

$$Q = mL \tag{5}$$

where m is the mass of the substance and L its latent heat. Note that there is no ΔT during a phase change. Substituting equations (2) and (5) into the various parts of equation (4) gives us

$$m_{ice}L_f + m_{ice}c_{water}\Delta T_{ice\,water}$$
$$= m_{cup}c_{cup}\Delta T_{cup} + m_{stirrer}c_{stirrer}\Delta T_{stirrer} + m_{cup\,water}c_{water}\Delta T_{cup\,water}$$

$$\tag{6}$$

Again, note that the ice water is warming up, and the cup water is cooling down.

Apparatus tips:

- Start with somewhat warm water in the cup. Room temperature distilled water is fine. If you want to use warmer water from the faucet, please rinse your calorimeter cup with distilled water when you're finished.

- Your sample of ice should be between 10 and 30 grams, or about the size of a teaspoonful or a couple of grapes. If the sample of ice is too large, the ice will not melt completely and you will have to repeat the experiment with a smaller sample.

- The ice should be at 0°C when you put it in the calorimeter. If the ice was taken fresh from a freezer, it might be colder. If that is the case, let the ice rest on the table until it starts to melt.

- Use a paper towel to remove excess water from the ice just before putting the ice into the calorimeter.

- Weigh the cup and "cup water" before adding the sample. Get the mass of the ice sample by weighing the cup containing the "cup water" and "ice water" after taking your temperature data. .

- In this case, you're looking for the minimum temperature achieved by the calorimeter.

Clean-Up Checklist:

- Please empty the water into the sinks.
- Dry the apparatus, the table, and any spilled water on the floor.
- Put all specific heat samples on the table <u>next to</u> one of the pots of boiling water.
- Turn off digital thermometers.
- Put all trash and recyclable paper into the proper receptacles.

Thank you!

Name: _____

Lab Section: _____ T.A.'s _____

Today's Lab Partners: _____

Data Sheets:

Basic Measurements:

Mass of calorimeter inner cup: _____

Mass of stirrer: _____

Room temperature (measured with calorimeter thermometer: _____

$\delta T =$ _____ $\delta(\Delta T) = \sqrt{(\delta T_f)^2 + (\delta T_i)^2} \cong \sqrt{2}(\delta T_{room}) =$ _____

$\delta m =$ _____ (estimate this by examining the balance)

You need consider only the larger error of $\dfrac{\delta m}{m}$ or $\dfrac{\delta(\Delta T)}{\Delta T}$ in your error calculations.

Experiment Question 1:

Measure two different materials. If you have a choice, it is slightly preferable to measure copper rather than brass as your second sample. You do not need to measure both copper and brass. A spare row is included in the table for your convenience.

Sample Material	Sample mass	Water Mass	Water Initial Temp.	Sample Initial Temp.	Final Temp.	Measured Specific Heat $c \pm \delta c$	Relative Error $\dfrac{\delta c}{c}$
Aluminum							

Show your calculations for Experiment Question 1. Attach pages if necessary.

Name: _____

Experiment Question 2:

Mass of cup water: _____

Initial Temperature of ice: _____0°C _____

Initial Temperature of cup water: _____

Final Temperature of cup and contents: _____

Mass of ice: _____

Final experimental result: $L_f \pm \delta L_f =$ _____ ±_____

Relative error $\dfrac{\delta L}{L} =$ _____

Show your calculations for Experiment Question 2. Attach additional pages if necessary.

Name: _____

Lab Section: _____ T.A.'s _____

Today's Lab Partners: _____

Analysis Questions:

1. Do your answers to Experiment Questions 1a and 1b agree with the accepted values? EXPLAIN.

Material:	Specific Heat
Aluminum	0.215 cal/g/°C
Copper	0.0923 cal/g/°C
Brass	0.089 – 0.092 cal/g/°C

2. Does your answer to Experiment Question 2 agree with the accepted value of 79. 5 cal/g? EXPLAIN.

3. When measuring specific heat, why should your final temperature be the maximum temperature reached by the calorimeter?

4. When measuring latent heat, why should your final temperature be the minimum temperature reached by the calorimeter?

5. What is the most important source of error in these calorimeter experiments?

6. In the specific heat measurement, does the sample have to be at 100°C, or would a lower
    initial temperature do just as well?   Explain your reasoning.

7. How would you experimentally determine the rate at which heat leaks into or out of your
    calorimeter?   (If time permits, you may try the experiment.)

8. What are your final thoughts and impressions about this lab? If you did any of your own
    experiments, this is a good time to talk about them!