Background

Calorimetry is a process for measuring heat transfer. All substances have the capacity to absorb heat and different substances vary in the amount of heat needed to raise their temperatures by 1 °C. The amount of heat (in calories or joules) needed to raise the temperature of 1 g of substance by 1 °C is the specific heat of the substance. Specific heat is unique to each substance and can be used to identify unknown substances. Equation 1 shows how to calculate specific heat.

$$\text{Specific heat} = \frac{\text{Amount of heat (cal or J)}}{\text{Mass (g)} \times \Delta\text{T (°C)}} \qquad \text{Equation 1}$$

Table 1 lists the specific heat values of water and some metals.

Table 1 Specific Heats of Water and Metals

Substance	Specific Heat (cal/g °C)	Specific Heat (J/g °C)
Water (liquid)	1.00	4.18
Iron	0.11	0.46
Copper	0.093	0.39
Aluminum	0.22	0.92
Lead	0.031	0.13

Notice that the specific heat of water is much larger than that of the other substances. In the first part of this experiment, you will use a calorimeter (a Styrofoam cup) to determine the specific heat of a metal and identify it.

In the second part of this experiment, you will burn a food sample to determine the number of kilocalories (Calories) it contains. When something is burned (as in combustion reactions), like a food sample, heat is released and can be transferred to another substance, like water. The temperature change of the water can be measured, therefore the amount of energy the water absorbed can be calculated. If a container of water is suspended over a burning food sample, the water will be heated by the energy given off in the combustion reaction. For the purposes of this experiment, it is assumed the heat lost to the calorimeter and the surrounding air is negligible.

Specific Heat of an Unknown Metal

In this portion of the experiment, you will assemble a calorimeter using a Styrofoam cup and cover, similar to what is shown in Figure 1.

You will heat an unknown metal sample in a water bath until the water boils. Then, you will transfer the metal to the calorimeter. The calorimeter will contain a measured and recorded amount of water. The temperature of the water inside the calorimeter will increase and the temperature of the metal will decrease until the water and metal are the same temperature. The amount of heat released by the metal is determined by measuring how much the water's temperature increased.

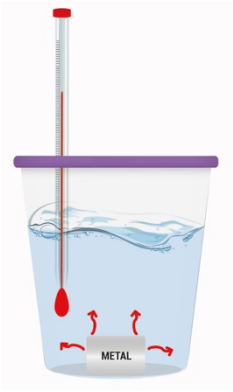

Figure 1 Styrofoam Calorimeter

Example:

Suppose a student heats a metal object with a mass of 30.7 g to 95.0 °C and transfers it to a calorimeter containing 100.0 g of water at 18.9 °C. The water and metal reach a final temperature of 24.1 °C. What are the identity and the specific heat of the metal in J/g °C?

$$\text{heat}_{\text{water}} = \text{mass (g)}\ \Delta T\ (°C) \times \text{specific heat}_{\text{water}} = 100.0\ \text{g} \times 5.2°C \times 4.18\ \text{J/g}\ °C$$
$$= 2173.6\ \text{J}$$

The heat gained by the water is equal to heat lost by the metal ($\text{heat}_{\text{metal}} = -\text{heat}_{\text{water}}$). Now, calculate the specific heat of the metal.

$$\text{specific heat}_{\text{metal}} = \frac{\text{heat}_{\text{metal}}\ (\text{J})}{\text{mass}_{\text{metal}}(\text{g}) \times \Delta T\ (°C)} = \frac{-2173.6\ \text{J}}{(30.7\ \text{g})(-70.9°C)} = 0.999\ \text{J/g}\ °C$$

Looking at Table 1, the metal is most likely aluminum.

Energy from Food

The calories in food can also be measured using a calorimeter. For this part of the experiment, you will weigh a food sample and then burn it beneath an aluminum can containing water. The temperature of the water in the can will increase as the food is burned. The change in the water's temperature can be measured, allowing for the calculation of heat or energy in the food sample.

Food is what provides our bodies with energy. A typical adult requires ~2000 Calories a day, however people who are more active or children who are growing may require different amounts of Calories. The unit Calories is equal to kilocalories. Food labels list the Calories, or energy, in the food and specify the Calories provided by different nutrients; fat, carbohydrates, and protein. These nutrients provide a different number of Calories per gram. Fat provides 9 Cal/g, carbohydrates 4 Cal/g, and protein 4 Cal/g. You can calculate the Calories, or kilocalories, for each nutrient from a food label.

