Experiments in Thermodynamics*
Spring 2024

Introduction

Today you will perform two short experiments that examine the specific heat of water and the latent heat of fusion.

Experiment 1 – Stone Soup: The Specific Heat of Water

Water on Earth plays a significant role in the climate, both globally and locally. The major reason it does so is because it takes the input or removal of a lot of heat (energy) to change the temperature of water. This property is called a high *specific heat*.

For a rock dropped into a cup of water, the rock loses heat, and the water absorbs heat, and both come to a final temperature, T_{final} given by:

$$T_{final} = \frac{m_{water}c_{water}T_{water} + m_{rock}c_{rock}T_{rock}}{\left(m_{water}c_{water} + m_{rock}c_{rock}\right)} \tag{0.1}$$

The laptop is connected to a Vernier Lab-Pro Temperature probe. Start *Logger Pro* by clicking on its icon (*at right*) on the task bar along the bottom of the screen. The temperature detected by the probe will appear in the bottom left corner of the Logger Pro window.

a. Place 150 *ml* of <u>water</u> (**no ice!**) from your calorimeter and place the temperature probe in it. Calculate the mass of the water from its volume, knowing that the density of water is $1\frac{g}{cm^3} = 1\,ml$.

b. Click the "Collect" button at the top of the Logger Pro window just before the rock is dropped in. Once it's dropped in, <u>**stir the water continually**</u> and the temperature should increase rather smoothly. Click "Collect" again to stop collecting data once the curve flattens out.

c. Record the temperature of the water (in *degrees Celsius*, °*C*) <u>just before</u> the rock is dropped in and the final temperature of the mixture as the curve flattens out (after about 90 to 100 *seconds* or so). Note that the water will keep warming slowly due to the heat in the room.

d. We need the temperature to be in units of *Kelvins* (*K*), so convert each measured temperature. Recall that the temperature conversion is $K = °C + 273$.

e. We will assume that the temperature of the hot rock is 100 °*C* since the rock has been submerged in boiling water for a significant time. Convert this temperature to *Kelvins* and record the mass of the rock (in *grams* and *kilograms*).

f. Use *Equation (0.1)* to calculate the expected final temperature of the rock and water mixture. Use the specific heat values for water and granite (rock) from the table at right. Be sure to use the <u>initial</u> temperatures of the water and rock and remember that your masses should be in *kg* and temperatures in *K*.

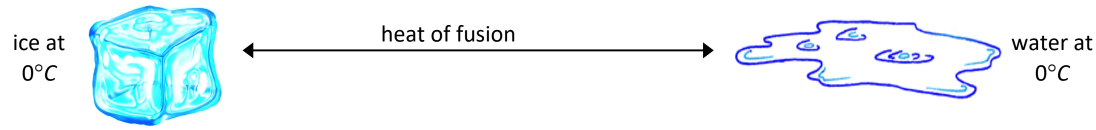
g. Convert your expected final temperature to °*C* and calculate the percent difference with the final temperature measured in Logger Pro. How well did the two values agree? Did the specific heat of water, as compared to the rock's, show up as a significant effect in this experiment? Think about what the result would have been if you dropped water of the mass and temperature of your rock into the cold water.

Substance	**Specific Heat, c** $\left(\frac{J}{K\cdot kg}\right)$
Air (50°C)	1050
Alcohol	2430
Copper	390
Iron or Steel	460
Glass	840
Quartz	762
Granite	804
Sandstone	1088
Shale	712
Soil (average)	1050
Wood (average)	1680
Ice	2100
Steam	2050
Water	4186

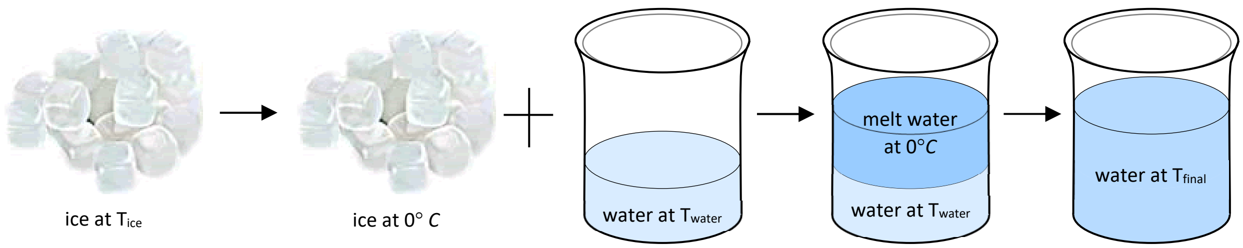
Based on an experiment by Prof. Aileen O'Donoghue Dept. of Physics, St. Lawrence University

Experiment 2 – Fire and Ice

When a substance changes phase, it absorbs or releases energy. This energy is called *latent heat of fusion, L_{fusion}*.



We will investigate the heat exchanged between warm water and ice.



a. Get one ice cube, measure its mass, and record it in your journal (in *g* and *kg*). Also record the temperature in the cooler (in °*C* and *K*).

b. Place 150 *ml* of hot water in your calorimeter and place the probe in it. Record the mass (in *g* and *kg*) of the water as you did in the previous experiment.

c. Click the "Collect" button at the top of the Logger Pro window just before the ice is dropped in. Once the ice is dropped in, **stir the water continually** and the temperature should decrease rather smoothly. Click "Collect" again to stop collecting data once the curve flattens out.

d. Record the temperature (in °*C* and *K*) of the water *just before* the rock was dropped in and the final temperature of the mixture as the curve flattens out (it will keep cooling slowly due to the heat in the room).

e. Use *Equation (1.1)* to calculate the expected final temperature of the water and ice mixture. Be sure to use the initial temperatures of the water and ice and remember that your masses should be in *kg* and temperatures in *K*. Convert your temperature back to °*C*.

$$T_{final,water\ mix} = \frac{m_{water}T_{water} + m_{ice}T_{ice}}{\left(m_{water} + m_{ice}\right)} \tag{1.1}$$

f. Use Equation (1.2) to calculate the final temperature for ice and hot water. The value of the latent heat of fusion is L_{fusion} = 334,000 *J/kg*. Convert your temperature back to °C.

$$T_{final,calculated} = \frac{\left(m_{ice}T_{ice} + m_{water}T_{water}\right)c_{water} - m_{ice}L_{fusion}}{\left(m_{water} + m_{ice}\right)c_{water}} \tag{1.2}$$

g. Comment on how the measured final temperature compares to the two calculated final temperatures. Is the energy used to melt the ice significant?

[*]Based on an experiment by Prof. Aileen O'Donoghue Dept. of Physics, St. Lawrence University