EXPERIMENT 0

Specific heat and food

A. Goal

The goal of this laboratory experiment is to measure the specific heat of a metal and to review the concept of energy value.

B. Materials

- ☐ metallic object
- ☐ 250mL (or 400mL) beaker
- ☐ hot plate
- ☐ string
- ☐ double styrofoam cup (a calorimeter)
- ☐ thermometer
- ☐ food product labels

C. Background

From energy to temperature

Heat transforms in a temperature change. Some substances like metals can increase their temperature very quickly with a small amount of heat received, whereas others need a larger amount of heat to rise their temperature. Think about why you use oil to deep fry food. Why not use water? First of all, oil can raise its temperature very quickly and on top of that it does not boil easily.

Heat capacity

The heat capacity c of a material is defined as:

$$c = \frac{\text{heat adsorbed}}{\text{temperature increase}} \tag{1}$$

This is a characteristic property of each material that indicates the energy required to rise its temperature and can be expressed in $\mathrm{cal}/°\mathrm{C}$ or $\mathrm{J}/°\mathrm{C}$ units. As this property depends on the amount of matter, oftentimes the heat capacity is expressed per mass as the specific heat capacity also known as *specific heat* (c_e) or mole unit as the *molar heat capacity* c_m. For example, the specific heat of water is $1\mathrm{cal}/\mathrm{g}°\mathrm{C}$ that is the same as $4.184\mathrm{J}/\mathrm{g}°\mathrm{C}$. That means that we need to give 1 calorie to warm up one gram of water $1°C$. Similarly, the specific heat of aluminum, a metal, is $0.2\mathrm{cal}/\mathrm{g}°\mathrm{C}$ or $0.89\mathrm{J}/\mathrm{g}°\mathrm{C}$; that means the energy needed to raise the temperature of an aluminum gram is 0.2 calories of 0.89 J. Mind the difference between these two values: we need to give 1 cal to increase the temperature of a gram of water in $1°C$, whereas we need to give 0.2 cal to increase the temperature of a gram of aluminum in $1°C$. Why are these two numbers so different? The answer is that water and aluminum are different materials. Normally metals warp up very easily, that is, they need less heat to increase their temperature, whereas liquids need more heat to increase their temperature. That is why pans and cooking pots tend to be metallic. Table 1 lists specific heats of common substances. Mind the specific heat if water is a well know value that you need to be familiar with:

$$\boxed{c_e^{\mathrm{H_2O}} = 4.184\mathrm{J}/\mathrm{g}°\mathrm{C} \qquad or \qquad c_e^{\mathrm{H_2O}} = 1\mathrm{cal}/\mathrm{g}°\mathrm{C}} \tag{2}$$

Heat

When a material receives heat, that heat normally becomes temperature as the temperature of the material increases. For example, if you warm milk in a microwave, the milk's temperature increases from room temperature (25°C) to a higher temperature. How to estimate the temperature increase given the heat received? Or how to estimate the heat needed to increase the temperature of an object? We can use the following formula:

$$\boxed{Q = m \cdot c_e \cdot (T_f - T_i)} \tag{3}$$

where:

Q is the amount of heat received, either in cal or J.

m is the mass of material in grams

c_e is the specific heat of the material (in cal/g°C or J/g°C)

$T_f - T_i = \Delta T$, is the temperature change from the initial to the final temperature

A system can receive or give away heat and this is indicated by the sign of Q. The sign convention for heat is:

$Q > 0$ the system receives heat *and* $Q < 0$ the system gives away heat

Sample Problem 1

How many calories are absorbed by a 45.2g piece of aluminum ($c_e = 0.214 \frac{cal}{g°C}$) if its temperature rises from 25°C to 50°C.

SOLUTION

1 **Step one:** list of the given variables.

Analyze the Problem	Given	Asking
	$c_e = 0.214 \frac{cal}{g°C}$ $m = 45.2g$ $T_{initial} = 25°C$ $T_{final} = 50°C$	Q

2 **Step two:** use the formula $Q = m \cdot c_e \cdot (T_{final} - T_{initial})$ to transform the temperature increase into heat absorbed. Mind this formula depends on the mass involved and the specific heat of the material, in this case, aluminum.

3 **Step three:** solve $Q = 45.2 \cdot 0.214 \cdot (50 - 25) = 241.82cal$.