Example:

Suppose a food label says in one serving of soup, there are 122 Calories, 2 g of fat, 21 g of carbohydrates, and 5 g of protein. Calculate the kilocalories (kcal) provided by fat, carbohydrates, and protein.

$$\text{Fat kcal} = 2\text{ g fat} \times \frac{9\text{ kcal}}{1\text{ g fat}} = 18\text{ kcal}$$

$$\text{Carbohydrate kcal} = 21\text{ g carbohydrate} \times \frac{4\text{ kcal}}{1\text{ g carbohydrate}} = 84\text{ kcal}$$

$$\text{Protein kcal} = 5\text{ g protein} \times \frac{4\text{ kcal}}{1\text{ g protein}} = 20\text{ kcal}$$

We can check the work by adding the individual kcal to get the total kilocalories in one serving.

$$\text{kcal} = 18\text{ kcal} + 84\text{ kcal} + 20 = 122\text{ kcal (or Calories)}$$

Objectives

- Distinguish between a calorie, kilocalorie, and nutritional Calorie
- Calculate the specific heat of a metal object and identify it
- Calculate heat lost or gained using the specific heat of water
- Calculate the caloric values of foods and kilocalories in servings of food
- Determine kilocalories in a serving of food using nutrition label

Materials

- Thermometer
- Hot plate
- Ring stand and iron rings
- Clamps
- Wire screen
- 400-mL beaker
- Stirring rod
- Metal object
- String or fishing line
- Balance
- Calorimeter
- Metal can
- Food sample
- Paper clip
- Aluminum foil
- Cork

Safety goggles must be worn at all times!

Check with TA or Instructor for any other supplies you may need.

Procedure

Determining the Specific Heat of an Unknown Metal

1. Obtain a hot plate and a 400-mL beaker and fill it with ~250 mL of water. Place the beaker on the hot plate and start heating the water.
2. Obtain an unknown metal and a string. Record the identification number of the metal.
3. Determine and record the mass of the metal.
4. Tie the string around the metal and gently lower it into the water in the beaker. Heat for 10 minutes.
5. Obtain a cover and calorimeter (Styrofoam cup) and determine and record the mass of the calorimeter only (do not include the cover).
6. Add enough water to the calorimeter so the metal will be completely submerged, ~50 – 100 mL. Determine and record the combined mass.
7. Once the water bath with the metal has heated/boiled for 10 minutes, determine and record the temperature of the water. This is the initial temperature of the metal.

8. Determine and record the temperature of the water in the Styrofoam cup (calorimeter). This is the initial temperature of the water.
9. Carefully remove the metal from the boiling water bath and gently place it in the calorimeter. Place the cover on the calorimeter and stir the water gently with a stirring rod, without bumping into the metal. Record the highest temperature obtained. This is the final temperature of the water and the metal.
10. Dry off the metal and repeat steps 5 – 10 one more time.

Data Analysis

11. Calculate the temperature change of the water in the calorimeter.

$$\Delta T_{\text{water}} = T_{\text{water final}} - T_{\text{water initial}} \qquad \text{Equation 2}$$

12. Calculate the heat, in calories, transferred from the metal to the water and record.

$$\text{Heat (cal)} = \text{mass}_{\text{water}}\,(\text{g}) \times \Delta T_{\text{water}}(^{\circ}\text{C}) \times \text{specific heat}_{\text{water}} \qquad \text{Equation 3}$$

13. Record the amount of heat lost by the metal.

$$\text{Heat (cal) lost by metal} = \text{Heat (cal) gained by water}$$

14. Calculate the temperature change for the metal. The initial temperature of the metal is the temperature of the boiling water. The final temperature of the metal is the highest temperature recorded in step 9.

$$\Delta T_{\text{metal}} = T_{\text{metal final}} - \Delta T_{\text{metal initial}} \qquad \text{Equation 4}$$

15. Calculate the specific heat of the metal (cal/g °C).

$$\text{Specific heat}_{\text{metal}} = \frac{\text{heat (cal)}}{\text{mass}_{\text{metal}}(\text{g}) \times \Delta T_{\text{metal}}(^{\circ}\text{C})} \qquad \text{Equation 5}$$

16. Convert the specific heat of the metal to J/g °C. (Look at Table 1 for the conversion factor.)
17. Identify the metal using Table 1and record.

