1 Background

Water is a very important substance, and some of its properties are vital to the development and continuation of life on Earth. In this project, you will be investigating three of its thermal properties: specific heat, latent heat of fusion, and latent heat of vaporization.

1.1 Specific heat

Heat capacity is the amount of heat needed to raise the temperature of a sample by some amount. Specific heat capacity, or specific heat, is heat capacity per unit mass. In symbols, we have

$$Q = mc\Delta T$$

where Q is heat added or removed from the sample, m is the mass of the sample, ΔT is the change in temperature, and c is the specific heat. Specific heat can be measured relatively directly if you have a precise method of controlling heat input (allowing you to know how much energy is entering a system).

Specific heat can also be measured via calorimetry by using a reference material with a known specific heat. Bring the reference material and the experimental material to different temperatures, combine them in a calorimeter, and let the system come to equilibrium. If the system is adequately isolated from the surroundings, all the heat leaving the hotter material will be transferred to the cooler material. Mathematically:

$$Q_{in} = Q_{out} \quad \Rightarrow \quad m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$$

Note that you may have more than one term on either side of this equation, depending on experimental setup.

1.2 Latent heat

During a phase transition (e.g. solid to liquid) heat added to a system, the energy is absorbed by the atoms to change chemical bonds. That is, potential energy is changing rather than kinetic energy. Since temperature is associated with kinetic energy, the temperature of a sample does not change during a phase transition. The amount of heat per unit mass required to change the phase of a substance is called the latent heat. In symbols:

$$Q = mL$$

A substance will have different latent heats for different phase transitions. We'll look at latent heat of fusion (solid $\leftrightarrow$ liquid; L_f) and latent heat of vaporization (liquid $\leftrightarrow$ gas; L_v). Like specific heat, latent heat can be measured directly if you have a reliable way of adding/removing a known amount of heat from the sample.

Latent heats can also be measured by calorimetry. If, for example, steam is introduced to a calorimeter containing cool water, heat flows from the steam into the water. First, the heat leaving the steam causes the steam to condense. Then you are left with some cool water and some hot water, which come to equilibrium:

$$Q_{in} = Q_{out} \quad \Rightarrow \quad \underbrace{m_1 c_w \Delta T_1}_{\textit{Heat up cool water}} = \underbrace{m_2 L_v}_{\textit{condense steam}} + \underbrace{m_2 c_w \Delta T_2}_{\textit{cool down condensed steam}}$$

A similar method can be used to measure latent heat of fusion.

2 Materials

In addition to "standard" equipment in physics lab (calipers, string, digital multimeter, beakers, etc.), you may find the following pieces of equipment useful:

- Calorimeter
- Steam generator
- Immersion heating coil
- Bunsen burner
- Thermometer
- Vernier temperature probe
- Metals with known specific heats: nickel, aluminum, tin, zinc, copper
- Ice

If there is something else you would like to use, just ask! If we don't have it, you face the same problem as working scientists: often you are limited by the resources you have on hand, and you must come up with a different procedure.

3 Measurements & uncertainty

Remember to report experimental uncertainty with each measurement and calculation. You can report uncertainty in calculated quantities in one of two ways:

1. Using a single data point (note you may still want to make multiple data runs) and applying propagation of error. Your calculated result would be reported as

$$x = x_{calc} \pm \delta x$$

2. Making many data runs (perform the same experiment multiple times) and apply statistics to find the mean and standard deviation. Your calculated result would be reported as

$$x = \overline{x} \pm \sigma_x$$

4 Discussion questions

1. Report the percent differences between your results and the accepted values (which can be found in your textbook, or any reputable reference). Within your experimental uncertainty, do your results agree with the accepted values?

2. Explain why water is often used as a heat storage medium, or as a heat sink.

3. Explain why a burn caused by 100 °C steam is more severe than a burn caused by an equal mass of 100 °C liquid water.