PHYS 1401
General Physics I

EXPERIMENT 12
SPECIFIC HEAT

I. INTRODUCTION

The objective of this experiment is to measure the specific heat of several different substances. This will be done by mixing two different substances and measuring their initial temperatures and then measuring their final temperature as they come to thermal equilibrium.

II. BASIC CONCEPTS

1. **The specific heat** of a substance is the amount of heat needed to raise the temperature of 1.00 kg of the substance $1.00^{\circ}C$. In the SI system, water has a specific heat of 4184 J/kg.°C which is a large value compared to other substances. In another system of units, the specific heat of water has the value 1.00 calorie/g°C.

2. The amount of heat, Q gained or lost by a substance is

$$Q = cm\Delta T \tag{1}$$

where c is the specific heat, m is the mass and ΔT is the change in temperature.

3. When hot and cold substances are mixed in an insulated container such as a calorimeter, heat will flow from the hot to the cold substance. Assuming the heat absorbed by the container and the heat lost to the environment are both negligible, then we have

$$\begin{aligned} \text{Heat lost by the hot substance} &= \text{Heat gained by the cold substance} \\ C_{\mathrm{h}} m_{\mathrm{h}} (T_{\mathrm{i,h}} - T_{\mathrm{f}}) &= C_{\mathrm{c}} m_{\mathrm{c}} (T_{\mathrm{f}} - T_{\mathrm{i,c}}) \end{aligned} \tag{2}$$

where the subscripts h and c refer to the hot and cold substances.

III. APPARATUS

Calorimeter, Celsius thermometer, beaker, electric hot plate, balance, string and various metals.

IV. EXPERIMENTAL PROCEDURE

1. Fill a beaker about half full of water. Place on the hot plate and start boiling the water. This will take several minutes.

2. Measure the mass of the given metal. Record all data in the data table.

3. Attach a string to the metal and lower it into the hot water. The metal should be completely submerged under water. Allow the metal to sit in the water throughout the boiling process and for 5 minutes while the water is boiling. With the metal being in the boiling water for this much time, we will make the assumption that the *temperature of the metal is the same as the temperature of the boiling water.* While this is going on, proceed to the next step.

4. Measure the mass of the empty calorimeter cup, m_{c}.

5. Fill the calorimeter cup about half full of cold water. Measure the mass of the cup and the water, $m_{\mathrm{c+w}}$. Subtract the mass of the cup to obtain the mass of the cold water, m_{w}.

6. Measure the initial temperature of the cold water, $T_{\mathrm{i,w}}$.

7. Measure the temperature of the boiling water. This is equal to the initial temperature of the hot metal, $T_{\mathrm{i,m}}$.

8. Using the string, pull the metal out of the boiling water and carefully transfer it to the calorimeter cup containing the cold water.

9. Stir the cold water and watch as the temperature of the cold water rises. When it reaches it highest value (it stops increasing), read this temperature as the final equilibrium temperature, T_{f}.

10. Repeat the above process for a different metal.

V. ANALYSIS

1. Assume the specific heat of water is known, $c_{\mathrm{w}} = 1.00\,\mathrm{calorie/g^{\circ}C}$, and calculate the amount of heat gained by the cold water. Show your calculation below and enter your result in the data table.

$$\text{Heat gained by the cold water} = C_{\mathrm{w}} m_{\mathrm{w}} (T_{\mathrm{f}} - T_{\mathrm{i,w}}) \tag{3}$$

2. From equation (2), the amount of heat lost by the metal (hot substance) is the same as this amount of heat you just calculated.

3. Now calculate the specific heat of the metal. Show your calculation below and enter your result in the data table.

$$\text{Specific heat} = \frac{\text{Heat lost by the metal}}{\text{Mass of metal} \times \text{change in its temperature}}$$

$$c_{\text{m}} = \frac{\text{Heat lost by the metal}}{m_{\text{m}}(T_{\text{i,m}} - T_{\text{f}})} \tag{4}$$

4. Calculate the percent differences between the measured specific heats of both metals and the accepted values given below. Show your calculation for both metals below.

5. Write a conclusion summarizing your results. Comment on the success of this experiment. Explain any percent differences which are larger than 10%. What do you think are the two most important sources of error in this experiment?

Experiment (12) Data Table				
Type of Metal	Mass of metal m_{m} (g)	Mass of cup+water $m_{\mathrm{c+w}}$ (g)	Mass of cup m_{c} (g)	Mass of water m_{w} (g)

Experiment (12) Data Table				
Type of Metal	Initial temp of hot metal $T_{\mathrm{i,m}}$ (°C)	Initial temp of cold water $T_{\mathrm{i,w}}$ (°C)	Final temp T_{f} (°C)	Specific heat of metal c_{m} (cal/g°C)

Specific Heats for Metal Samples at $20°C$						
Iron Fe (cal/g°C)	Copper Cu (cal/g°C)	Tin Sn (cal/g°C)	Zinc Zn (cal/g°C)	Aluminum Al (cal/g°C)	Lead Pb (cal/g°C)	Brass (cal/g°C)
0.119	0.092	0.054	0.0925	0.214	0.0306	0.0917