STUDY CHECK

How many calories are absorbed by 100g of Gold ($c_e = 0.0308 \frac{cal}{g°C}$) if its temperature rises from 25°C to 100°C.

Answer: $Q = 231cal$.

Table 1 Values of specific heat for different materials

Material	Specific heat (J/g°C)	Material	Specific heat (J/g°C)
$H_2O_{(l)}$	4.184	$Fe_{(s)}$	0.444
ethyl alcohol$_{(l)}$	2.460	$Au_{(s)}$	0.129
vegetable oil$_{(l)}$	1.790	$Cu_{(s)}$	0.385
$NH_{3(l)}$	4.700	$H_2O_{(s)}$	2.010
Dry Air$_{(g)}$	1.0035	$CO_{2(g)}$	0.839

Calories in food

How much food do you eat? How many calories do you ingest a day? When you are watching your food intake, the Calories you are counting are kilocalories (1000cal, Kcal, or Cal). In the field of nutrition, it is common to use the Calorie, Cal (with an uppercase C) to indicate 1000 cal or 1 kcal.

$$\boxed{1Cal = 1000cal} \quad \text{or} \quad \boxed{\frac{1Cal}{1000cal}} \quad \text{or} \quad \boxed{\frac{1000cal}{1Cal}} \tag{4}$$

Energy values

Do you ever eat pasta? Think about how does your body feel after you eat pasta? Normally, whenever you eat pasta in a few hours you need to eat again more food. Differently, whenever you eat meat, that is enough to keep you going for a longer time. Similarly, eating a salad for lunch brings you less energy than a pizza slice. This is because each type of food–each ingredient–contains different energy. We refer to this as the energy value of food ϵ. Table 2 lists energy values for common ingredients. To compute the energy (E) provided by a certain mass of food (m) we need to multiply the mass times the energy value (ϵ):

$$E = m \cdot \epsilon \tag{5}$$

For example, the energy value of fat ϵ_{fat} is $9\dfrac{kcal}{g}$, which means that if you eat three grams of fat that will bring you a given amount of energy E_{fat}:

$$E_{fat} = 3\cancel{g} \times 9\frac{kcal}{\cancel{g}} = 18kcal$$

Normally, when you eat a food plate, you ingest energy from the different types of ingredients of that plate: fat, carbs, or protein.

Sample Problem 2

A Big Mac from McDonalds contains 28g of fat $(9kcal/g)$, 46g of carbs $(4kcal/g)$ and 25 g of protein $(4kcal/g)$, where the caloric values are indicated in parenthesis. What is the total energy content of a Big Mac?

SOLUTION

1 **Step one:** list of the given information and the unknown.

	Given	Asking
Analyze the Problem	$m_{fat} = 28g$ $\epsilon_{fat} = 9\frac{kcal}{g}$ $m_{carb} = 46g$ $\epsilon_{carb} = 4\frac{kcal}{g}$ $m_{prot} = 25g$ $\epsilon_{prot} = 4\frac{kcal}{g}$	Energy Content

2 **Step two:** use the formula $E_{fat} = m_{fat} \cdot \epsilon_{fat}$ to calculate the energy coming from fat. And do the same for carbs and protein.

3 **Step three:** Compute the energy coming from each ingredient and add all the values:

$$E_{fat} = m_{fat} \cdot \epsilon_{fat} = 28\cancel{g} \times 9\frac{kcal}{\cancel{g}} = 252kcal \qquad \text{energy from fat}$$
$$E_{carb} = m_{carb} \cdot \epsilon_{carb} = 46\cancel{g} \times 4\frac{kcal}{\cancel{g}} = 184kcal \qquad \text{energy from carbs}$$
$$E_{prot} = m_{prot} \cdot \epsilon_{prot} = 25\cancel{g} \times 4\frac{kcal}{\cancel{g}} = 100kcal \qquad \text{energy from protein}$$

The total energy content of a Big Mac is: $E_{fat} + E_{carb} + E_{prot} = 532kcal$

STUDY CHECK

A pepperoni pizza slice contains 11g of fat ($9kcal/g$), 36g of carbs ($4kcal/g$) and 14 g of protein ($4kcal/g$), where the caloric values are indicated in parenthesis. What is the total energy content of a pizza slice?

