5 Specific Heat of a Metal

Purpose

The objective of this experiment is to determine the specific heat of zinc sample using coffee-cup calorimeter.

Theory

In a chemical reaction, the quantity of heat that is exchanged between a system and its surroundings changes the temperature of the system. The temperature change experienced by the system when it absorbs a certain amount of energy is determined by its heat capacity. Heat capacity of an object can be defined as the amount of heat required to raise its temperature by 1 K or 1°C. The heat capacity of 1 g of a substance is known as its specific heat capacity or specific heat.

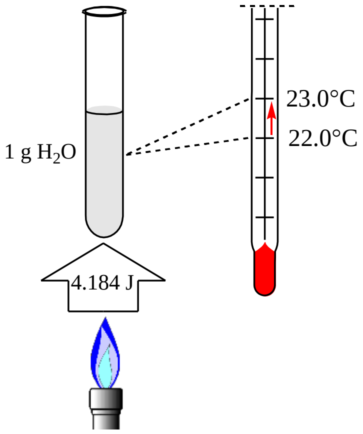

Figure 1. Specific heat capacity.

$$Specific\ Heat = \frac{Energy\ change\ in\ joules\ of\ calories}{(Mass\ in\ grams)\ x\ (Temperature\ change)}$$

For many reactions the heat flow can be measured using an instrument called calorimeter. In the laboratories, coffee-cup calorimeters are generally used to measure the heat changes in the system. These calorimeters are not sealed; so the reaction occurs under constant pressure of the atmosphere. Because coffee-cup calorimeter is very good insulator, when the reaction takes place, the calorimeter prevents the gain or loss of heat from the solution to its surroundings. Therefore, when the reaction evolves heat, q_{rxn}, it will stay within the resulting solution in the calorimeter. For example, when we have an exothermic reaction, the heat lost by the reaction is gained by the solution, and thus the temperature of the solution increases. And also for an endothermic reaction, the heat is gained by the reaction from the solution and so the temperature of the solution decreases. Therefore, we have the following relationship between the heat of reaction and the heat of solution:

$$q_{rxn} = -q_{soln}$$

$$q_{soln} = \text{(specific heat of solution)x(mass of solution)x}\Delta\text{T=-}q_{rxn}$$

For the dilute aqueous solutions, the specific heat of solution is taken as that of water.

In this experiment, calorimetry will be used to determine the specific heat of an unknown metal. This will be done using a coffee cup calorimeter containing water.
The zinc sample with a known mass and initially at higher temperature will be immersed into a coffee-cup calorimeter, which is filled-up with water with a known mass and which is at lower temperature. Then, the final equilibrium temperature of water and zinc will be measured. Because the coffee-cup calorimeter is insulated from the surroundings, the heat lost by the zinc will be equal to the heat gained by the water. Using the following equations, the specific heat of zinc will be determined using the experimental data.

Energy released by metal = Energy gained by water

$$-\,q_{Zn} = q_{water}$$

$$-\text{(specific heat of Zn)x(mass of Zn)x}\Delta\text{T(Zn)=(specific heat of water)x(mass of water)x}\Delta\text{T(water)}$$

$$\Delta\text{T(Zn)=}T_{final,Zn} - T_{initial,Zn}$$

$$\Delta\text{T(water)=}T_{final,water} - T_{initial,water}$$

NOTE ! : The specific heat values are given below:

Specific heat of water = 4.184 J/g-K = 0.998 cal/g-°C.
Specific heat of zinc = 0.093 cal/g –°C (theoretical)

Experimental Procedure

Chemicals List	***Equipments***
Metal sample (Zn) Distilled Water	Thermometer 250 mL Beaker Balance Styrofoam cups Hot plate

1. Weigh the zinc sample and write its mass on the data report sheet.
2. Place 150 ml of water into glass beaker and heat water to its boiling temperature (around 100°C) using hot plate.
3. When water reaches the temperature of approximately 100°C**,** place the zinc sample into the heated water. Heat for at least 10 min.
4. While water with zinc is boiling, weigh 60-70 g of water at room temperature into the Styrofoam cup. Write the mass of water on the data report sheet.
5. Take a thermometer and place it into the Styrofoam cup and measure and write the initial temperature of water.
6. After zinc has heated for 10 minutes, measure the temperature of the hot water with zinc. Write this temperature as the zinc initial temperature on the data report sheet.
7. Take the zinc sample from the beaker and insert it into the Styrofoam cup filled with water without splashing water out of the cup. The mass of water in the Styrofoam cup must be conserved.
8. Stir the water once after inserting the zinc <u>quickly</u> in it and measure and write the temperature inside the Styrofoam cup every 10 seconds. While stirring do not splash water out of the cup.
9. When the system reaches a constant temperature (read the same temperature value for 6 times), measure and write the value of temperature as the final equilibrium temperature.

Experiment 5 – Report

Name of the student:	Student ID:
Name and signature of the assistant:	Section & Date:

Data and Calculations

(5 pts) Mass of Zinc	
(5 pts) Mass of water in the Styrofoam cup	
(5 pts) Initial temperature of water in calorimeter, $T_{initial,\ water}$	
(5 pts) Initial temperature of Zinc, $T_{initial,\ Zn}$	
(5 pts) Final temperature of water, $T_{final,\ water}$	
(5 pts) Final temperature of Zinc, $T_{final,\ Zn}$	
(10 pts) Temperature change of Zinc	
(10 pts) Temperature change of water	
(5 pts) Theoretical specific heat of Zinc	
(15 pts) Experimental specific heat of Zinc	
(10 pts) % Error	

Experiment 5 – Report (page 2)

Name of the student:	Student ID:

QUESTIONS

1. (10 pts) Which metal would cause the greatest increase in the temperature of the water in the calorimeter: the one with the higher specific heat, or the one with the lower specific heat? Explain.
2. (10 pts) If equal masses of two metals are heated to a temperature of 100 °C, which would cause a more severe burn – the one with the higher specific heat or the one with the lower specific heat? Explain.