EXPERIMENT 14
SPECIFIC HEAT OF WATER

INTRODUCTION:

Heat is a form of energy which can pass from an object of relatively high temperature to an object of relatively low temperature. One physical property of all matter is the **specific heat** of a substance. Specific heat describes the ability of a substance to absorb heat without becoming warm itself, in other words, it describes the amount of heat required to raise the temperature of one gram of a substance by 1 ^oC. To illustrate the concept, imagine you had two pots; one had a handle composed of aluminum and the other handle was composed of a durable heat-resistant plastic. After heating the pots for 10 minutes, which handle would you grab if the pots are still being heated? More often than not, you would most likely grab the durable heat-resistant plastic handle and you would wait for the aluminum handle to cool to the temperature of the surrounding environment. The durable heat-resistant plastic has a high specific heat value whereas aluminum has a low value. The durable heat-resistant plastic can absorb more heat energy than the aluminum without getting warm itself.

The unit of heat is either the calorie (cal) or the Joule (J) for SI units. The calorie is defined as the quantity of heat required to raise the temperature of 1 gram of water by 1 degree Celsius. The conversion from calories to joules is:

$$1 \text{ cal} = 4.184 \text{ J}.$$

The specific heat of water is 1 cal/g^{o}C or 4.184 J/g^{o}C.

The quantity of heat (q) required to cause a temperature change in a substance depends on the nature of the substance and is proportional to the mass of the substance (m) and the temperature change (ΔT):

$$q = m\ s\ \Delta T$$

In this equation, the "s" stands for the specific heat of the substance and the change in temperature, ΔT, represents $T_{final} - T_{inital}$. For our purposes in this experiment, ΔT may also be expressed as $T_{hot} - T_{cold}$. The units for specific heat are cal/g^{o}C or J/g^{o}C.

Specific heat is an important quantity because it can be used to calculate the amount of calories required to heat a known mass of a substance from one temperature to another. It can also be used to describe the amount of heat flow from one object to another object. This is an example of the Law of Conservation of energy. According to this law, the heat gained by the cold object must be equal to the heat lost by the hot object. Mathematically, this can be expressed as:

$$q_{Hot} = q_{cold}$$
or
$$(m_{hot})*(s_{hot})*(T_{hot} - T_{final}) = (m_{cold})*(s_{cold})*(T_{final} - T_{cold})$$

The waters in the oceans, lakes, and swimming pools can absorb large amounts of heat without undergoing extreme temperature changes, whereas the dry land surrounding these bodies of water changes its temperature drastically when it absorbs a comparable amount of heat. This is why large bodies of water act as natural temperature moderators. As a result the coastal areas enjoy mild winters and cool summers in contrast to the desert areas which exist with extreme high temperatures in the summer and extreme cold temperatures in the winter.

The specific heat of a liquid can be measured in a well insulated container which loses or gains very little heat to the surroundings. Such a container is called a calorimeter. In this experiment you will measure the specific heat of water in a calorimeter made out of two Styrofoam cups, one placed inside the other, and covered with a piece of cardboard adhered to the lid. A thermometer is inserted through a hole in the center of the cardboard cover then the "calorimeter" is stabilized by placing it inside a 250 mL beaker.

In this experiment you will test the heat capacity of your calorimeter by verifying the specific heat of water. A precisely massed amount of deionized water at room temperature will be mixed with a precisely massed amount of heated deionized water. The mixing will be accomplished by pouring the room temperature liquid into the warm water contained in the Styrofoam calorimeter. The mixture must be constantly swirled starting from initial mixing otherwise the data collected will be as erratic as the stop and stir method dictates. Precise time measurements are also crucial for this experiment to be a success, so use the most reliable and accurate timepiece available and pay attention. This experiment must be done in groups of two, one person measures the temperature while the other person marks the time.

