Specific Heat Capacity

Equipment

You will need a 600 mL beaker, a hot plate, a ring stand, a test tube clamp, a coffee cup calorimeter, a digital thermometer, and some sort of timer.

Chemicals

Water and unknown metal shot.

Introduction

When something hot and something cold are in contact, energy flows from the hot object to the cold object until they are both at the same temperature.

The equation we use to describe how much energy goes into or out of something is:

$$q = m \times SH \times \Delta T \quad \textbf{(Equation 1)}$$

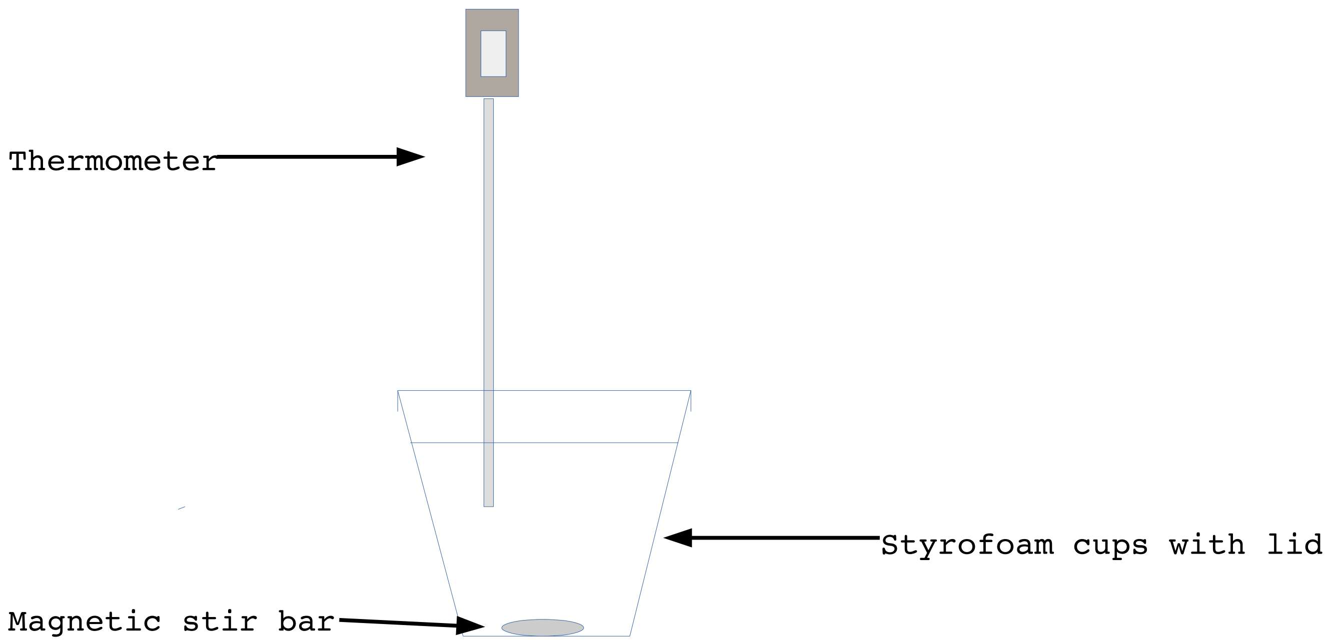
In this equation

q = the amount of energy that goes into or leaves the object (J)
m = the mass of the object in grams (g)
SH = the specific heat capacity of the object $\left(\frac{J}{g \cdot {}^{o}C}\right)$
$\Delta T = T_{Final} - T_{Initial}$ of the object (°C)

If we know how much energy goes into or comes out of an object (q), we can find the specific heat capacity (SH) of the substance that object is made of.

$$SH = \frac{q}{m \cdot \Delta T} \quad \textbf{(Equation 2)}$$

In this experiment you will use a coffee cup calorimeter to find the specific heat capacity of an unknown metal.



A Coffee Cup Calorimeter
(Figure 1)

To do this, you will heat up a sample of your unknown metal shot and add it to cold water in the calorimeter. You will see the change in temperature of the water in the calorimeter.

