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Experiment 19 – Specific Heat Capacity

The heat absorbed by any sample of matter when its temperature rises by 1 ^oC is called its heat capacity. Clearly, the heat capacity of a sample depends on its mass; the greater the mass of a sample, the greater the amount of heat it must absorb to increase its temperature by one temperature degree. The heat capacity of one gram of a substance is called its specific heat capacity, which is measured in J/g ^oC or J/g K.

The molar heat capacity is the quantity of heat that must be absorbed by one mole of a substance to raise its temperature by 1 ^oC or 1 K. Its units are J/mol ^oC or J/mol K. The SI unit of energy is the Joule (J), where 4.184 Joules of heat are equal to 1 calorie. A calorie is defined as the energy required to raise 1 gram of water by 1 ^oC.

The relationship between the temperature change and the heat associated with the change is given by the equation: $Q = ms\Delta T$, where Q = heat, m = mass, s = specific heat, and ΔT represents the change in temperature ($T_{final} - T_{initial}$). In any experiment involving calorimetry, the amount of heat lost by the solid is equal to the amount of heat gained by the water. However, since heat loss is given a negative sign, we state that:

$$Q(\text{gain}) = -Q(\text{loss})$$

This can also be represented by: Q(gain) + Q(loss) = 0.

Procedure

1. Weigh and record the mass of a DRY metal sample. Please note that the mass of the attached string WILL NOT affect your results.

2. Place the loop of the string over an appropriate clamp to suspend the metal into a boiling D.I. water bath and allow the metal enough time to equilibrate to the temperature of the boiling water (about 5 minutes). Make certain that the metal is completely immersed at ALL times and does not touch the bottom of the beaker. After a constant temperature is observed, measure the temperature of the boiling water with a thermometer obtained from the lab cart, noting how to correctly read its scale. This is the initial temperature of the metal sample and should be recorded to within 0.01 ^oC. Afterwards, remove the thermometer from the water bath, and allow it to cool gradually.

3. Weigh an empty calorimeter (two styrofoam coffee-cups nested together with a plastic cover as the top). Use this same mass of the empty calorimeter for ALL TRIALS unless you use a different calorimeter.

4. Add between 50 – 100 mL of water to the calorimeter (less for a small sample, more for a large sample). Weigh and record the mass of the calorimeter and water using the SAME analytical balance.

5. Place the styrofoam calorimeter into a glass beaker for added stability. Insert the thermometer through a hole in the calorimeter lid. Use a thermometer clamp to hold it in place while water equilibrates to a constant temperature (should remain constant for approximately 2 minutes). Occasionally swirl the water to obtain its average temperature. Record this equilibrium temperature to within 0.01 ^{o}C. Be careful not to place the calorimeter near the Bunsen burner.

6. Quickly and carefully place the hot metal into the water in the calorimeter. Carefully return the lid and thermometer to the calorimeter. Gently swirl the calorimeter while observing the temperature. Remove the thermometer from the clamp for this part and hold by hand so that the cup can be constantly swirled. Note the temperature immediately and continuously observe until a constant, HIGHEST stable temperature is reached. Record this final, highest temperature to within 0.01 ^{o}C.

7. Repeat the experiment. Use the same calorimeter and piece of metal. Pour out the original water from the calorimeter and add a fresh 50 – 100 mL portion of water. Weigh and record this new mass. <u>Note</u>: If your temperature change was less than 1.2 ºC, use less water in your second experiment.

8. When completely finished, dry the calorimeter, thermometer, and metal sample. Return them to the lab cart. Be sure to place the metal in its correct container.

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Data and Calculations

	Trial 1		Trial 2		Trial 3
Mass dry calorimeter	__________	=	__________	=	__________
Mass calorimeter + volume H_2O	__________		__________		__________
Initial temperature of water in calorimeter	__________		__________		__________
Mass of metal	__________	=	__________	=	__________
Initial temperature of hot metal (before adding it to calorimeter)	__________		__________		__________
Final temperature of water + metal in calorimeter	__________		__________		__________
Δt_{water}	__________		__________		__________
Δt_{metal}	__________		__________		__________

1. Calculate the specific heat of the metal from each trial and find the average value. If the two values do not agree to within 0.06 J/g ^{o}C, a third trial must be run. SHOW CALCULATIONS:

   Trial 1 __________ Trial 2 __________ Trial 3 __________

   Average Specific Heat__________ J/g ^{o}C

2. Find the actual value for the specific heat of your metal in a reference book. Give this value in J/g ^{o}C or J/g K. Calculate the % error of your average value.

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Post-lab Questions

1. Do objects that have the same temperature have the same amount of heat? Briefly explain.

2. What is the difference between something which is hot and something which has a lot of heat?

3. How much heat would it take to raise the temperature of 645 g of water by 25^{o}C? SHOW CALCULATIONS.

4. When a 15.411 gram sample of metal gains 128.0 J of heat, its temperature changes from 18.55 ^{o}C to 83.00 ^{o}C. What is the specific heat of the metal? SHOW CALCULATIONS.

5. A metal sample weighing 71.9 g and at a temperature of 100.0 ^{o}C was placed in 41.0 g of water in a calorimeter at 24.5 ^{o}C. At equilibrium, the temperature of the water and metal was found to be 35.0 ^{o}C.

   A. What was Δt_{water}?

   B. What was Δt_{metal}?

   C. How much heat flowed into the water?

   D. Calculate the specific heat of the metal.