GRAPHING:

The temperature measurement at the exact time of mixing is difficult to obtain since no reliable temperature reading will be taken at the precise time the two liquids are being mixed. This is why the respective temperature changes (T_{mix}) are determined by **graphical extrapolation**. The temperature readings will be plotted on the Y axis and the time, in minutes, will be plotted on the X axis. To extrapolate the temperature of mixing, first you will draw a vertical line the length of the graph representing the point of mixing, then you will draw the best fitting straight line which connects this vertical line to all the data points collected. To keep up with the 21st century, you may also plot this graph and calculate T_{mix} by using the computer and Excel, a software program designed for this type of extrapolation.

PROCEDURE:

PART I DETERMINATION OF THE SPECIFIC HEAT OF WATER

1. Place a 250 mL beaker containing about 150 to 200 mL of DI water on a wire gauze, supported by an iron ring and heat to about 95 to 100 ^oC.

2. While you are waiting for the water to heat up, weigh the empty styrofoam cup and record your measurement on the report sheet. Next set up a calorimeter by placing Styrofoam cup (#1) in a 400 mL beaker for stability. Next weigh another Styrofoam cup (#2), record the weight, then pour 75 mL of cold DI water into this beaker and re-weigh. Record this weight as cold water then calculate the weight of the cold water.

3. When the temperature of the water being heated reaches 85 to 95 ^oC, first pour about 25 mL of hot water into one of the styrofoam cups to heat the cup, dump this water then quickly but carefully measure out 75 mL of the hot water into the pre-weighed styrofoam cup. Quickly measure and record the precise mass of the hot water. Immediately go to step 4B.

4. **A.** One partner should start measuring and recording the temperature of the cool water at 1 minute intervals for five minutes to the nearest 0.1^oC until the temperature is constant. About 4 readings should be taken. Record the constant temperature of the cool water as T_C on the report sheet. During the measurements, the thermometer should not touch the bottom of the calorimeter or beaker but make sure the bulb is always submerged.

B. The other partner should insert the thermometer through the slit hole in the lid at the center of the calorimeter which is filled with hot water. Find the correct position for the thermometer by sliding it up and down until you are sure that the mercury bulb of the thermometer does not touch the bottom of the calorimeter but it is completely submerged in the hot water. Start taking temperature readings immediately for about 5 minutes at 1 minute intervals and record these temperatures to the nearest 0.1^{o}C. Do not allow the temperature of the hot water to get below 70 ^{o}C.

WORK QUICKLY BUT DELIBERATELY IN THE NEXT STEPS

5. On the 5th minute, pour the cooler water from Styrofoam cup #2 into the hot water in the calorimeter. Cover well, making sure the thermometer is in the correct position. Mix thoroughly by gently swirling at a steady constant rate, not too vigorously. Be prepared to resume taking the temperature readings for the 6th minute. The temperature measurements should be recorded in 1 minute intervals.

6. Record the temperature for the mixture, in 1 minute intervals, until you reach the 16th minutes.

7. When finished discard the water down the sink, wipe the inside of the calorimeter.

Specific Heat of Water Name________________________

Data and Report Sheet

Table of MASS Data

trial one	MASS	trial two	MASS
styrofoam cup		styrofoam cup	
styrofoam+ cool water		styrofoam+ cool water	
cool water		cool water	
styrofoam cup		styrofoam cup	
styrofoam+ hot water		styrofoam+ hot water	
hot water		hot water	

Part I

Table of TEMPERATURE Data

GRAPH DATA

Time (min)	Temperature of cool water	Temperature of hot water	Temperature of mixture
0			X
1			X
2			X
3			X
4			X
5	time	of	mixing
6	X	X	
7	X	X	
8	X	X	
9	X	X	
10	X	X	
11	X	X	
12	X	X	
13	X	X	
14	X	X	
15	X	X	
16	X	X	

CALCULATIONS:

1. Calculate the heat lost by the hot water, assuming the specific heat of hot water is 1 cal/g °C. Use the equation $q = m\ s\ \Delta T$ and solve for q.

2. Calculate the specific heat of cool water, assuming all of the heat lost by the warm water was gained by the cool water, that is $q_h = q_c$ from question 1.

3. Calculate the percent error associated with the calorimeter.

$$\%error = \frac{\text{theoretical - experimental}}{\text{theoretical}} * 100$$

QUESTIONS:

1. Is the Styrofoam calorimeter adequate for this experiment? Explain your answer.