24 Specific Heat
Hot Stuff

Purpose

To determine the specific heat of common metals.

Required Equipment and Supplies

200 grams each of aluminum, lead, and copper shot, or specific heat specimens
Styrofoam cups
hot plate with large beaker of 90°C water
paper towels
thermometer and timer *or*
Apple II Series computer
LabTools software
interface box
temperature probe
ring stand assembly and test tube clamp (optional)

Discussion

If you mix hot and cold water together, the temperature of the final mixture depends on *how much* hot water is added to *how much* cold water.

If you throw a hot branding iron into a pail of cool water, you know that the temperature of the iron will go down. You also know that the temperature of the water will rise—but will its rise in temperature be more, less, or the same as the temperature drop of the iron? That is, will the temperature of the water rise as much as the temperature of the iron goes down? Or will the changes of temperature instead depend on the relative masses of the iron and the water?

In this experiment, you are going to investigate the quantity of heat per gram per degree, known as the *specific heat,* for different metals. Water has a specific heat of 1.00 cal/g·°C—relatively large compared to most substances.

The heat lost by a specimen, say a piece of metal, submerged in water equals the heat gained by the water.

$$Q_{\text{lost}} = Q_{\text{gained}}$$

$$m_s c_s \Delta T_s = m_w c_w \Delta T_w$$

The specific heat of the specimen is:

$$c_s = \left(\frac{m_w \Delta T_w}{m_s \Delta T_s} \right) c_w$$

where c_w = 1.00 cal/g·°C

If you use a computer with a temperature probe instead of a thermometer, connect the temperature probe to the interface box. Select the "Thermometer" program from *LabTools,* and follow the instructions on the disk to

Data Table 24.1

	MASS (g)		
	m_{Al}	m_{Pb}	m_{Cu}
m_{cup}			
$m_{combined}$			
m_{water}			

calibrate the temperature probe. By setting the time interval to 30 seconds, the computer will automatically plot and record the temperature. Have a data disk ready to save your data. To facilitate monitoring the temperature, use a ring stand assembly to hold the thermometer or temperature probe mounted in a slotted rubber stopper. This arrangement also decreases the possibility of accidental spillage.

Procedure

Step 1. Assemble as many pairs of Styrofoam cups with one cup inside the other as you have types of shot (or specimens). You have just constructed inexpensive double-walled calorimeters! Crease a paper towel to facilitate manipulating the shot. Measure approximately 200 grams of aluminum shot and place it onto a dry paper towel. Try not to handle the shot with your hands any more than is absolutely necessary (why?). Record the mass of the shot in Data Table 24.1.

Step 2. Determine the mass of a *dry* Styrofoam cup. Record your results in Data Table 24.1.

Step 3. Carefully add about 100 ml of water at about 90°C to the cup. Measure the mass of the cup and water. Record your results in Data Table 24.1. Calculate the mass of the water in the cup. Immediately, proceed to Step 4.

Step 4. Position the tip of the thermometer or temperature probe near the top of the water in the cup. Monitor the temperature of the water at 30 second intervals for 5 minutes. Record the temperature in Data Table 24.2. At precisely 5 minutes, add the shot, being careful not to splash or spill the water or the shot. Continue monitoring the temperature of the mixture for another 10 minutes. Do not attempt to stir the water.

Step 5. If you are using the computer, printout the screen and save your data on a data disk. Drain the water from the cup, and put the shot on a dry paper towel. Allow the shot to dry so it can be reused.

Step 6. Repeat Steps 1- 5 using lead and copper shot.

Data Table 24.2

TIME	WATER TEMPERATURE (°C)		
(MINUTES)	ALUMINUM	COPPER	LEAD
ZERO			
1.0			
1.5			
2.0			
2.5			
3.0			
3.5			
4.0			
SHOT ADDED → 4.5			
5.0			
5.5			
6.0			
6.5			
7.0			
7.5			
8.0			
8.5			
9.0			
9.5			
10.0			
10.5			
11.0			
11.5			
12.0			
12.5			
13.0			
13.5			
14.0			
14.5			
15.0			

Analysis

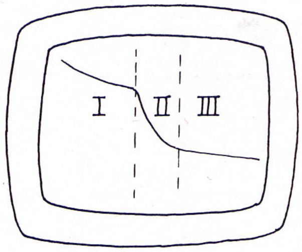

Figure 24.1

1. If you did not use a computer, make a graph of temperature vs. time for each kind of shot.

2. Study your graphs. They should like something like Figure 24.1. Draw vertical dashed lines to break your graphs into three distinct regions. Region I covers the time before the shot was added. Region II covers the time while the shot was coming to equilibrium with the water. Region III covers the time after the shot came into equilibrium and began losing heat to the room.

The cup lost heat to the room before, during, and after the shot was added. After the shot is added to the water, it takes several minutes for the shot and water to reach thermal equilibrium. The heat lost *to the room* during that time did *not* go into *warming the shot.*

To determine the heat gained by the shot more accurately, extrapolate the graph from when the temperature stabilized (at the beginning of Region III) to when the shot was added. Use this extrapolated value for the final temperature of the shot-water mixture.

Assuming the initial temperature of the shot is room temperature, calculate the change in temperature for the shot and for the water. Record your calculations in Data Table 24.3.

Data Table 24.3

$\Delta T_{AL} =$	$\Delta T_{Cu} =$	$\Delta T_{Pb} =$
$\Delta T_{w} =$	$\Delta T_{w} =$	$\Delta T_{w} =$

3. Calculate the specific heat, *c*, for each kind of metal shot and record in Data Table 24.4.

Data Table 24.4

	$c[(cal/g)°C]$
ALUMINUM	
COPPER	
LEAD	

4. How do your calculated values for the specific heats compare with those found in your textbook? Describe and suggest sources of error in the design of your experiment.

5. Suppose that you are served room temperature cream and hot coffee and you wish to wait a while before drinking the coffee. If you want the mixture to be as hot as possible, should you add the cream when served or wait until you are about to drink it? Explain.