Specific Heat of Solids

Object: To determine the specific heat of a given solid specimen.

Theory: Thermal energy is an internal energy that consists of the kinetic and potential energies associated with the random motions of the atoms, molecules, and other microscopic bodies within an object. If there is an environment with temperature T_E and a system with temperature T_S, then the two will reach thermal equilibrium ($T_E = T_S$) if given enough time. The transfer energy is called heat and has the symbol Q. Heat is positive when absorbed and negative when lost. Heat is the energy that is transferred between a system and its environment because of the temperature difference that exists between them. The SI unit for heat is the Joule, J. The British thermal, BTU unit is defined as the amount of heat to raise 1 lb of water from 63^o F to 64^o F. The calorie is defined as the amount of heat to raise the temperature of 1 gm of water 1^o C.

$$1\,cal = 3.969 * 10^{-3}\,BTU = 4.1860\,J$$

Heat capacity C of an object is the proportionality constant between the heat and the temperature change.

$$Q = C\Delta T = C(T_f - T_i)$$

Specific heat is defined as heat capacity per unit mass, c.

$$Q = cm\Delta T = cm(T_f - T_i)$$

If we have two objects of different material and temperature, according to conservation of energy then

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

$$m_2 c_2 (T_f - T_2) = m_1 c_1 (T_1 - T_f)$$

For this experiment the specific heat of the calorimeter which is used to measure heat capacity must be measured.

$$\Delta Q_{gained}(water) + \Delta Q_{gained}(calorimeter) = \Delta Q_{lost}(water)$$

$$m_3 c_3 (T_f - T_2) + m_2 c_2 (T_f - T_2) = m_1 c_1 (T_1 - T_f)$$

$$c_2 = \frac{m_1 c_1 (T_1 - T_f)}{m_2 (T_f - T_2)} - \frac{m_3 c_3}{m_2}$$

Where we have m_1 is the mass of the heated water, m_2 is the mass the calorimeter, m_3 is the mass of the water in the calorimeter, $c_1 = c_3$ is the specific heat of the water, and c_2 is the specific heat of the calorimeter.

To find the specific heat of the metal specimen a similar calculation is formed.

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

$$\Delta Q_{gained}(water) + \Delta Q_{gained}(calorimeter) = \Delta Q_{lost}(metal)$$

$$m_3 c_3 (T_f - T_2) + m_2 c_2 (T_f - T_2) = m_1 c_1 (T_1 - T_f)$$

$$c_1 = (m_3 c_3 + m_2 c_2) \frac{(T_f - T_2)}{m_1 (T_1 - T_f)}$$

It is assumed that none of the heat is lost to the surroundings.

Apparatus: Double boiler, calorimeter, two Celsius thermometers, metal specimen, metal shot container and mass- balance.

Procedure:

Fill approximately one half of the double-boiler with water, and start heating it.

1. Measure the mass of the shot container, fill shot container with water, and measure mass of the shot container with water. The difference will be the mass, m_1. Place the shot container inside the boiler with stopper/thermometer inserted.
2. Measure the mass of the inner cup of the calorimeter. Fill with approximately 15 grams of water, measure the mass, place inside outer calorimeter, insert rubber stopper/thermometer and measure the temperature, T_2. The difference in the mass will be m_3, the mass of the calorimeter will be m_2.
3. Once the temperature of the water in the boiler has reached 85^0 C (this will be T_1), remove the water and pour the now heated water into the calorimeter. Record the highest temperature, T_f of the mixture. Use the above equation to solve for the specific heat of the calorimeter.
4. Determine the mass, m_1, of the given metal specimen and then place it in the inner cup of the double-boiler. Now place the inner cup in the double-boiler. The temperature of the specimen is monitored with a thermometer (range 100°C) placed in this inner cup. (The bulb of the thermometer should not touch the specimen.) Wait until the temperature reaches a constant value before taking a reading.
5. In the meantime, determine the mass, m_e, of the inner cup of the calorimeter. Then fill it partially with water — enough to cover the metal specimen completely when the specimen is later dropped in this cup in a subsequent step. The mass, m_2, of the water added to the calorimeter cup is now determined from the difference between the masses of the empty and filled cup, $m_2 = m_f - m_e$.
6. Place the inner calorimeter cup in the outer assembly of the calorimeter. Stir the water gently and record the initial temperature, T_2, (assumed to be constant).
7. Record the temperature, T_1, of the metal specimen on the computer spreadsheet. Then quickly remove the lids of the cups and transfer the specimen to the inner calorimeter cup. Place the lid on this cup immediately, and *gently* stir the water while keeping an eye on the thermometer. Record the highest temperature reached which is the final equilibrium temperature, T_f .
8. Calculate the specific heat of the specimen from the data and then compare it with the standard value to find the percentage error.

Material	$\frac{J}{K * Kg}$	$\frac{cal}{g * K}$
Lead	128	.0305
Aluminum	900	.215
Copper	386	.0923

Question: What are the assumptions made in the experiment?