Poopy Power
Regents Chemistry

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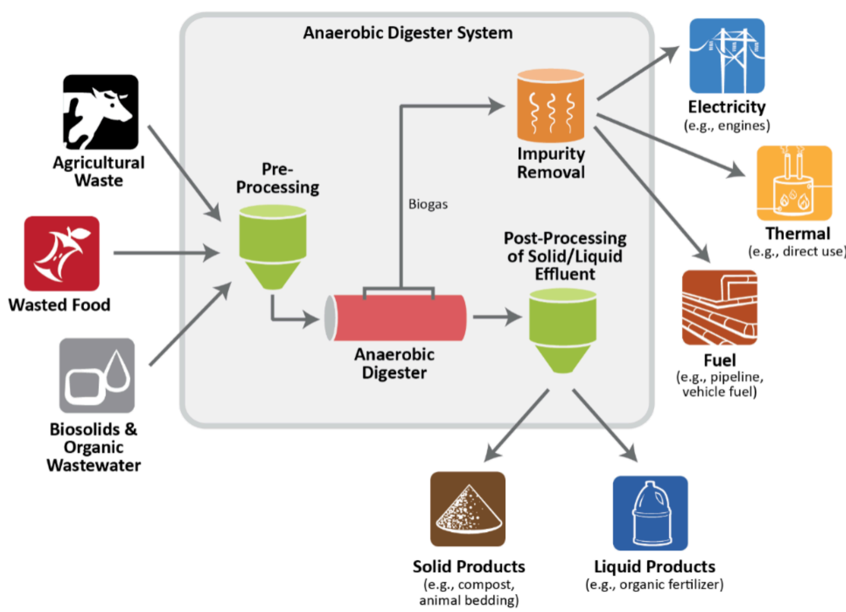
Name: ___________________________ Class Section: ____

Background

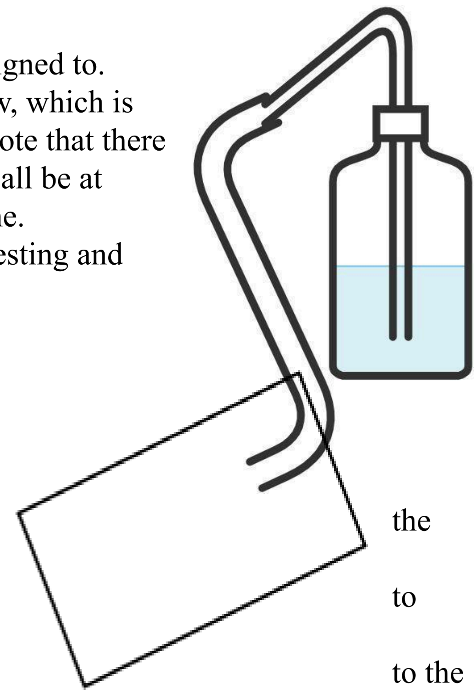
Anaerobic digestion occurs when microbes break down organic materials in the absence of oxygen. When the organic matter decomposes, it is converted to biogas, which contains methane that can be used as a fuel source, just like propane. Anaerobic digestion happens in nature all the time. The same process happens in cow stomachs, which causes them to release methane gas. Anaerobic digestion also happens at the bottom of swamps and lakes where organic wastes such as dead leaves and plants slowly break down. The biogas that is released from swamps is often called "swamp gas." Anaerobic digestion is used by engineers all over the world to break down complicated organic wastes such as garbage, and food, yard and human waste. Not only does anaerobic digestion create biogas, but it also releases all of the nutrients in the organic "waste" making them available again as raw resources for new plant growth. Anaerobic digestion is a form of *Resource Recovery* – it can help recover energy and nutrients from food waste.

The United Nations Framework Convention of Climate Change estimates that the global warming potential of methane gas is 21 times more than that of carbon dioxide over a 100-year period. It is imperative that we can create the infrastructure for the dairy and beef industries to harness the potential energy of methane to be used for electricity and heat to reduce the greenhouse gas effect of the gases released from the dairy and beef industries. During the combustion of one mole of methane, one mole of carbon dioxide is produced. Therefore, the greenhouse gas effect is reduced by 21 times by combusting the methane. On top if this benefit, the amount of energy that can be harnessed from this combustion is staggering, as you will see in your analysis of this experiment.