Because you will have weighed the water, and measured the initial temperature of the water you will be able to calculate the energy that goes into the water (q_{water}) (you know SH_{water}).

The law of conservation of energy tells us that the amount of energy that goes into the cold water is equal to the amount of energy that comes out of the hot water (we neglect any of that energy that might go into the cup, the stir bar, or the thermometer). The way we say this is:

$$\mathbf{q_{Water} = -q_{Metal}} \textbf{ (Equation 3)}$$

Once you calculate q_{Water} you will set it equal to $-q_{Metal}$. You will then know everything except SH_{Metal}, which you will find.

Procedure

Obtain an unknown from the stockroom. Tape the unknown number in the space in the Data and Analysis section that is labeled "Unknown Number" **(A1)**.

Fill your 600 mL beaker about 3/4 of the way full with tap water and place it on a hot plate. Turn on the hot plate setting the heat dial to it's highest setting. This is your hot water bath.

Place a dry beaker on a balance, close the balance doors, and tare the balance.

Remove the beaker without losing the tare on the balance and add all of your unknown metal shot to the beaker.

Place the beaker back on the balance and close the balance doors. Record the mass of your unknown to three places past the decimal **(A2)**.

Put all of your unknown back into the large test tube you got it in and place it in the hot water bath holding it with a test tube clamp on a ring stand.

Make sure that the level of water is at least at the level of the metal in the test tube. Also make sure the test tube is not touching the bottom or sides of the beaker.

Place two Styrofoam coffee cups one inside of the other (make sure there are no holes in the bottoms). This is your calorimeter.

Place these cups on a balance, close the doors to the balance, and tare the balance.

Remove the cups, being sure not to lose the tare on the balance, and add about 20 mL of D.I. water using your graduated cylinder.

Place the cups with water back on the balance, close the doors to the balance, and record the mass of water to three places past the decimal **(A3)**.

You will need something to measure time in seconds (your phone, a watch, or the clock).

Once the water in your hot water bath (where your metal shot inside of a test tube is) has been boiling **vigorously** for at least 10 minutes, begin measuring the temperature of the water in your calorimeter every 15 seconds for 120 seconds using a digital thermometer (one place past the decimal).

Record these temperatures in the table in the data section.

Between the 120 second and 135 second intervals measure the temperature of the water in the hot water bath (one place past the decimal). Record this in your data section **(A4).**

Remove the lid of your calorimeter.

CAUTION, THE TEST TUBE AND HOT WATER BATH ARE HOT! Using caution, remove the test tube clamp holding the test in the hot water bath and carefully add all of the metal shot to the cool water in the calorimeter. Make sure not to splash any of the water out of your calorimeter.

Place the lid back on the calorimeter. Continue recording the temperature of the water in the calorimeter **immediately.** If you miss one reading that is o.k., continue at the next 15 second interval.

Record the temperature of the water in your calorimeter every 15 seconds for 10 more minutes in the table given in the data section below.

NAME:____________________ **SECTION:**___________

Data and Analysis

Data:

Unknown Number:______________________**(A1)**

Mass of unknown metal shot:______________________**(A2)**

Mass of water in calorimeter:______________________**(A3)**

Initial temperature of metal shot:______________________**(A4)**

Initial temperature of water in calorimeter:______________________**(A5)**

Final Temperature:______________________**(A6)**

Time (s)	**Temperature (℃)**
0	
15	
30	
45	
60	
75	
90	
105	
120 (ADD METAL SHOT)	**TIME OF MIXING (NO DATA)**
135	
150	
165	
180	
195	
210	
225	
240	
255	
270	
285	

Time (s)	**Temperature (℃)**
300	
315	
330	
345	
360	
375	
390	
405	
420	
435	
450	
465	
480	
495	
510	
525	
540	
555	
570	
585	
600	
615	
630	
645	
660	
675	
690	
705	
720	

Analysis:

1.) Using Excel or Calc plot the data in the above table (Temperature vs. Time).

