Lab # 10: Specific Heat

INTRODUCTION

Just as people can be identified by their appearance and their behavior, substances are described and identified by their physical (appearance) and chemical (behavior) properties. Physical properties are those than can be studied without attempting to change the substance into a different substance, while chemical properties can only be studied while trying to change the substance into another substance. You will measure the physical property of specific heat and knowing the density of an unknown metal from the first lab, you will use your data to try to identify the substance.

In today's experiment you will be measuring the specific heat of a metal. Heat is a form of energy. Temperature is used to describe the intensity of heat. The two are NOT the same. A flame of a match and the burner of a stove may be at the same temperature but the stove burner possesses a great deal more heat. The amount of heat required to raise the temperature of a quantity of matter is directly related to the amount of matter, that is, its mass. The amount of heat is also directly related to the size of the temperature change. These proportionalities are reflected in equation 1, where q is heat, m is mass in grams and s and ΔT are described below.

$$q = sm\Delta T \qquad (1)$$

ΔT means change in temperature and is always calculated as $T_{final} - T_{initial}$. The constant s is a proportionality constant known as specific heat and it is a characteristic property of the kind of matter being studied. It has the units of cal/g·°C or J/g·°C. We will be using joules as our heat unit in this experiment.

Temperature is a rough measure of molecular motion. The same quantity of heat will produce a different temperature change in equal masses of different substances. This is not at all odd. Engines of the same horsepower will move a Lincoln and an Escort at rather different speeds. It takes less heat to raise the temperature of a cup of milk a given number of degrees than it does a cup of water. In other words, different and characteristic amounts of heat are required to heat the same mass of different substances through the same temperature range. Be sure not to confuse temperature and quantity of heat. Which should melt more ice, a thimbleful of boiling water or a bucket of water at 90°C? Vote for the bucket!

Some fundamental definitions would seem to be in order now.

Heat: Heat lost is **negative** and heat gained is **positive,** because of the way in which heat is defined scientifically.

Calorie (cal): Quantity of heat liberated or absorbed when 1.00 g of water is cooled or heated 1.00°C. (To be exact, this is true only between 14.5° and 15.5°C. However, the amount of heat associated with 1°C temperature change is usually so close to 1 cal that this figure is used unless very precise work is in progress.) The calorie is the unit most often used in the older Metric System.

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Joule (J): Unit of heat most commonly used in the SI system. 1.00 cal = 4.184 J

Specific Heat (s): The quantity of heat liberated or absorbed when the temperature of 1.00 gram of a substance falls or rises 1.00°C. Specific heat is temperature (and phase) dependent. Thus one must know not only the substance but also the temperature range and whether a solid, liquid or gas is involved. Specific heats of selected substances are given in the following table.

Substance	Specific Heat (J/g·°C)
water (gas)	1.874
water (liquid)	4.184
water (solid)	2.113
ammonia (liquid)	4.39
ammonia (solid)	2.09
ethanol (liquid)	2.43

In this activity the specific heat of a metal will be determined using the concept of the zero'th law which states that in any process where heat is transferred,

$$\text{Heat loss} = -\text{Heat gain} \quad (2)$$

Heat will be transferred from the metal to both the water and the calorimeter. The following equation takes all three components into account.

$$q_{metal} = -(q_{calorimeter} + q_{water}) \quad (3)$$

To simplify calculations, unless otherwise stated, you will assume that the calorimeter constant, C, is zero. Since $q_{calorimeter} = C\Delta T$, $q_{calorimeter}$ thus equals zero and equation 4 is obtained.

$$q_{metal} = -q_{water} \quad (4)$$

A sample of hot metal (of known mass and temperature) will be mixed with water (also of known mass and temperature). The metal will lose heat and water will gain heat. The temperature after mixing will be uniform, that is, the water and metal will be at the same temperature.

The specific heat of water is 4.184 J/g·°C. Thus, the heat gained by the water can be calculated. From the zero'th law the amount of heat must be equal to the heat lost by the metal sample. From this, the specific heat of the metal is calculated.

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PROCEDURE:

1. Put about 400 mL of water (tap or distilled) into a 600 mL beaker and heat it to boiling on a hot plate.

2. The instructor will give you the same metal sample that you used for the density lab. Take your two largest test tubes and weigh the metal samples into them using the following instructions.

   a. Take your metal sample, a large beaker, the two large test tubes (labeled 1 and 2), your data sheet and pen to a balance.

   b. Weigh the full container of metal, without the cover.

   c. TARE the balance.

   d. Pour approximately half the metal sample into test tube #1.

   e. Weigh the half full bottle of metal, without the cover. The mass that is shown (ignoring the negative sign) is the mass of metal that is in test tube #1. Record this mass.

   f. TARE the balance with the half full bottle of metal on it.

   g. Pour the rest of the metal into test tube #2.

   h. Weigh the empty bottle, without the cover. The mass that is shown (ignoring the negative sign) is the mass of metal that is in test tube #2. Record this mass.

