Specific Heat

Objectives

In this lab you will

- measure the specific heats of aluminum and lead using a calorimeter and the Vernier Temperature Sensor.
- observe how the temperature of your system reaches equilibrium in real time.
- plot your data and analyze it using the Vernier Logger Pro™ software.

Equipment

Vernier Temperature Sensor, Vernier LabPro™ system (includes computer and Logger Pro™), boiler, calorimeter, thermometer, aluminum stirring rod, pan balance, measuring cup, cork, safety goggles, gloves, aluminum sample, and lead sample.

Theory

Heat is the energy transferred due to temperature differences between two different objects. The exact amount of heat Q transferred due temperature difference ΔT is given by

$$Q = mc\Delta T \qquad \textbf{Equation 1}$$

where m is the mass of the object and c is the specific heat of the material of which it is composed. An ideal *calorimeter* shields its contents from exchanging heat with its surroundings. (Think of a perfect Thermos™ bottle.) Real-world calorimeters typically consist of an inner and outer aluminum cup separated by thermal insulation (e.g. air, foam, glass, or plastic).

In this lab you will begin with the inner cup filled 2/3 way with tap water at room temperature T_{room} and an aluminum stirring rod. An aluminum or lead sample is heated in a boiler (at temperature T_{hot}) and then added to the calorimeter (see Figure 1). Clearly, the metal sample loses heat to the water + stirring rod + inner cup system until a new thermal equilibrium is reached (at T_{equil}). We assume that a negligible amount of heat is released to the surroundings. Using Equation 1 and energy conservation, we can express the heat transfer as

$$mc(T_{\text{hot}} - T_{\text{equil}}) = m_{\text{w}}c_{\text{w}}(T_{\text{equil}} - T_{\text{room}}) + m_{\text{rc}}c_{\text{Al}}(T_{\text{equil}} - T_{\text{room}}) \qquad \textbf{Equation 2}$$

The left-hand side of Equation 2 is the heat lost by the metal sample of mass m and specific heat c (= c_{Al} for aluminum or c_{Pb} for lead). The first term on the right-hand side of Equation 2 is the heat gained by water of mass m_{w} and specific heat c_{w} = 1.00 kcal/(kg·°C); the second term is the heat gained by the stirring rod and inner cup of total mass m_{rc} and specific heat c_{Al}.

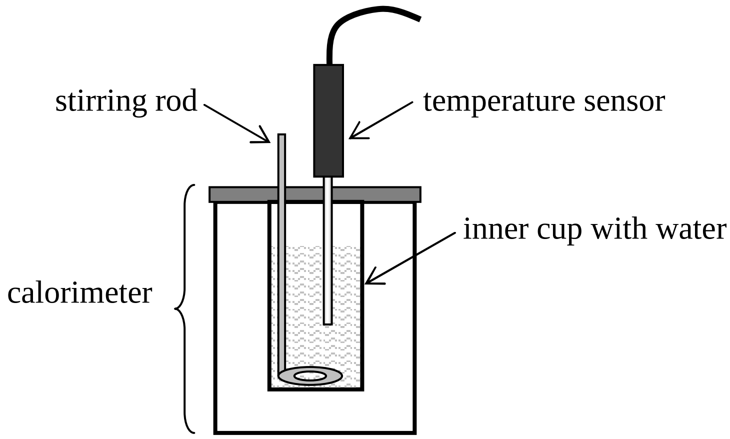


Figure 1

Procedure

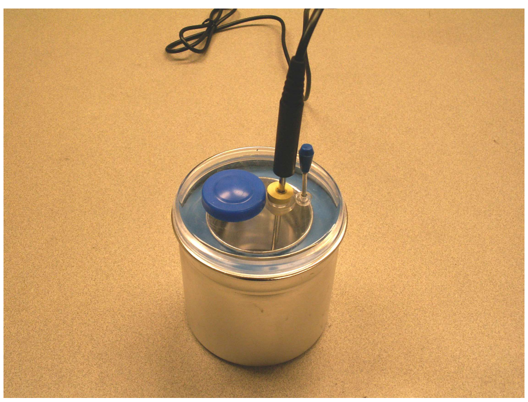


Photo 1

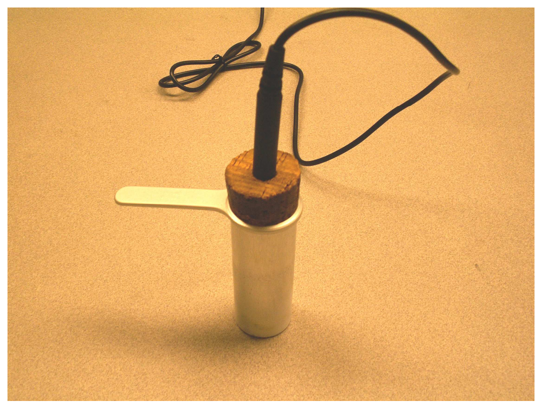


Photo 2

1) Connect the temperature sensor to the Lab Pro interface and open "32 Newton's Law of Cooling" from the "Physics with Computers" file. With this file you will be able to measure the temperature (in °C) as a function of time (in seconds). Check that the sensor reads the same temperature as your thermometer before you begin collecting data. If the temperature shown on the computer does not agree, close out Logger Pro and open it again.