Answer: $299kcal$.

Table 2 Energy value of food

Food Type	Energy value ($\frac{kcal}{g}$)
Carbohydrates	4
Fat	9
Protein	4

D. Procedure

1. Specific heat of a metal The goal of this mini experiment is to calculate the specific heat of an unknown metal. You will do this by warming up the metal in a hot water bath and by using a calorimeter to cool down the metal.

Step 1: – Obtain a metallic object. Record its mass.

Step 2: – Place a 250mL beaker (or a 400mL) on top of a hot plate. Place a thermometer in the beaker so that it does not touch the walls of the beaker and secure it with a clam. Start warming up the water at high heat so that the water boils. Add some boiling chips.

Step 3: – Tie a string to the object and submerge it in the how bath. Let it there for 10 min.

Step 4: – Obtain a double styrofoam cup and weight it. Record its mass.

Step 5: – Add 50mL of water to the cup and weight again. Record the new mass. Make sure the water is enough to fully cover the metal. If not add some more.

Step 6: – Measure the temperature of the hot bath after the metals it's been there for 10 min. Record the value.

Step 7: – Using the string and being careful not to drop the object, transfer the metal object from the hot bath to the cup with water. Cover the cup quickly and stir.

Step 8: – Using the thermometer in the calorimeter, measure the highest temperature reached by the water in the cup after you drop the object.

Step 9: – You might have to replicate the experiment.

2. Food value in food The goal of this mini experiment is to calculate the number of Calories, or Kcal, in different food products using the energy values of different food ingredients–carbs, fats and protein.

Step 1: – Obtain a food product labels.

Step 2: – Write down the name of the product in the table below.

Step 3: – Write down the mass of a serving in the table below.

Step 4: – List the grams of carbohydrates, fats and protein in your product.

Step 5: – calculate the number of Calories (kcal) for each food type in a serving. The accepted energy values of carbohydrates, fats and proteins are 4, 9 and 4 Cal/g.

Step 6: – Calculate the total number of calories in a serving and compare the value with the one in the food label.

STUDENT INFO

Name: ________________________ Date: ______

Pre-lab Questions

Specific heat and food

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1. What is the formula to calculate the energy needed to warm up a metal? Explain the meaning of each variable.

2. The specific heat of Al is 0.215 cal/g/°C whereas the one for brass is 0.09 cal/g/°C. Explain the implications.

3. How many calories are absorbed by a 45.2g piece of aluminum (C_e =0.215 cal/g/°C) if its temperature rises from 10°C to 40°C.

4. What is the difference between cal and Cal?

5. A pepperoni pizza slice contains 10g of fat (9kcal/g), 36g of carbs (4kcal/g) and 14 g of protein (4kcal/g), where the caloric values are indicated in parenthesis. What is the total caloric intake of the slice?

STUDENT INFO	
Name: ______________________	Date: ______

Results
EXPERIMENT

Specific heat and food

1. Specific heat of a metal

1	Mass of the metal, m_{metal} (g)	________
2	Mass of the calorimeter (g)	________
3	Mass of the calorimeter + water (g)	________
3 – 2	Mass of the water,m_{water} (g)	________
4	Temperature of boiling water (°C)	________
5	Initial temperature of water in calorimeter (°C)	________
6	Final temperature of water in calorimeter (°C)	________
6 – 5	Temperature change , ΔT (°C)	____________

Calculate the specify heat of the metal by means of the following formula in which $C_{e,water}$ is the specific heat of water (1cal/g/°C):

$$m_{metal}C_{e,metal} \times \Delta T + m_{water} \times C_{e,water} \times \Delta T = 0$$

$C_{e,metal} =$____________

2. Food value in food

Name of food product	______________
Mass of a serving (g)	______________
Mass of carbohydrate(g)	______________
Mass of fats(g)	______________
Mass of protein(g)	______________
Calories from carbohydrates (Cal, or Kcal)	______________
Calories from fat (Cal, or Kcal)	______________
Calories from protein (Cal, or Kcal)	______________

STUDENT INFO

Name: ______________________ Date: ______

Post-lab Questions

Specific heat and food

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1. What percentage of the total calories in your food product is coming from fats?

2. What percentage of the total calories in your food product is coming from carbs?