

Experiment 15: Specific Heat of a Metal

Purpose: To determine the specific heat of a substance.

Procedure:

Record all data in Data Table 1.

1. Heat 250 mL of water in a 400-mL beaker until it is boiling gently.
2. While the water is heating, determine and record the mass of a clean, dry 50-mL beaker to the nearest 0.01 g. Add between 80 g and 120 g of lead shot to the beaker. Measure the combined mass of the beaker and lead to the nearest 0.01 g and record the measurement.
3. Transfer the lead shot to a large, dry test tube. Use the utility clamp to suspend the test tube in the boiling water as shown in Figure 15.1. The lead shot should be below the level of the water in the beaker. Leave the test tube in the boiling water bath for at least 10 minutes.
4. While the lead shot is heating, measure 100 mL of distilled water in a graduated cylinder. Pour the water into a Styrofoam cup and place the cup in a 250-mL beaker for support.
5. Measure and record the temperature of the water in the Styrofoam cup and of the water in the boiling bath.
6. Remove the test tube from the boiling water and quickly pour the lead shot into the water-filled, plastic-foam cup. Place a thermometer and a glass stirring rod into the cup. Use the stirring rod to gently stir the lead shot. *Do not stir the shot with the thermometer.* Note the temperature frequently and record the maximum temperature reached.
7. Pour the water off and return the lead shot to your teacher.
8. Follow the same procedure to determine the specific heat of a second metal.

Data Table 1:

Measurements of Mass and Temperature		
	Trial 1 (Pb)	Trial 2 (Al)
Mass of metal shot (g)	55.7	68.1
Mass of water in cup (g)	100.0	100.0
Initial temperature of water in cup ($^{\circ}\text{C}$)	22.0	23.0
Initial temperature of metal shot ($^{\circ}\text{C}$) (same as temperature of boiling water)	101.1	99.8
Maximum temperature of metal + water	27.1	32.0

Analysis Questions:

1. Determine the changes in temperature of the water (ΔT_{water}) and of the lead shot (ΔT_{metal}) for each trial.
2. Calculate the heat gained by the water in each trial.

- Remembering that the heat gained by the water is equal to the heat lost by the metal, calculate the specific heat of the metal for each trial.
- If you tested an second metal, repeat these calculations to determine the specific heat of the unknown metal.
- Calculate the percent error in the specific heat values that you determined experimentally. Use the accepted values given by your teacher.

$$\% \text{ Error} = \frac{|\text{Accepted value} - \text{Experimental value}|}{\text{Accepted value}} \times 100\%$$

- You assumed that the initial temperature of the lead shot was the same as that of the boiling water. If the lead shot was actually at a lower temperature than the water, how would your value for the specific heat be affected?

Calculations:

Trial 1 Lead: $\Delta T_{\text{lead}} = 27.1\text{ }^{\circ}\text{C} - 101.1\text{ }^{\circ}\text{C} = -74.0\text{ }^{\circ}\text{C}$

Trial 1 $\Delta T_{\text{water}} = 24.1\text{ }^{\circ}\text{C} - 22.0\text{ }^{\circ}\text{C} = 2.1\text{ }^{\circ}\text{C}$

Heat gained by water = $q_{\text{water}} = m \times c_{\text{water}} \times \Delta T_{\text{water}} = (100.0\text{ g}) \times (1.00\text{ cal/g}^{\circ}\text{C}) \times (2.1\text{ }^{\circ}\text{C}) = 210\text{ cal}$

Heat lost by lead $q = -510\text{ cal}$

Specific Heat of lead: $c = \frac{q}{m \times \Delta T} \quad c = \frac{-210\text{ cal}}{55.7\text{ g} \times -74.0\text{ }^{\circ}\text{C}} = .05094861 = .051\text{ } \frac{\text{cal}}{\text{g}^{\circ}\text{C}}$

$\% \text{ Error} = \frac{|0.031 - .051|}{0.031} \times 100\% = 64.5\%$

Trial 2 Aluminum: $\Delta T_{\text{aluminum}} = 32.0\text{ }^{\circ}\text{C} - 99.8\text{ }^{\circ}\text{C} = -67.8\text{ }^{\circ}\text{C}$

Trial 1 $\Delta T_{\text{water}} = 33.0\text{ }^{\circ}\text{C} - 23.0\text{ }^{\circ}\text{C} = 9.0\text{ }^{\circ}\text{C}$

Heat gained by water = $q_{\text{water}} = m \times c_{\text{water}} \times \Delta T_{\text{water}} = (100.0\text{ g}) \times (1.00\text{ cal/g}^{\circ}\text{C}) \times (9.0\text{ }^{\circ}\text{C}) = 9.0 \times 10^2\text{ cal}$

Heat lost by aluminum = $q = -9.0 \times 10^2\text{ cal}$

Specific Heat of aluminum: $c = \frac{q}{m \times \Delta T} \quad c = \frac{-900\text{ cal}}{68.1\text{ g} \times -67.8\text{ }^{\circ}\text{C}} = .1948241 = .19\text{ } \frac{\text{cal}}{\text{g}^{\circ}\text{C}}$

$\% \text{ Error} = \frac{|0.22 - .19|}{0.22} \times 100\% = 13.6\%$

Conclusions:

The specific heat of two metals was determined experimentally. The technique utilized was calorimetry. A sample of each metal was massed and then heated in a hot water bath. The hot metal was then poured into a known quantity of water in a calorimeter. The amount of heat gained by the water was calculated. The heat gained by the water is equal to the heat lost by the metal. This allows for the calculation of the specific heat of the metal. A sample of lead was determined to have a specific heat of $0.51 \text{ cal/g}^\circ\text{C}$. The accepted value for lead is $0.031 \text{ cal/g}^\circ\text{C}$, which is a 64.5% error. The specific heat of aluminum was determined to be $0.19 \text{ cal/g}^\circ\text{C}$. The accepted value for aluminum is $0.22 \text{ cal/g}^\circ\text{C}$, which is a 13.6 % error. Since only one trial was performed for each metal, the experimental error is large. A better method would be to conduct several trials for each metal. Another source of error is the volume measurement. The water volume should be measured using a more precise piece of equipment. The masses should be determined on an analytical balance capable of measuring to the thousandths place. Other sources of error include: difficulty reading the thermometer, heat lost to the room due to a crude calorimeter, human error in transferring the metal shot to the calorimeter. If this experiment were repeated, the results could be improved by: increasing the number of trials, use of better measuring devices such as a pipette for volume and an analytical balance for measuring mass. In conclusion, the specific heats of metal samples can be determined experimentally through the use of calorimetric methods.

Conclusion: Example of a very BAD one

I liked this lab a lot. It was really fun, especially since we used the Bunsen burners. The metals were hard to measure because they were so small and bouncy. I think my partner and I spilled some on the way back from the balance. I forgot to measure how much water we used. This lab had too many calculations, but I think I did them all okay. My results are excellent because I followed the directions. If I were to do the experiment again I would do it exactly the same way, because my partner and I followed the directions perfectly.