2) Add some tap water to the inner cup of the calorimeter while the stirring rod is inside (Photo 1). Use the sensor to measure the temperature of the water + rod + inner cup system (which, of course, should be around 25°C). It will take a few minutes for the temperature to stabilize. <u>Use the X button along your temperature graph to record this temperature as T_{room} on your data sheet.</u>

3) Fill the boiler to the half-way mark as indicated on the side of the boiler and plug it in to start the boil. (Do not plug in if it does not contain water!)

4) Measure the mass of the measuring cup (Photo 2). Record this mass on your data sheet. Now fill the cup half-way with your aluminum sample and measure the total mass. Subtract to find the net mass of aluminum m and record your result on the data sheet.
5) Use the cork to secure the temperature sensor in the measuring cup. Make sure that the temperature sensor is in contact with the aluminum sample inside the cup (Photo 2). Now place the measuring cup in the boiler.

Important Safety Note: Please be careful!! The boiler itself and its contents can cause serious burns. Wear your goggles and gloves in case of a splash or spill.

6) Click the Collect ▷ button (Clock Logo) and select 35 minutes for your maximum collection time. Monitor the temperature of the metal sample. Stop the data collection when the temperature stabilizes (Graph 1). You should expect the temperature to level out before reaching 100°C.

7) While you are waiting for thermal equilibrium, measure the mass of the inner calorimeter cup + stirring rod in your data sheet. Fill the calorimeter cup 2/3 with tap water and measure the total mass of the water + rod + inner cup. Subtract to find the net mass of the water m_w and record your result on the data sheet.

8) When the temperature of the metal sample inside the boiler has stabilized, use the X button on the graph to read temperature T_{hot} and record it on the data sheet. Print the temperature graph of your metal sample.

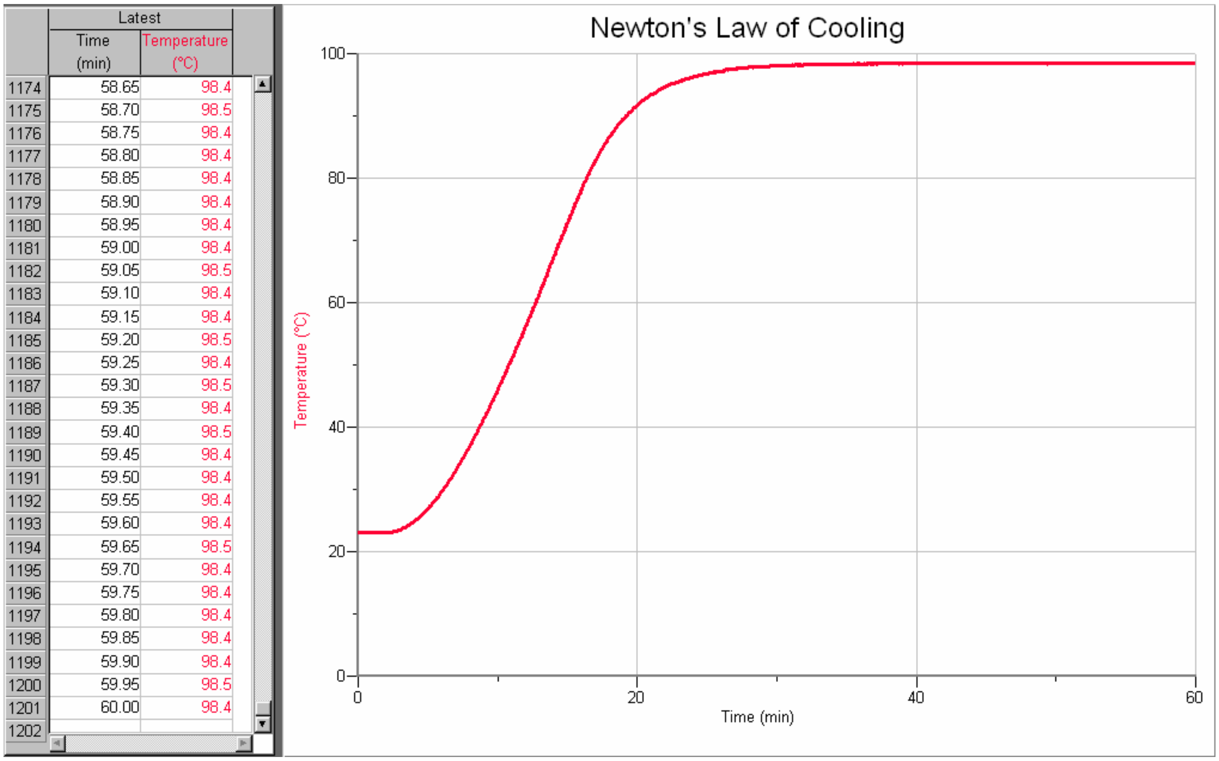
9) Carefully pour the aluminum sample into the inner calorimeter cup (containing the water and stirring rod). Close the lid of the calorimeter and mix the water and metal sample with the rod.

