Matter & Energy Unit – Week 2 Labwork

Name: ____ Hour________Date: ____________________

Date Packet is due:_______________ Why late? ____Score: _______
Day of Week Date If your project was late, describe why

Driving Question: What happens to molecules during combustion?

Anchoring Phenomenon: When something burns (or is *combusted*), it seems like that substance disappears. What happens to the molecules of a substance when it is combusted?

Deeper Questions

1. What happens to the atoms in molecules during combustion?
2. What happens to energy in molecules during combustion?
3. How does what we can observe during combustion (e.g., heat & light) relate to the changes happening at the molecular level?

Weekly Schedule

Part 1: Introduction
- Initial Ideas
- Data Dive – Changing O_2 & CO_2
- Discussion & Developing Explanations

Part 2: Core Ideas
- Nutshell Video
- Core Ideas
- Revisions of Part 1 Explanations

Part 3: Investigation
- Molecular Modeling
- Revisions of Part 1 Explanations
- Optional: Voluntary Quiz

Part 4: Review & Assessment
- Critiquing Ideas
- Assessment

Part 5: Life Connections
- Weekly Recap
- Life Connections

NGSS Standards:
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Semester Schedule

Matter & Energy
Week 1: What happens when something burns?
Week 2: What happens to molecules during burning?
Week 3: Unit Assessment

Animals
Week 1: What are animal cells and food made from?
Week 2: What happens to food when it is consumed?
Week 3: What happens inside animal cells?
Week 4: Unit Assessment

Plants
Week 1: What are plant cells made from?
Week 2: How do plants get their food?
Week 3: What happens inside plant cells?
Week 4: Unit Assessment

Ecosystems
Week 1: How do living organisms affect each other?
Week 2: Tracing Matter
Week 3: Global Biodiversity
Week 4: Humans & Biodiversity

