LAB 14. HEAT AND INTERNAL ENERGY

1. Specific Heat Capacity

The property of matter that describes temperature's response to applied heat is called 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 hot metal to the cool water until they come to thermal equilibrium at the same temperature. 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.

Materials

Tongs, boiling water pot, metal sample, foam cup, thermometers

Data Collection

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

1. The following equation expresses the conservation of thermal energy between the water and the block, assuming that no energy goes anywhere else or enters from anywhere else. Solve this equation for c_m. Show your steps.

$$M_w \cdot \Delta T_w \cdot c_w = -M_m \cdot \Delta T_m \cdot c_m$$

2. Calculate the specific heat capacity of the unknown metal (c_m) using the formula you just derived. (Don't forget the units!)

2. Cooling Curve

Temperature is related to heat, but the relationship can be complicated. Heat flows between objects at different temperatures until their temperatures become equal. Adding heat to an object usually raises its temperature. Since temperature is a measure of molecular kinetic energy and heat is transferred energy, heat transfer usually causes a temperature change.

However, if the *potential* energy of the system can vary, the possible outcomes are much richer. 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 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 test tube 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.

Materials

Test tube, foam cup, thermometer, ice, salt, stirrer, distilled water, graph paper

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 test tube. 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 test tube to a depth of about 5 cm and measure its temperature. Place the test tube 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 cup 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.

4. Note the times when you first see ice forming in the test tube 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.

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

3. 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.