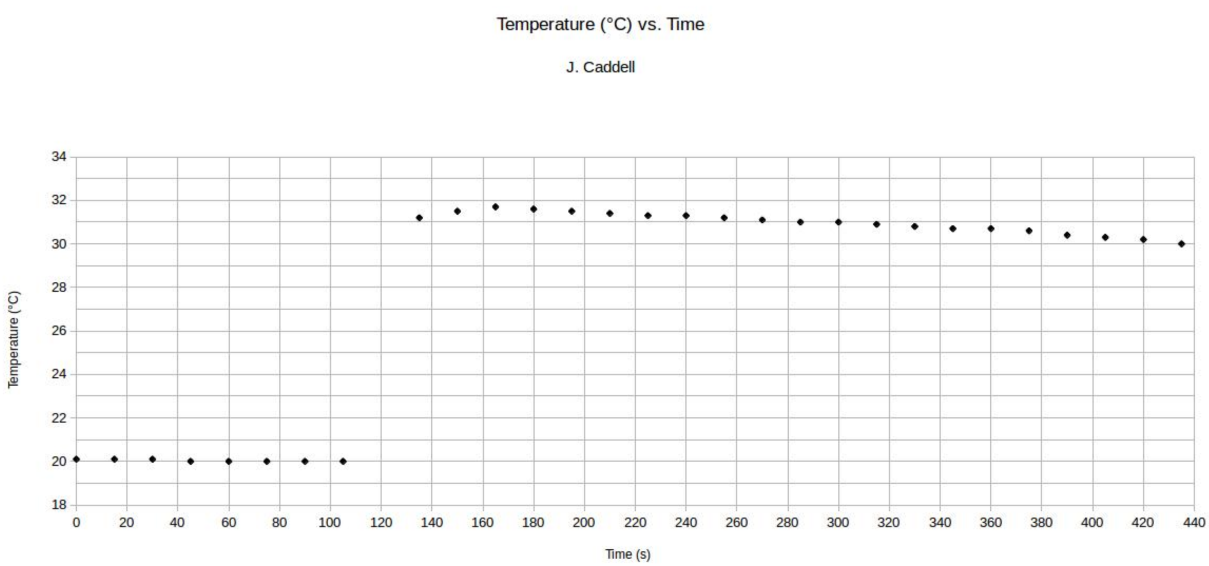
a.) Enter the data into the spreadsheet, time in column A and temperature in column B.

b.) Highlight all of the data and insert—chart—scatter plot(XY)-line.
c.) The title should read "Temperature vs. Time" with your name on the second line.

d.) The y-axis should be labeled "Temperature (℃)" and the x-axis "Time (seconds)".

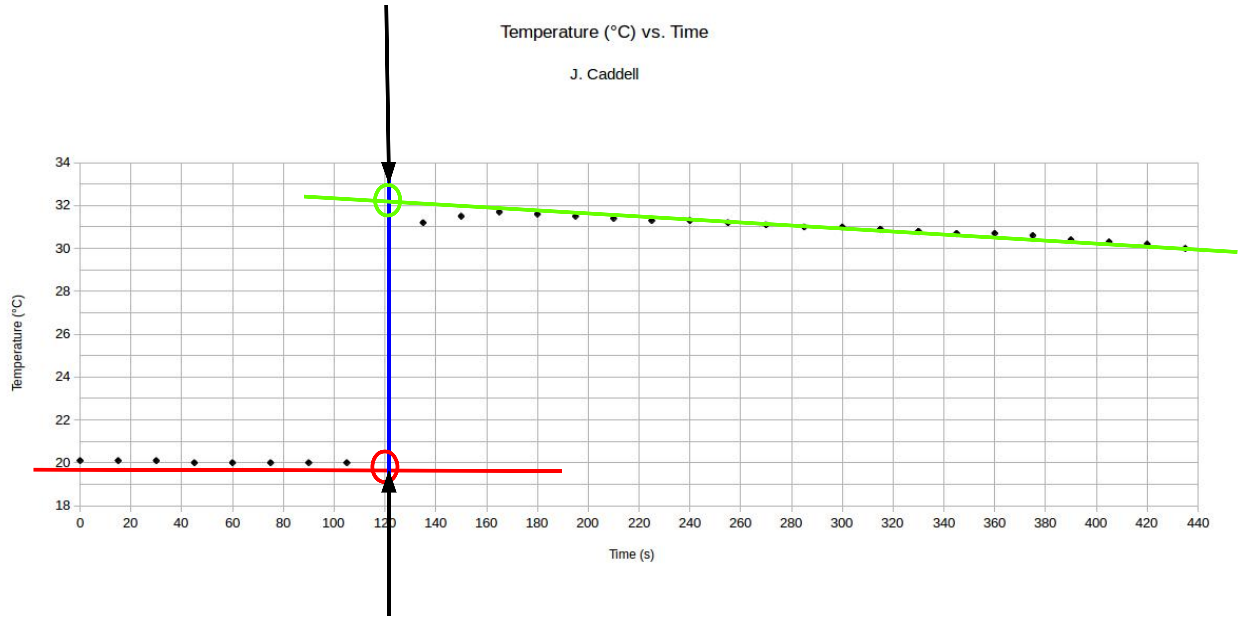
e.) Print the graph.