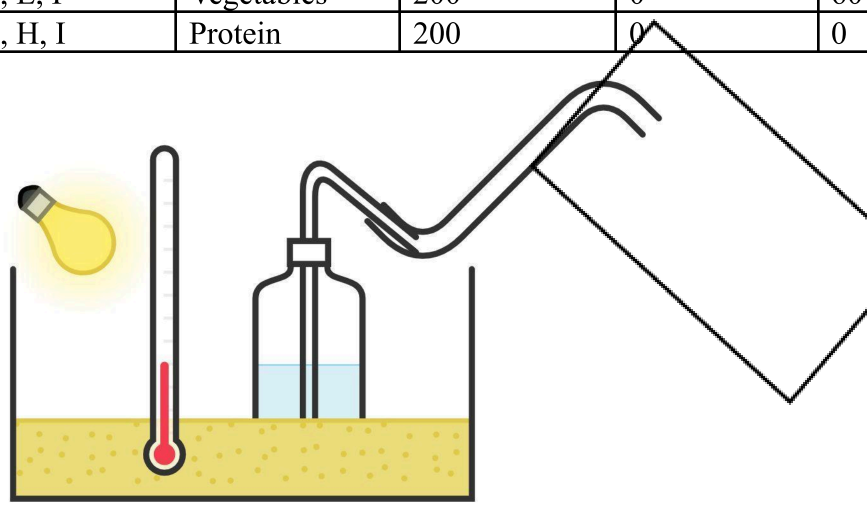
Procedure

1. Go to the station you and your partner have been assigned to. This station corresponds to a recipe in the table below, which is also taped to the lab bench you will be working at. Note that there are multiple groups using the same recipes. You will all be at different lab benches, so don't fight over the same one.
2. Label the bottle to indicate which substrate you are testing and your initials:
    a. Control
    b. Starch
    c. Vegetables
    d. Protein
3. Put on gloves! Transfer all of the ingredients indicated according to the recipe at your Station to the bottle. Be careful not to spill the effluent.
4. Close the plastic bottle tightly and attach the tubing to the spout. Attach the other end of the tubing to the gas sampling bag. Your setup should now look like the diagram to the right.



5. Place the bottle in the glass tank indicated to you. Adjust the bottle so that it is partially buried in the sand to help maintain a temperature above the ambient temperature.
6. Wash your hands with soap and water after handling the effluent and manure.
7. Over the course of the next five school days, monitor the bag so that it does not get too full and explode. If you need to replace the bag, shut the valve on the gas sampling bag (righty-tighty) and pinch the tubing tightly shut so no oxygen enters the system. Then pull the sampling bag away from the tubing, while keeping it pinched the whole time, and replace it with an empty sampling bag. Then…
8. Label the full gas bag. At the end of the week, determine the volume of the gas by water displacement. Enter your results on a Google Sheet found here: https://goo.gl/xLSeYM
    a. We will also collect data on the percentage of methane in the gas.
    b. We will also collect data on the temperature of the tanks throughout the week.

Station	**Substance**	**mL of Effluent**	**Grams of "Starch"**	**Grams of "Vegetables"**	**Grams of "Protein"**
(Control)	Control	200	0	0	0
A, B, C	Starch	200	60	0	0
D, E, F	Vegetables	200	0	60	0
G, H, I	Protein	200	0	0	60



Your tank should look like this at the end, except you will have more bottles in one tank. Make sure the bags are outside so they don't block the heat from the light.

Data

Table 1 – Qualitative observations of appearance, sampling bag size, odor, etc.

Date	**Observations**
Monday	
Tuesday	
Wednesday	
Thursday	
Friday	

Table 2 – Daily Temperature (°C) Readings

Date	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Average**
Temperature (°C)						

Table 3 – Control Digester

*Fill this out at the end of the week

	Bag 1 Vol. (L)	Bag 1 Methane %	Bag 2 Vol. (L)	Bag 2 Methane %	Total Volume (L)	Methane Volume (L)	Overall Methane %
2nd Per							
4th Per							
5th Per							

Table 4 – Individual Experiment Results

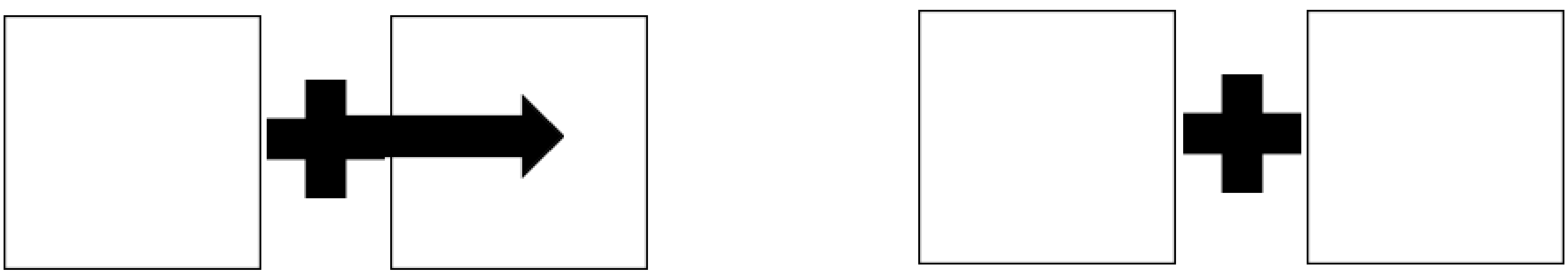
Group Letter	**Substance**	**Bag 1 Volume (L)**	**Bag 1 Methane %**	**Bag 2 Volume (L)**	**Bag 2 Methane %**	**Total Volume (L)**	**Methane Volume (L)**	**Overall Methane %**

Table 5 – Overall Results of All Chemistry Periods
*Fill this out after the week is over. Calculate the last two columns on your own.

