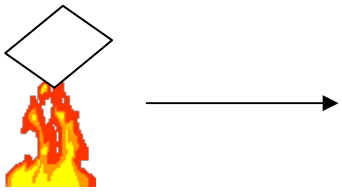
Calorimetry & thermodynamics

INTRODUCTION

Answer the following True/False questions – we will go over them in class.

a.	The piece of paper this page is printed on contains $E_{thermal}$ and $E_{chemical}$
b.	During the process of photosynthesis E_{light} is converted to $E_{chemical}$
c.	A molecule of glucose contains $E_{chemical}$
d.	An exergonic reaction results in products that have more $E_{chemical}$ than the reactants.
e.	Energy can flow (be transferred) from one object to the next.
f.	One (science) calorie is equal to the amount of energy to raise 1gram of water 5^{o}C

The flame is going to burn up the paper - draw what the paper will look like afterwards.



Why does the paper look different after it has burned?

Did a chemical reaction occur? Was energy transferred?

Is there any energy in the paper before? What about in the ashes afterwards? Explain

Food Calorimetry: Measuring the energy in Food

In the following lab you are going to determine how much energy (or calories) is stored in the chemical bonds in various food samples. You are going to do this measuring how much energy is released when the chemical bonds in the food are broken.

Procedure:

Carry out the following procedure using a banana chip as the "food sample."

1. Pour 10 mL of tap water into a test tube.
2. Mount the test tube in a test tube clamp and place a thermometer in the test tube.
3. Measure the initial temperature of the water and record it in the table below.
4. Zero the balance. Measure the mass of the food item on a small square of aluminum foil and record the value in the table below (be as precise as possible). Try to obtain a sample such that its mass (along with the foil square) is between 1.0 and 1.5 grams. Don't forget to zero the balance BEFORE you put on the aluminum square – you want to include the aluminum square in your weight. This is the initial mass (M_i)
5. Hold the food with a pair of metal forceps.
6. Ignite the food by placing it in the flame of a Bunsen burner. (Be sure the Bunsen flame is not near the test tube of water).
7. As soon as possible after the food ignites, move the burning food beneath the test tube. The flame should touch the tube (and will likely cause the tube to blacken). Continue to hold the burning food under the test tube, repositioning it as necessary to keep the flame directly under the tube, until the flame goes out. **If the temperature of the water reaches 80°C, extinguish the flame prematurely.**
8. After the temperature of the water stops rising, record its final temperature in the table below.
9. Scrape any food residue from the forceps onto your square of aluminum foil. Measure the remaining mass of the food residue+foil and record it in the table below (be as precise as possible). This is the final mass (M_f)
10. Calculate the change in temperature and the mass of food burned by subtracting the initial values from the final values.

Food Item	Final Temp (T_f) (°C)	Initial Temp (T_i) (°C)	Change in Temp ($T_f - T_i$) (°C)	Initial Mass (M_i) (grams)	Final Mass (M_f) (grams)	Mass of food burned ($M_i - M_f$) (grams)
Banana chip						

Answer the following:

1. Where is the energy coming from to raise the temperature of the water in the test tube?

2. Draw a diagram showing the answers from 1 and 2. That is, sketch a cartoon showing the flow of energy as it is transformed and transferred during this experiment.

3. On your diagram label all the types of energy you can think of. At minimum, you should have $E_{chemical}$, $E_{thermal}$, E_{light}, E_{sound}.

   Add arrows between the energy types to show where the conversions happen. LABEL THEM CLEARLY – even explain!

4. Why was it important to keep the match or Bunsen burner away from the tube of water?

Calculating Calories:

We can use this food burning technique, where the energy released by the burning food is captured in water, to compare the amount of energy in different foods. Calories are a measure of energy. A calorie is defined as the amount of energy required to raise the temperature of 1 gram of water by 1°C.

1. To calculate the energy (calories) released by burning a food item, multiply the mass of the water used (1 mL = 1 g of water) by the change in temperature. This gives you the number of calories that were transferred to the water from the burning food sample.

   Change in temperature x Grams of water used = Number of calories released

   _____ x _____ = _____

2. To fairly compare the calories from one sample to another, we need to adjust this value for the amount of food burned. Determine the amount of food actually burned by subtracting the mass of the banana chip "after" from the mass of the banana chip "before."

   Mass of food before - Mass of food after = Mass of food burned

   _____ - _____ = _____

3. Take the calories calculated in step #1 and divide by the mass of food that was actually burned which you calculated in step #2. This gives you the number of calories released per gram of banana chip burned.

