FROM FEAR TO FUN IN THERMODYNAMICS: Ice Lab (PERC 2013)

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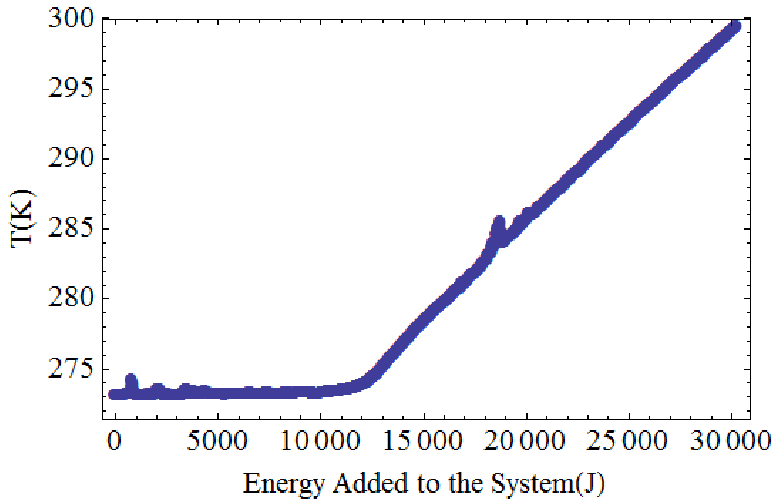
The Activity

Using the apparatus on display (or see link at the bottom of the page), put into a styrofoam cup 46 g of ice and 142 g of 0°C water. The student then heated the ice-water with a resistor while measuring the temperature of the water. Below is plotted the temperature versus energy added to the system, the latter of which is computed from the electrical power and time.



1. Find the latent heat of fusion, which is the amount of energy required to melt ice.
2. Find the heat capacity C_p of the system, which is the amount of energy per degree Kelvin required to raise the temperature of the system at fixed atmospheric pressure.
3. Find the change in entropy of the ice when it is melted. You may use the property that

$$\Delta S = \int \frac{dQ}{T}$$

   where Q is the energy added to the system by heating.
4. Find the change in entropy of the water, when it is heated from 275 K to 295 K.

For further information about this session, scan the QR code at the right, or navigate to:
`http://physics.oregonstate.edu/portfolioswiki/workshops:perc13:start`
or contact David Roundy `<roundyd@physics.oregonstate.edu>`.

Solution

Latent heat

The latent heat of fusion can be found by observing the energy at which the temperature begins to rise above freezing.

Heat capacity

The heat capacity is the inverse of the slope of the plotted curve as it rises. The heat capacity of the ice-water mixture is infinite, since you can add energy to that system without increasing its temperature at all.

Change of entropy from melting

The change of entropy from melting does not require integration, because the temperature is indepdent of the amount of energy that has been added to the system, so

$$\Delta S = \frac{L}{T}$$

where L is the latent heat found above.

Change of entropy of warming water

The entropy change as water is warmed is a bit more tricky. One valid option would be to perform the integral numerically using a spreadsheet—after removing the spike that resulted from a lapse in stirring. In this case, however, the curve is sufficiently linear that we can assume the heat capacity is indepdent of temperature and compute

$$\begin{aligned}
\Delta S &= \int \frac{dQ}{T} \\
&= \int \frac{C_p dT}{T} \\
&= C_p \int_{T_i}^{T_f} \frac{dT}{T} \\
&= C_p \ln \frac{T_f}{T_i}
\end{aligned}$$