	Average Total Volume (L)	**Average Methane Volume (L)**	**Average Methane %**	**Moles of Methane at STP**	**Maximum kJ of Heat Possible**	**kJ per gram of food-waste**
Control						
Starch						
Vegetables						
Protein						
AVERAGE						

In the space below, balance the reaction for the combustion of methane, CH_4, and draw a particle diagram for each reactant and product. Incorporate the heat produced by the reaction in your particle diagrams for the products.

_____CH_4 + _____O_2 □ _____CO_2 + _____H_2O + ________kJ



Analysis

1. Were there any issues with your individual digester experiment? How did you troubleshoot them?

2. What was used as the control for this experiment? What was the purpose of including a control?

3. What was the reason for setting up multiple digesters including the same type of food-waste?

4.
    a. Which type of food-waste produced the highest total volume of biogas?

    b. Which type of food-waste produced the highest percentage of methane in the biogas?

    c. Using Table 5, what type of food-waste would you attempt to primarily include in your digester if you were a small-scale farmer? Use specific data from Table 5 to justify your conclusion.

5. What is the advantage of including food-waste in a manure digester instead of just using manure to produce the biogas?

6. To support combustion, you typically need a sample of biogas with a methane concentration over 50%. Which of the types of food-waste would be able to support combustion? What types of local businesses/organizations would a farmer seek out to form a partnership with to obtain these types of food-waste?

Proportional Applications

1. How much heat would be released from combusting 3 moles of methane?

2.
    a. How much heat would be released from combusting 50 liters of methane? (2-step)

    b. Some cars run on using hydrogen as a fuel according to the following reaction:
    $2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g) + 483.6\ kJ$
    Calculate the amount of heat released from combusting 50 liters of hydrogen gas?

    c. Some communities have started collecting methane from their landfills or other sources to power vehicles using compressed natural gas (CNG). Compare your results in 2a and 2b to determine whether a hydrogen-powered or CNG-powered vehicle would be more efficient per liter of fuel used?

    d. Which type of vehicle would result in more greenhouse gases being released?

    e. Overall, suggest which type of vehicle would be more “environmentally friendly”. Remember that methane is a much worse greenhouse gas than carbon dioxide.

    f. What are some disadvantages to each type of vehicle?

3.

a. Re-identify the type of food-waste that would be able to produce the most amount of energy (kJ). How many kJ could it produce?

Food-waste = __________________ Maximum kJ = __________

b. We used 60g of this food-waste. Determine the ratio of kJ to g.

Ratio = ____________kJ/g

In other words: "1 gram of _____________(food-waste) can produce ________kJ"

4.

a. Convert the maximum kJ identified in Question 3a to J.

________________J

b. A watt is a unit of power. 1 watt is equivalent to 1J/s. How many Joules does a 60-watt lightbulb consume over the course of 10 seconds?

c. How many seconds could a 60-watt bulb be powered for using the energy in 4a?

d. How many seconds could a 12-watt LED bulb be powered for using the same amount of energy?

5. During the 5-day period from March 11 to March 15, 2019, 194-pounds of food-waste was collected from the Canton Middle and High Schools.

a. How many pounds is this per day?

b. How many grams is this per day?

c. How many grams is this per 180-day school year?

6.

a. According to Table 5, what is the average kJ of heat produced by all of the food-waste?

b. Convert this amount of heat to J.

c. We used 60g of food-waste. How many J per g of food-waste is produced?

d. Using your answers from 5c and 6c, how many J of heat could be produced from all of the food waste produced by our school in one school year?

e. How many seconds could a 12-watt LED bulb be powered for using this total J? How many months is this?

f. How many grams of water could be raised from room temperature (20°C) to the boiling point using the total amount of J produced in Question 6d?

g. There are 3785g of water in 1 gallon. Convert Question 6f to gallons.

7.

a. Using the average volume of methane produced, which you calculated in Table 5, calculate how many liters of methane would be produced per gram of food-waste. We used 60g of food-waste.

b. Using your answer from Question 5c and 7a calculate how many liters of methane would be produced in a school year.

8. Go to www.co2levels.org. Use the menu in the top right corner to examine the graphs of CH_4 and CO_2. When viewing each graph, hit the logo in the top left corner to insert the temperature record. Examine the timescale. Is this cause for alarm? Justify your reponse. Google "NASA climate time machine" to view more evidence you can use in your justification.

9. When burning CH_4, CO_2 is released, which is also a greenhouse gas. Justify why anaerobic digesters are seen as environmentally friendly when combusting the gas made from it (CH_4) still produces a greenhouse gas. Refer to this lab's Background.

10. Explain at least three Principles of Green Chemistry that are addressed by the use of anaerobic digesters at farms.

11. Explain some issues that would prohibit certain farmers from being able to install and make use of anaerobic digesters at their farms. What are some ways that these issues could potentially be addressed?

12. Why isn’t oxygen a greenhouse gas? In your response, explain what properties make a greenhouse gas a greenhouse gas. This response might require research.