Investigation 23B: Specific heat of water and steel

Essential questions: What is the difference between temperature and heat?
How does the specific heat differ between water and steel?

In everyday conversation we often use the words heat, thermal energy, and temperature interchangeably. In physics, on the other hand, they are different (albeit related) quantities. Temperature is the measure of the average kinetic energy per atom or molecule. Thermal energy is the total energy a substance contains. Heat is the flow of thermal energy from a hotter to a colder material. In this investigation you will see that water and steel contain very different amounts of thermal energy for the same mass—even though they are at the same temperature.

Materials: Two foam cups (8 oz. or larger); water; hot plate (or very hot water from tap); ice; mass scale; ten or more steel washers ($m \geq 100$ g); string; ring stand; clamp; and a thermometer.

1. Tie the steel washers together with the string.
2. Tare the scale with one of the empty foam cups. Measure the mass of the steel washers. Choose a number of steel washers that will have a total mass close to 100 g.
3. Cover the washers with ice and cold water. Allow to equilibrate close to the freezing point. Measure the temperature of the cold water.
4. Mount the foam cup in the ring stand and ring clamp.
5. Heat water in an appropriate container using a hot plate.
6. Measure 100 g of hot water into the other foam cup. Measure the temperature of the water.
7. Quickly move the steel washers from the ice water into the hot water. Stir them for a minute or two until the temperature equilibrates. Measure the final temperature of the water.
8. Repeat the experiment by adding 100 g of ice water to the cup containing 100 g of hot water.

Table: Initial and final temperatures

material	initial temperature	final temperature
100 g warm water		
100 g cold steel		

	initial temperature	final temperature
100 g warm water		
100 g cold water		

Questions

a. Which caused a larger change in the temperature of the hot water, the 100 g of 0°C steel or the 100 g of 0°C ice water?

b. Which material do you think has a higher specific heat, steel or water? Why?

c. Calculate the specific heat of steel from your data, given the specific heat of water: c_{p_water} = 4.18 J/(g °C) = 4,180 J/(kg °C). Ask your teacher for the correct value—or look it up in an authoritative reference book, such as the CRC Handbook of Chemistry and Physics. Was your calculation correct?

d. Approximately equal masses of hot water and cold steel were mixed, yet the final temperature is not halfway between the two temperatures. Why not?

e. Now imagine you are given an unknown metal. Explain very specifically and in detail how you would design an experiment to determine if the unknown metal is steel.

f. How did the distribution of energy between the washers and water change during the experiment?

g. What would happen to the final temperature if you put twice as many (i.e., 200 g) cold steel washers into the water? How does the final temperature depend on the relative mass of the steel and water?