   Number of calories released. / Mass of food burned (g) = calories (c) per gram of food

   _____ / _____ = _____

4. Dietary calories (C) are actually kilocalories. To turn the calorie value you just calculated to dietary Calories (C), divide your calories (c) per gram of banana chip by 1000.

   calories (c) per gram of food / 1000 = Calories (C) per gram of food

   _____ / 1000 = _____

   Record this value for the banana chip in the table on the next page.

We are going to use this technique to compare the energy found in the following foods:

- Banana chip
- Corn chip
- Pecan or Walnut
- Honeycomb™ cereal
- Oyster cracker
- a wooden stick (toothpicks or a wooden applicator) - ok, not a food.

Before conducting this experiment, **predict** how the foods will compare in their stored $E_{chemical}$. List them in the order you think from greatest to least amount of energy.

MOST ENERGY ⟶ LEAST ENERGY

1. _____ 2_____3._____4._____5. _____

Explain your reasoning:

Measure the energy found in the foods listed in the table below by using the procedure you used previously. You can reuse your test tube but get fresh cool water for each measurement.

Calculate the Calories per gram by following the steps on page 4 and fill in the table below:

Food Item	Final Temp (T_f) (°C)	Initial Temp (T_i) (°C)	Change in Temp ($T_f - T_i$)	Initial Mass (M_i) (grams)	Final Mass (M_f) (grams)	Mass of food burned ($M_i - M_f$) (grams)	Calories (C) per gram
Banana chip							
Corn Chip							
ecan or Walnut							
neycomb cereal							
Cracker							
Stick							

Answer the following:

1. How do the foods compare in their Caloric content? Based on your data, rank them from highest to lowest Calories per gram.

   MOST ENERGY ⟶ LEAST ENERGY

   1_____ 2_____3._____4._____5. _____

   How do your actual results compare to your predictions?

2. What might explain any differences observed in the Caloric content of the different foods? That is, why did the honeycomb cereal have a different amount of Calories/gram than the pecan? Think about this at a molecular level!

Comparing Results to Nutritional Information

Let's compare the energy content you have measured with the caloric values listed in the nutritional information for these foods. We could find this data on the packaging or in a nutritional database such as: https://www.calorie-charts.net/search.aspx

Complete the following table to compare your experimentally determined Caloric values and the nutritional values:

Food Item	**Calories/gram (Experimental) (from page 5)**	**Calories/gram (Nutritional) (from database)**
Banana Chip		5.19 Cal/g
Corn Chip		5.39 Cal/g
Pecan or Walnut		6.91 Cal/g
Honeycomb Cereal		3.95 Cal/g
Cracker		4.34 Cal/g

Analysis of Results

1. How do these five foods compare in their Caloric content according to the **nutritional information from the database**? Rank them from highest to lowest.

   MOST ENERGY ⟶ LEAST ENERGY

   1. _____ 2_____3._____4._____5. _____

   How do your actual results compare to your predictions?

2. How does this ranking compare to what you determined experimentally?

3. Consider the highest Calorie foods tested versus the lowest Calorie foods tested. What do you think might explain the difference in their Caloric content? Do you have any evidence to support your idea?

4. Would you classify the combustion of the food items as an exergonic or endergonic reaction? What is your evidence?

5. Draw an energy diagram for the combustion of food. Do the products have more or less energy than the reactants?

6a. What is the First Law of Thermodynamics?

6b. How does this experiment demonstrate the “First Law of Thermodynamics?”

7a. What is the Second Law of Thermodynamics>

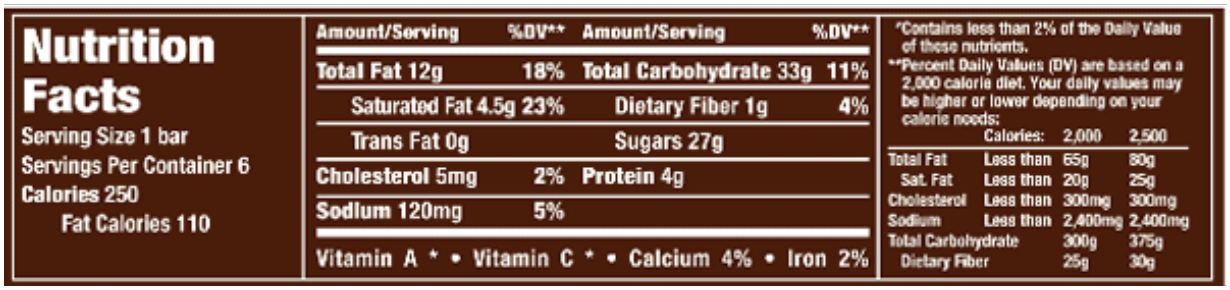
7b. How does this experiment demonstrate the “Second Law of Thermodynamics

Applications: Calories, Diet, and Biology

Today the amount of Calories in individual food items is determined by measuring the amounts of carbohydrates, fats and protein in the food and then multiplying this by the number of calories per gram in each of these types of molecules.