2.) Your graph will likely look something like the following (with different numbers for temperature and time).



3.) Using a ruler draw straight lines on the first set of points (like the red line), and a vertical line at the time of mixing (120 seconds) (like the blue one) and a third line through the second set of points (like the green one). It should look something like this:

Final temperature (A6)



Initial temperature of water (A5)

4.) The temperature where the red line and the blue line intersect (red circle) is the initial temperature of the water. In my example it would be about 19.9 °C. Write this in your data section on the **(A5)** line.

5.) The temperature where the green line and the blue lines intersect (green circle) is the final temperature of both your water and unknown. Write this temperature in the data section on the **(A6)** line.

6.) Calculate the amount of energy that went into warming up the water in your calorimeter. We will call this q_{Water}. Use the following equation.

$$q_{Water} = m_{Water} \cdot SH_{Water} \cdot \Delta T_{Water}$$

Here m_{Water} is what you wrote for **(A3)**, $SH_{Water} = 4.184 \frac{J}{g \cdot {}^{o}C}$, and $\Delta T_{Water} = T_{final} - T_{initial}$(water) = **(A6)−(A5)**.

Write this number, to the correct number of significant figures and with the correct units here.

q_{water}: ________________________ **(A7)**

The law of conservation of energy tells us that this is equal to the amount of energy that came out of the metal shot when it cooled (with the opposite sign. Because of **(Equation 3)** and **(Equation 2)** we can now say that

$$SH_{Metal}=\frac{-q_{Water}}{m_{Metal}\cdot\Delta T_{Metal}}$$ **(Equation 4)**

Here q_{Water} = **(A7)**, m_{Metal} = **(A2)**, and ΔT_{Metal}= **(A6)—(A4).** Do this calculation here and place your result, to the correct number of significant figures with the correct units on the line here.

SH_{Metal}: ________________________________ **(A8)**

6.) The Dulong-Petit law tells us that we can approximate the molar mass of a metal if we know it's specific heat capacity. The Dulong-Petit law is:

$$SH_{Metal}\cdot \text{Molar Mass}_{Metal}=24.94$$ **(Equation 4)**

In this equation the molar mass is the same as the **average atomic mass (AAM)** of the metal, which is given on the periodic table as the number beneath the symbol. For example, the average atomic mass of carbon (C) is 12.011 amu.

Because you have now figured out the specific heat capacity of your unknown you can calculate the molar mass of your metal.

$$\text{Molar Mass}_{\text{Metal}} = \frac{24.94}{\text{SH}_{\text{Metal}}}$$ **(Equation 5)**

Calculate this now and place the result on the following line to the correct number of significant figures. Do not worry about units.

Molar Mass of Unknown:__________________(A9)

7.) Now look at a periodic table and predict the identity of your unknown metal. Keep in mind that it is a metal, and that we are not going to give you anything that is expensive, exotic, or dangerous. Write what you determine the identity of your unknown metal to be on the following line.

Identity of Unknown Metal:___________________(A10)

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