3. Gently insert a thermometer into the metal sample in one of the test tubes. Place both test tubes in the 600 mL beaker, which by now should contain very hot water.

4. Allow the metal samples to heat until the temperature is stable (~100°C). Meanwhile, weigh two empty, nested foam cups. TARE the balance. Remove the cups from the balance and, using a graduated cylinder or small beaker, place 80 mL of distilled water into the cup. Reweigh to obtain the mass of the water. Place a second thermometer through the cover of the cup. Support the thermometer by a paper clip and clamp arrangement, so that the bulb of the thermometer will be in the center of the water. Read the temperature of the water in the cup to 0.1°C, and record the temperature when it becomes steady. This is the initial temperature of the water.

5. When the temperature of the metal is stable, record it to 0.1°C. This is the initial temperature of the metal.

6. Remove the thermometer from test tube #1 and gently place it in the metal in test tube #2. Carefully remove test tube #1 of metal from the water bath; caution, it will be hot. Pour the metal quickly into the water in the cup. Quickly replace the cover, swirl, and watch the temperature of the water/metal mixture. Record the highest temperature reached by this mixture. This is the final temperature for the metal and for the water.

7. Repeat steps 4 - 6 with the sample of metal in the other test tube, reusing the same cups after drying them out.

8. From your data, calculate the specific heat of your unknown metal in each trial and average the results.

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DATA

Density of solid (from lab #1, if you do not have this lab, see the instructor) ___________ g/mL

	Trial 1	Trial 2
Metal Unknown #	__________	__________
Mass of metal (g)	__________	__________
Mass of water in cup (g)	__________	__________
Initial temperature of water (°C)	__________	__________
Initial temperature of metal (**hot**) (°C)	__________	__________
Temperature of water/metal mixture (°C)	__________	__________

CALCULATIONS

Change in temperature of water (ΔT_w) (°C)	__________	__________
Change in temperature of metal (ΔT_m) (°C)	__________	__________
Heat gained by water. Show set-up and calculations for trial 1. (J)	__________	__________
Heat lost by the metal. (J) Remember that $q_{metal} = - q_{water}$	__________	__________
Specific heat of metal (show set-up and calculations for trial 1) (J/g·°C)	__________	__________

Average specific heat (J/g·°C) ____________

Instructor's Initials __________

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IDENTIFY YOUR METAL

POSSIBLE METALS

Metal	Density (g/mL)	Specific Heat (J/g·°C)	Appearance
Ag	10.5	0.235	white
Al	2.70	0.90	tin-white with somewhat bluish tint
Ba	3.51	0.15	yellow silver
Bi	9.80	0.11	silvery-white
Ca	1.55	0.63	lustrous, silver-white surface
Cd	8.65	0.23	silver-white, blue-tinged, lustrous
Cu	8.96	0.38	reddish, lustrous
Fe	7.86	0.44	silvery-white or grey, soft
Mg	1.74	1.02	silvery-white
Ni	8.90	0.44	lustrous white, hard
Pb	11.4	0.13	bluish-white, silvery, grey
Sn	7.30	0.227	almost silver-white, lustrous
Sr	2.6	0.30	silvery-white
W	19.3	0.13	steel-grey to tin-white
Zn	7.14	0.39	bluish-white, lustrous

1. Based on the above data and your density, specific heat and the appearance of the metal, what is your unknown metal? (If you cannot choose one, list all the possible choices.)

2. What is the percent error for your density? $\left(\% \text{ error} = \frac{|\text{actual} - \text{experimental}|}{\text{actual}} \text{ x } 100 \right)$

3. What is the percent error for your specific heat?

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PRESTUDY

Attach additional sheets to show your calculations if necessary.

1. (2) How many joules are necessary to raise the temperature of 745.125 g of water from 19.8°C to 96.1°C?

_________________ J

2. (2) What is the specific heat of a metal if 111.486 g of the metal requires 1992.8 joules for a 71.5°C temperature change?

_________________ J/g·°C

3. (3) 61.247 g of an unknown metal, at a temperature of 106.4°C are mixed with 70.762 g of water at a temperature of 21.1°C. The resulting mixture reached a maximum temperature of 26.9°C. Assuming that the calorimeter constant is 0, what is the specific heat of the metal?

_________________ J/g·°C

4. (3) Using the information found in problem 3, recalculate the specific heat of the metal using a calorimeter constant (C) of 17.6 J/°C instead of zero. (ΔT for the calorimeter equals ΔT for the water. Use $q_{calorimeter} = C\Delta T$ and equation 3 to find q for the metal.)

_________________ J/g·°C