Proteins and carbohydrates have approximately 4 Calories per gram, and fats have approximately 9 Calories per gram.

	Calories/gram
Carbohydrates	**4**
Protein	**4**
Fat	**9**



Nutrition Facts

Serving Size 1 bar
Servings Per Container 6
Calories 250
Fat Calories 110

Amount/Serving	%DV**	Amount/Serving	%DV**
Total Fat 12g	18%	Total Carbohydrate 33g	11%
Saturated Fat 4.5g	23%	Dietary Fiber 1g	4%
Trans Fat 0g		Sugars 27g	
Cholesterol 5mg	2%	Protein 4g	
Sodium 120mg	5%		

Vitamin A * • Vitamin C * • Calcium 4% • Iron 2%

*Contains less than 2% of the Daily Value of these nutrients.
**Percent Daily Values (DV) are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

Calories:		2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

This is the nutritional label from a Snickers bar.
Using the information that fats contain 9 Calories/g, carbs contain 4 Calories/g and protein contains 4 Calories/g we can calculate the total Calories in one bar:

What is the total mass in grams of fat molecules in a Snickers bar?

How many calories in this amount of fat?

What is the total mass in grams of carbohydrate molecules in a Snickers bar?

How many Calories in this amount of carbohydrate?

What is the total mass in grams of protein in a Snickers bar?

How many Calories in this amount of protein?

Add together the Calories from fat + carbs + protein. Does your final answer agree with the Calories in a whole snickers bar?

"Burning Food" in Biological Systems

In this experiment, you have oxidized the food and converted its stored energy to thermal energy by actually burning it. In the human body, food is enzymatically oxidized (you have probably heard of people refer to us "burning our food") by a process called **cellular respiration**. In this process, the food is oxidized more slowly, and while some of the energy is released as heat, some of it is captured and transferred via coupled reactions to other energy-storing molecules such as ATP.

It is estimated that, at maximum, cellular respiration transfers about 37% of the energy of food to ATP and the rest is lost as heat.

This means for every 100 Calories of food that you burn in your body, you make 37 calories worth of ATP molecules, that your body needs to survive, and 63 calories of energy is lost from your body as heat.

1. Suppose that cellular respiration were much more efficient. Supposed that 75% of the calories in food were transferred to ATP. If your cells' need for ATP remained the same, how would this change your daily caloric requirements? Would you need to eat more Calories or less?

2. Suppose that cellular respiration only transferred 5% of the energy to ATP. If your cells' need for ATP remained the same, how would this change your daily caloric requirements? Would you need to eat more Calories or less to make the ATP you need?

3. Certain drugs and illnesses <u>decrease</u> the efficiency of cellular respiration. How would these conditions affect the organism's body temperature, assuming that the body still required the same amount of ATP molecules to be made daily? How would these conditions affect the organism's use of food and stored energy reserves?

Calorimetry of Wood

1. Based on your results, what is the Calorie content per gram of wood?

2. If there were a nutritional label on a package of wooden sticks (for example, popsicle sticks, or toothpicks), it would read "Calories 0." How might you explain the discrepancy between the label and your results?

The nutrition facts of All Bran Cereal is shown below. Use the same process that you did for the snickers bar to calculate the number of Calories per serving for All Bran cereal:

Nutrition Facts	
Serving Size	1/2 cup (31 g; 1.1 oz)
Servings per package	About 17
Amount per Serving	
Total Fat	1 gram
Total Carbohydrate	24 grams
Fiber	11 grams
Sugars	6 grams
Other carbohydrates	7 grams
Protein	4 grams

The Calories per serving listed on the box are **80**. How does this compare with your calculation?

How can you explain any difference observed?

Get Ready for the Lab Quiz!!

Next week there will be a 20 point lab quiz going over the concepts from this week's lab.

On this sheet make a list of the concepts that were covered in lab today that you think will be asked about in the lab quiz. Be more specific than "Energy" and "Calories"

Use your list of concepts above to predict at least four questions that you think might be asked in the quiz and what your instructor will be looking for in a correct answer.

Don't Forget:

There is a practice quiz on Canvas that you can take as many times as you want so you can get an idea of what kinds of questions will be on the quiz.

Metric Exit Ticket (2pts)

How many grams of sodium are there in one serving of Snickers bar? (you will need information from page 9 to calculate this)

There are 6.91 Calories / gram of Pecans. How many Calories would you have eaten if you ate this whole bag of Pecans? It might be helpful to know that 1 Kg = 2.2lb