



Purpose

The purpose of this experiment is to identify a metal by measuring its specific heat and to determine the amount of calories released by burning a food sample.

Learning Objectives

- Define the terms calorie, kilocalorie, and nutritional Calorie.
- Carry out conversions between energy units such as calorie, kilocalorie and nutritional Calorie.
- Calculate heat lost or gained by water using the specific heat and mass of water
- Determine the specific heat of a metal object from data obtained using a Styrofoam-cup calorimeter.
- Identify a metal by its specific heat.
- Calculate the caloric values of foods from data using an aluminum-can combustion calorimeter.
- Determine kilocalories in a serving of food using information found on a nutrition label.

Laboratory Skills

- Set up and use a coffee-cup calorimeter.
- Use a balance.
- Use a thermometer.

Equipment

- | | |
|-----------------------------|----------------------|
| ▪ Thermometer | ▪ Balance |
| ▪ Hot plate | ▪ Coffee-cup |
| ▪ Ring stand and iron rings | calorimeter |
| ▪ Clamps | ▪ Aluminum soda can |
| ▪ Wire screen | ▪ Cork |
| ▪ 400 mL beaker | ▪ Nutritional Labels |
| ▪ Stirring rod | from the food |
| ▪ String or fishing line | products tested |

Chemicals

- | | |
|-------------------|------------------------|
| ▪ Food samples | ▪ Aluminum foil |
| (crackers, chips, | ▪ Metal objects (iron, |
| nuts) | copper, aluminum, |
| ▪ Paper clip | and lead) |

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 CP.1 shows how to calculate specific heat.

$$\text{specific heat} = \frac{\text{heat (cal or J)}}{\text{mass (g)} \times \Delta T (^{\circ}\text{C})} \quad (\text{Equation CP.1})$$

Table CP.1 lists the specific heat values of water and some metals. Note that the specific heat of water is much larger than that of the other substances.

Table CP.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

In the first part of this experiment, students 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, students will burn food samples to determine the number of kilocalories (Calories) each sample contains. When a food or fuel is burned (undergoes a combustion reaction) heat is released. This heat can be transferred to another substance, like water, causing its temperature to rise. If the temperature change of the water is known, the amount of energy absorbed by the water absorbed can be calculated. A container of water suspended over a burning food sample will absorb much of the heat energy given off by 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, students will assemble a calorimeter using a Styrofoam cup and cover, similar to that shown in Figure CP.1.

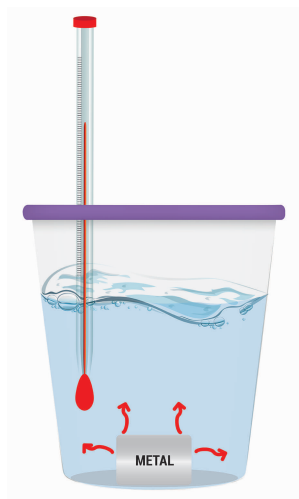


Figure CP.1: Styrofoam Cup Calorimeter

An unknown metal sample will be heated in a water bath until the water boils, after which the metal is transferred to the calorimeter. The calorimeter will contain a measured and recorded mass of water at a measured temperature. 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 equal to the amount of heat absorbed by the water. Thus the heat released by the metal can be calculated from the mass of the water, and the temperature change of the water. The heat released and the mass of the metal can then be used to calculate the specific heat of the metal. Example CP.1 shows how to do these calculations.

Example CP.1: Calculating the Specific Heat of a Metal

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?

$$\text{heat}_{\text{water}} = \text{mass}_{\text{water}} (\text{g}) \times \Delta T_{\text{water}} (^\circ\text{C}) \times \text{specific heat}_{\text{water}} (\text{J/g } ^\circ\text{C})$$

$$\text{heat}_{\text{water}} = 100.0 \text{ g} \times 5.2 ^\circ\text{C} \times 4.18 \text{ J/g } ^\circ\text{C}$$

$$\text{heat}_{\text{water}} = 2173.6 \text{ J}$$

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.

$$\text{specific heat}_{\text{metal}} = \frac{\text{heat}_{\text{metal}} (\text{J})}{\text{mass}_{\text{metal}} (\text{g}) \times \Delta T_{\text{metal}} (^\circ\text{C})}$$

$$\text{specific heat}_{\text{metal}} = \frac{-2173.6 \text{ J}}{(30.7 \text{ g})(-70.9 ^\circ\text{C})}$$

$$\text{specific heat}_{\text{metal}} = 0.999 \text{ J/g } ^\circ\text{C}$$

Based on the specific heats given in Table CP.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, students will each 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.