10) Cool the temperature sensor under tap water and then insert it into the calorimeter (Photo 12). Monitor the temperature of the mixture in the inner cup. When the temperature has stabilized, use the X button on the graph to read temperature T_{equil} and record it on the data sheet.

11) Use Equation 2 and your measurements to compute the specific heat of aluminum c_{Al}. Show your calculation on your data sheet.

12) Repeat Steps 2 through 11 to measure the specific heat of lead c_{Pb}.

Each student is required to submit a completed data sheet in order to receive full credit. Your lab group needs to submit only one Temperature -Time graph. This graph is to be stapled to the data sheet of one of your lab partners – Each lab partner does not need to submit his/her own graph.



	Time (min)	Temperature (°C)
1174	58.65	98.4
1175	58.70	98.5
1176	58.75	98.4
1177	58.80	98.4
1178	58.85	98.4
1179	58.90	98.4
1180	58.95	98.4
1181	59.00	98.4
1182	59.05	98.5
1183	59.10	98.4
1184	59.15	98.4
1185	59.20	98.5
1186	59.25	98.4
1187	59.30	98.5
1188	59.35	98.4
1189	59.40	98.5
1190	59.45	98.4
1191	59.50	98.4
1192	59.55	98.4
1193	59.60	98.4
1194	59.65	98.5
1195	59.70	98.4
1196	59.75	98.4
1197	59.80	98.4
1198	59.85	98.4
1199	59.90	98.4
1200	59.95	98.5
1201	60.00	98.4
1202		

Graph 1 – Temperature vs. time graph

Data Sheet – Specific Heat

Name ______________________________________ Date ____________

Partners' Names ____

Part 1 – Specific Heat of Aluminum

Mass of measuring cup = ___________________ kg

Total mass of measuring cup + Al sample = ______________________ kg

Net mass of Al sample m = _______________________ kg

Mass of stirring rod + inner cup m_{rc} = ___________________________ kg

Total mass of water + rod + cup = ________________________ kg

Mass of water m_w = _______________________ kg

Room temperature T_{room} = ___________________ °C

Equilibrium temperature of Al in boiler T_{hot} = _____________________ °C

Equilibrium temperature of mixture T_{equil} = _______________________ °C

Solve Equation 2 for c_{Al}. Show your calculations below. Use c_w = 1.00 kcal/(kg·°C).

$$mc_{Al}(T_{hot} - T_{equil}) = m_w c_w(T_{equil} - T_{room}) + m_{rc} c_{Al}(T_{equil} - T_{room})$$

Your calculated value for c_{Al} = _____________________ kcal/(kg·°C)

The accepted value for c_{Al} = 0.22 kcal/(kg·°C) Percent error = ___________ %

Part 2 – Specific Heat of Lead

Mass of measuring cup = ______________________ kg

Total mass of measuring cup + Pb sample = _________________________ kg

Net mass of Pb sample m = __________________________ kg

Mass of stirring rod + inner cup m_{rc} = ______________________________ kg

Total mass of water + rod + cup = ___________________________ kg

Mass of water m_w = ___________________________ kg

Room temperature T_{room} = _____________________ °C

Equilibrium temperature of Pb in boiler T_{hot} = _______________________ °C

Equilibrium temperature of mixture T_{equil} = __________________________ °C

Solve Equation 2 for c_{Pb}. Show your calculations below. Use c_w =1.00 kcal/(kg·°C) and c_{Al} = 0.22 kcal/(kg·°C):

$$mc_{Pb}(T_{hot} - T_{equil}) = m_w c_w(T_{equil} - T_{room}) + m_{rc}c_{Al}(T_{equil} - T_{room})$$

Your calculated value for c_{Pb} = _______________________ kcal/(kg·°C)

The accepted value for c_{Pb} = 0.030 kcal/(kg·°C)   Percent error = ____________ %