LAB 14. HEAT AND INTERNAL ENERGY

This lab contains two activities. Both involve temperature, heat transfer, and internal energy.

Materials

Activity 1: Tongs, boiling water pot, metal sample, foam cup, thermometers

Activity 2: Metal vessel, foam cup, thermometer, ice, salt, stirrer, distilled water, graph paper

1. Specific Heat Capacity

Introduction

The property of matter that describes temperature's response to applied heat is the *specific heat capacity*. In this experiment, you will determine the specific heat capacity of a metal sample.

When the hot metal contacts the cool water, heat flows from the metal to the water until they come to thermal equilibrium. We will make the approximation that there is no heat flow between the system (water + metal) and the surroundings (everything else). Thus, the energy lost from the metal as it cools is exactly the same as the energy gained by the water as it warms.

The heat input q to the water raises its temperature an amount $\Delta T_{\mathrm{w}} = \frac{q}{c_{\mathrm{w}} M_{\mathrm{w}}}$, where c_{w} is the specific heat capacity of water and M_{w} is the water's mass. Correspondingly, the heat output q from the metal lowers its temperature an amount $\Delta T_{\mathrm{m}} = -\frac{q}{c_{\mathrm{m}} M_{\mathrm{m}}}$, where c_{m} and M_{m} are the metal's specific heat capacity and mass. These two equations contain two unknown quantities between them: q and c_{m}. Your job is to find c_{m}.

Experiment

You will heat a metal piece to a known temperature (that of boiling water) and then measure how much its temperature drops when it is placed in a cup of cool water. The measured change in temperature will allow you to calculate the block's heat capacity.

Procedure and Observations

1. Measure the mass of your metal block. Record this and subsequent data in Table 1.
2. Measure the mass of the empty foam cup.

   Mass of cup: ______________
3. Place the metal block in the cup and add just enough water to cover the block.
4. Remove the block and transfer into the pan of boiling water. Record the temperature T_{m} of the boiling water. Record it in the Table.

5. Make sure that there is enough water in the pan that the block is completely covered. Heat the block in boiling water for at least three minutes. If the water stops boiling when you add the block, wait until it resumes boiling and start timing then.
6. While the water is boiling, add a little bit of ice to the water in the cup. Once all the ice has melted (if any ice remains, remove it), measure the mass of the calorimeter containing the cool water.

   Mass of cup and water: ____________________
7. Subtract the mass of the empty cup to find the mass M_w of the water inside. Enter this value in the Table.
8. Just before removing the metal block from the boiling water, stir the cold water in the cup and measure its temperature T_1. Record this value in the Table.
9. Use tongs to remove the metal block from the boiling water and immediately place it in the cup. Stir until the temperature of the water in the cup stops increasing. Record this value T_2 in the Table.
10. Calculate the temperature changes of the water and the metal block. The temperature change of each substance is its final temperature minus its initial temperature.

    Make sure you have the correct signs for the two ΔT's! Enter these values in the Table.

Table 1. Metal block in water

Description of block:	
Mass of block (M_m):	
Mass of water in cup (M_w):	
Temperature of boiling water (T_m)	
Temperature of cool water before immersion of block (T_1):	
Final temperature of equilibrated calorimeter water + block (T_2):	
Temperature change of water $\Delta T_w = T_2 - T_1$	
Temperature change of block $\Delta T_m = T_2 - T_m$	

Data Processing

Calculate the specific heat capacity of the unknown metal (c_m) using the formula you derived in the prelab. (Don't forget the units!) We know that c_w, the specific heat capacity of water, is 4.184 J/(kg·K).

2. Latent Heat

Introduction

Hear and temperature are related, but the relationship can be complicated. Since temperature is correlated to molecular kinetic energy and heat is transferred energy, adding heat to an object usually raises its temperature, and taking heat from an object usually lowers its temperature.

However, if the *potential* energy of the system can vary, more outcomes are possible. Energy transferring between potential and kinetic can change a system's temperature even if no heat flows between the system and its surroundings. By the same token, transferred heat energy can change a system's potential energy without affecting its kinetic energy, keeping its temperature, though not its total energy, constant.

Phase changes can release or absorb heat without an accompanying change in temperature. Conversely, phase changes can change a system's temperature without a transfer of heat. In this activity, you will see examples of both of these types of process.

Experiment

You will add salt to ice to make a slush bath that is colder than the starting ice. Water in a metal vessel placed in the cold bath will freeze as you observe its temperature at regular intervals. This will allow you to plot a cooling curve for the water-to-ice phase change.

Procedure and observations

1. Make a cold bath. Load a foam cup about half full with crushed ice. Make sure there is plenty of room in your cup for both the ice and the metal vessel. Put in a layer of salt and add a little water to help the salt dissolve if necessary. Stir from the bottom frequently and carefully until the temperature drops to about –10 °C. It should be a soupy mix of ice and salt water. If your cold bath stops getting colder before it reaches –10 °C, stir in more salt.
2. Organize three people for data collection. The roles are (1) call out 1-min intervals using the timer, (2) read and call out the temperatures, and (3) record the temperatures in Table 2.
3. Add water to the metal vessel to a depth of about 5 cm and measure its temperature. Place the vessel in the cold bath and take temperature readings every minute until the temperature of the water reaches –5 °C. Record your data in Table 2. **Stir the water sample in the vessel frequently**, at a very minimum each time before taking its temperature. Check periodically that the cold bath remains cold. If it warms, set up a new cold bath and transfer your sample cup to it. Take care to keep all material form the ice bath out of the water in the vessel; contamination will ruin the experiment.
4. Note the times when you first see ice forming in the vessel and when there is no more liquid water there. Enter these times in the spaces beneath Table 2. At the end, the thermometer will be stuck in the ice.
5. Don't yank the thermometer out of the ice for clean-up! To speed the process of getting things in order, place the vessel, ice, and thermometer in a bucket of warm water. Clean up any water on the table top or the floor.

Table 2. Phase change of water

Time (min)	Temp (°C)	Time (min)	Temp (°C)	Time (min)	Temp (°C)	Time (min)	Temp (°C)	Time (min)	Temp (°C)
0		15		30		45		60	
1		16		31		46		61	
2		17		32		47		62	
3		18		33		48		63	
4		19		34		49		64	
5		20		35		50		65	
6		21		36		51		66	
7		22		37		52		67	
8		23		38		53		68	
9		24		39		54		69	
10		25		40		55		70	
11		26		41		56		71	
12		27		42		57		72	
13		28		43		58		73	
14		29		44		59		74	

Time ice first formed: ___________ Time sample froze solid: ____________

Data Processing

On graph paper or a spreadsheet, make a plot of temperature vs. time from the data. Scale your graph to use at least half of each axis. Title your graph.

Questions

1. How does the specific heat capacity of the metal sample compare to the specific heat capacity of water?
2. In the Latent Heat activity, why did the temperature of the freezing water change the way it did?