Introduction to Calorimetry

I. Specific Heat of a Metal

Calorimetry is the process of measuring the loss or gain of heat energy in a system.

Temperature is a measure of the average kinetic energy of the molecules in a substance and is used to compare the average kinetic energies of different systems . As the average kinetic energy of a system increases, the temperature of the system increases. If two systems are at the same temperature, the molecules in the two systems have the same average kinetic energy. This does not mean that every molecule in the sample has the same kinetic energy or the same speed since the molecules in any substance have a range of kinetic energies. Only the average of the many different kinetic energies will be the same.

If two systems at different temperatures are placed in contact with each other, they will exchange energy, reach thermal equilibrium at which time the temperature will be the same throughout both systems. The First Law of Thermodynamics, the Law of Conservation of Energy, states that the energy lost or gained by a system must equal the energy lost or gained by its surroundings. This principle is the basis for calculations used in calorimetry.

If a solid is heated, the energy absorbed increases the average kinetic energy of the molecules and the temperature increases. The amount of energy required to produce a given change in temperature depends on product of the mass of the substance, the specific heat of the substance, and the change in temperature.

This is expressed mathematically in the formula:

Heat = (mass of the substance)(specific heat of the substance)(change in temp.)

$$Q = mc\Delta T$$

The mass is measured in grams. The specific heat, **c** , is the amount of energy required to raise the temperature of one gram of the substance one Celsius degree. It is an intensive property that is characteristic of the substance and is measured in Joules/g ^{o}C. The specific heat of a substance is usually a different value for each physical state. The specific heat for liquid water is 4.184 J/g^{o}C and the specific heats for ice and steam are 2.1 J/g^{o}C .

To determine the specific heat of a metal, a sample of the metal is heated and placed in a known mass of water. The metal will lose energy to the water and decrease in temperature while the water will gain energy and increase in temperature. Eventually a uniform temperature will be reached throughout the system which is the final temperature of the system. The heat lost by the metal equals the heat gained by the water. This can be expressed as:

Heat lost by the metal = Heat gained by the water

$$(m_{metal})(c_{metal})(\Delta T_{metal}) = (m_{water})(c_{water})(\Delta T_{water})$$

Note:
1. We want a positive value for ΔT :

$\Delta T_{metal} = T_{initial\ metal} - T_{final\ metal}$

$\Delta T_{water} = T_{final\ water} - T_{initial\ water}$

2. $T_{final\ metal} = T_{final\ water}$
3. $T_{initial\ metal}$ = Temp. of the boiling water

Procedure:
1. Heat 200 ml of distilled water in a 400 ml beaker to boiling on a hotplate or Bunsen burner.
2. Mass a metal cylinder to the nearest 0.01g and tie a short length of thread to the cylinder.
3. Using the thread, hang the metal cylinder in the water and heat the water to boiling. Continue boiling the water for five minutes to allow the metal sample to reach thermal equilibrium.
4. While the water is heating, mass a polystyrene cup and cover to the nearest 0.01g. Add 100. ml of distilled water and mass the cup, cover, and water to the nearest 0.01g. Place the calorimeter in a 250 ml beaker for support.
5. Set up the CBL using the temperature probe in channel 1 and link the CBL to the calculator.

a) Turn on the CBL and the calculator.

b) Select, **[PRGM]**, on the calculator.

c) Using the arrow keys, highlight the program called "**HEAT**". Press **[ENTER]**.
(Display should read "**PRGM HEAT**")

(c) Press **[ENTER]**.
(Display should read "How much time between points in seconds?")

(d) You want to enter a time of **3** then press **[ENTER]**. (The calculator display should read "**Press [ENTER] to start**" and the CBL should have three dashes across the display.)

6. Press **[ENTER]** and after 2-3 data point have been taken, quickly move the cylinder from the boiling water to the calorimeter. Cover the calorimeter and swirl it to be sure that the heat is transferred evenly throughout the system.
7. Record your initial and maximum temperatures by pressing **[STAT]** **[ENTER].** Your data are in L_3 and L_4.
8. Empty and dry the calorimeter and the cylinder for a second trial.
9. Repeat the experiment.
10. Calculate the specific heat of the metal. Check with your instructor for the actual value for you sample and calculate your percent error.

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NAME:______________________________________ PERIOD:________

LAB PARTNER:______________________________ DATE:___________

DATA TABLE

Specific Heat of a Metal

	Trial 1	Trial 2	
1. Name of metal	________	_________	
2. Mass of metal	________	_________	g
3. Mass of calorimeter and water	________	_________	g
4. Mass of calorimeter	________	_________	g
5. Mass of water	________	_________	g
6. Intial temperature of metal	________	_________	^{o}C
7. Initial temperature of water	________	_________	^{o}C
8. Final temperature of metal and water	________	_________	^{o}C
9. Change in temperature of the water	________	_________	^{o}C
10. Change in temperature of the metal	________	_________	^{o}C
11. Experimental specific heat of the metal	________	_________	$J/g^{o}C$
12. Accepted specific heat of the metal	________	_________	$J/g^{o}C$
13. Percent error in the specific heat	________	_________	%

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Instructor's Notes

Specific Heat of a Metal

Literature values for the specific heats of some common metals:

Aluminum	0.899 J/g ^{o}C
Copper	0.385 J/g ^{o}C
Iron	0.444 J/g ^{o}C
Lead	0.158 J/g ^{o}C
Magnesium	1.02 J/g ^{o}C
Nickel	0.443 J/g ^{o}C
Silver	0.237 J/g ^{o}C
Tin	0.213 J/g ^{o}C
Zinc	0.388 J/g ^{o}C
Cadmium	0.230 J/g ^{o}C

The Law of Dulong and Petit states that one mole of any pure metal has the same capacity for absorbing heat, approximately 25 J/mole ^{o}C. This is expressed as:

(Specific heat of the element in J/g ^{o}C) (atomic mass in g/mole) = 25 J/mole ^{o}C
The Dulong and Petit constant may vary by 10% or more but approximate atomic masses can be obtained and would be useful if the metal is treated as a unknown in this experiment.

Reference: Brady and Beran, Laboratory Experiments to accompany General Chemistry-Principles and Structure, Calorimetry Exp.,pp213-223, John Wiley Publishers.