In the human body, metabolic processes utilize chemical reactions to release energy from food. A typical adult requires ~2000 Calories a day. However, people who are very active and growing children typically require more Calories. The unit Calories is equivalent to the metric unit, kilocalories. Food labels list the Calories, or energy, in foods and specify the Calories provided by three common 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, provided by each nutrient from a food label, as shown in Example CP.2.

Example CP.2: Calculating Calories per Nutrient

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 each individual nutrient: fat, carbohydrates, and protein.

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

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

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

Check the work by adding the individual kcal to get the total kilocalories in one serving.

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

Procedure

Safety Precautions

Be careful with boiling water and an open flame.

Determining the Specific Heat of an Unknown Metal

Data Collection

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. Measure 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, as seen in Figure CP.1). Measure and record the mass of the calorimeter *without the cover*.
6. Add enough water to the calorimeter so the metal will be completely submerged, ~50-100 mL. Measure and record the combined mass.
7. Once the water bath with the metal has heated/boiled for 10 minutes, measure and record the temperature of the water. This is the initial temperature of the metal.
8. Measure 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 the procedure to collect a second set of data.

Determining Calories per gram in Food Sample

Data Collection

1. Obtain a food sample and measure and record its mass.
2. Obtain an aluminum can and measure and record its mass.
3. Add ~100 mL of water to the can and measure and record the combined mass.

- Obtain a ring stand, iron ring, wire gauze, paper clip, aluminum foil, cork, thermometer, and thermometer clamp. Assemble the setup as shown in Figure CP.2.
- Ensure that the thermometer bulb is completely submerged in the water inside the can. Record the initial temperature of the water.
- 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.

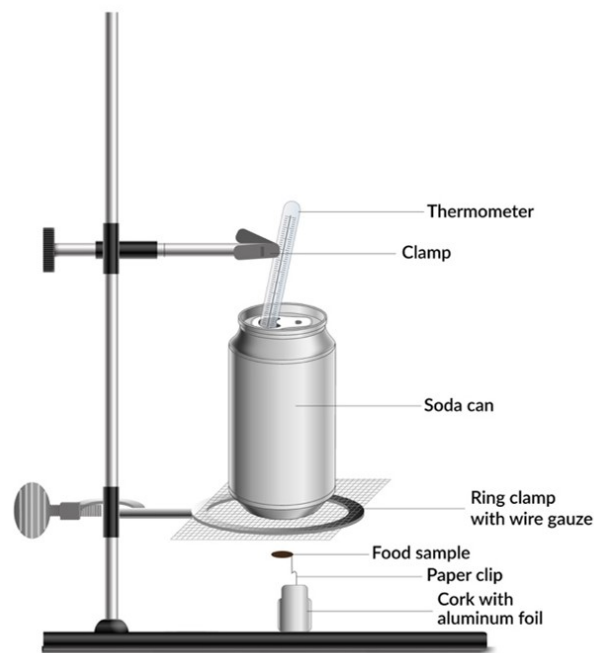


Figure CP.2: Aluminum Can Calorimeter

- Measure and record the mass of the ash and remaining food sample.

Data Analysis

- Calculate the mass of the water in the can.
- Calculate the temperature change of the water after it is heated by the burning food sample.
- Calculate the heat, in calories, gained by the water in the can.

$$\text{heat}_{\text{water}} (\text{cal}) = \text{mass}_{\text{water}} (\text{g}) \times \Delta T_{\text{water}} (^\circ\text{C}) \times \text{specific heat}_{\text{water}} (\text{cal/g } ^\circ\text{C})$$

- Convert this answer to kilocalories using $1 \text{ kcal} = 1000 \text{ cal}$. This is also the heat lost by the food sample.
- 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.

6. Calculate the Calories per gram in the food sample.

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

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.



Name: _____

Section: _____ Date: _____

Specific Heat of Unknown Metal

Identification # of metal _____

Mass of metal (g) _____

Mass of calorimeter (g) _____

Report Table CP.1: Specific Heat of Metal Data and Calculations

	Trial 1	Trial 2
Mass of unknown metal (g)	_____	_____
Mass of calorimeter (g)	_____	_____
Mass of calorimeter and water (g)	_____	_____
Temperature of boiling water bath (°C)	_____	_____
Initial temperature of calorimeter water (°C)	_____	_____
Final temperature of water and metal (°C)	_____	_____

Determining Calories per gram in Food Sample

Type of food sample _____

Mass of can (g) _____

Mass of can and water (g) _____

Initial mass of food sample (g) _____

Final mass of food sample (g) _____

Initial temperature of water (°C) _____

Final temperature of water (°C) _____





Nutrition Label Analysis

Food type _____

Serving size (g) _____

Total Calories in one serving (kcal) _____

Mass of fat in one serving (g) _____

Mass of carbohydrates in one serving (g) _____

Mass of protein in one serving (g) _____