Determining Calories per gram in Food Sample

1. Obtain an aluminum can and determine and record its mass.
2. Add ~100 mL of water to the can and determine and record the mass.
3. Obtain a food sample, determine its mass, and record.
4. Obtain and ring stand, iron ring, wire gauze, paper clip, aluminum foil, cork, thermometer, and thermometer clamp. Assemble the setup as shown in Figure 2.
5. Ensure that the thermometer bulb is completely submerged in the water inside the can.
6. Place the food sample on the paper clip and ignite it using either a match or lighter. Once the sample is burning, remove the heat source and let it burn. Record the highest temperature the water reaches. This is the final temperature.
7. Determine the mass of the ash and remaining food sample and record.

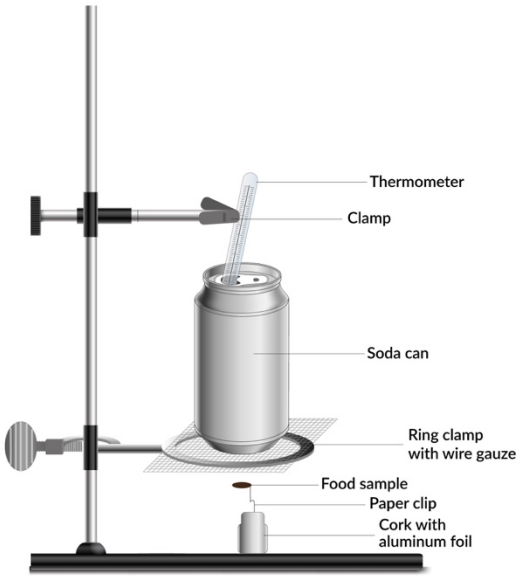

Figure 2 Calories per Gram Setup

Data Analysis

8. Calculate the mass of the water in the can.
9. Calculate the temperature change of the water after it is heated by the burning food sample.
10. Calculate the heat gained by the water in the can in calories and kilocalories. This is also the heat lost by the food sample.

$$\text{heat (cal)} = \text{mass}_{\text{water}}(\text{g}) \times \Delta T_{\text{water}}\ (^{\circ}\text{C}) \times 1.00\ \text{cal/g}\,^{\circ}\text{C} \qquad \text{Equation 6}$$

$$\text{heat (kcal)} = \text{heat (cal)} \times \frac{1\ \text{kcal}}{1000\ \text{cal}} \qquad \text{Equation 7}$$

11. Calculate the mass of the food sample that burned by subtracting the mass of any remaining food and the mass of the ash from the starting mass of the food sample.
12. Calculate the Calories per gram in the food sample.

$$\text{Calories per gram (Cal/g)} = \frac{\text{kcal (Cal)}}{\text{mass}_{\text{food}}\ (\text{g})} \qquad \text{Equation 8}$$

Nutrition Label Analysis

1. Obtain a nutrition label from a food product and record the serving size.
2. Record the grams of fat, grams of protein, and grams of carbohydrates in one serving.
3. For one serving, calculate the Calories provided by each nutrient using the grams of each nutrient listed on the label.

4. Calculate the total Calories in one serving and compare this number to the total Calories for one serving listed on the nutrition label.

Lab 13 Energy and Specific Heat Report Sheet

Team _____

Specific Heat of Unknown Metal

Identification Number of Metal _____

Mass of Metal _____

	Trial 1	**Trial 2**
Mass of calorimeter (g)		
Mass of calorimeter and water (g)		
Temperature of boiling water bath (°C)		
Initial temperature of water in calorimeter (°C)		
Final temperature of water and metal in calorimeter (°C)		
Temperature change of water (°C)		
Heat gained by water (cal) *show calculations*		
Heat lost by metal (cal)		
Temperature change of metal (°C)		
Specific heat of metal (cal/g°C) *show calculation*		

Specific heat of metal (joules/g °C)		

Identity of metal _____

Determining Calories per gram in Food Sample

Type of Food Sample _____

Mass of Food Sample _____

Mass of can (g)	
Mass of can and water (g)	
Final temperature of water (°C)	
Initial temperature of water (°C)	
Temperature change of water (°C)	
Mass of food sample remaining (g)	
Mass of water (g)	
Temperature change of water (°C)	
Heat gained by water (cal) *show calculation*	
Heat gained by water (kcal)	
Heat lost by food sample (cal)	
Heat lost by food sample (kcal)	
Mass of food burned (g)	
Calories per gram of food sample (kcal/g) *show calculation*	

Food Type _____		Serving Size _____
	Mass in one serving (g)	Calories in one serving (kcal)
Fat		
Carbohydrates		
Protein		
Total Calories per serving (kcal)		
Total Calories per serving from label (Cal)		