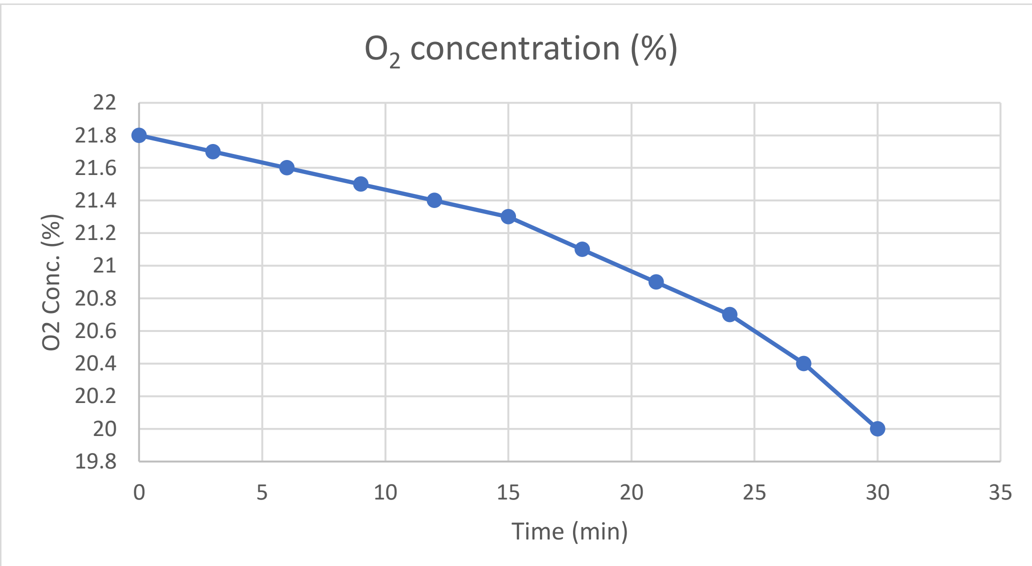
Part 1: Introduction

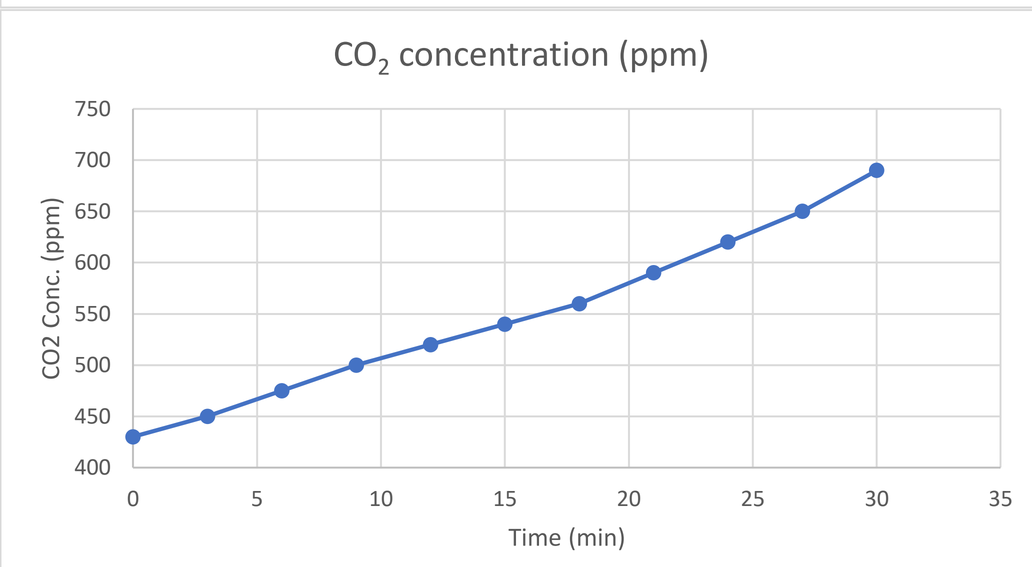
Overview: In this activity, your group will review data from two different scenarios in order to identify patterns and trends that you will use to develop an explanatory model. You will then compare your observations and explanations to those of other groups in order to check your accuracy and refine your explanatory model.

<u>Data Dive: Lost Lumber</u>

Directions: Begin by reading the hypothetical scenario below. Then look at the data provided below. Use this information to answer the questions on the following page. If you are unsure about how to interpret the data, work with your group and seek help from your instructor if necessary. Your instructor will decide how you should record your answers (e.g., whiteboard, digital document, scratch paper, etc.).

Introduction: A class is conducting an experiment. They ignited a petri dish of ethanol inside of a sealed box. The box contained sensors that recorded changes in the amount of oxygen (O_2) and carbon dioxide (CO_2) in the air within the box. These changes were recorded in 3-minute intervals The data is shown below.





How to read these graphs: The top graph shows changes in the oxygen (O_2) concentration. The bottom graph shows changes in carbon dioxide (CO_2) concentration.

The horizontal x-axis for each graph shows the change in time (from 0 min on the left to 30 min on the right). The vertical y-axis for each graph shows the change in the amount of each gas (O_2 or CO_2). O_2 is measured as a percent of the total volume of air. CO_2 is measured in parts per million (ppm).

To determine trends in each graph, match each point on each line with where it lines up on the x- and y-axis. For example, at three minutes, O_2 was at 21.7% and CO_2 was at 450 ppm.

1. **Begin by individually attempting to make sense of this image**. What trends or patterns do you notice? How does this relate to any prior knowledge or experience that you have?

2. **Next, work in your teams to discuss your ideas**. Where do you agree? Where do you disagree? Can you use this data to reach agreement? Do others have prior knowledge/experience that could help?

3. **Based on this data, what is one conclusion that would be supported by this data?**
   a. How is this conclusion supported by this data?
   b. What specifically suggests that your claim is accurate?

4. **Based on this data, what is a second conclusion that would be supported by this data?**
   a. How is this conclusion supported by this data?
   b. What specifically suggests that your claim is accurate?

5. **Decide whether you agree or disagree with each of the following.**
   A) "Some of the oxygen atoms were turned into carbon atoms to make CO_2." AGREE/DISAGREE
   B) "The oxygen atoms were destroyed in the fire; CO_2 came from the ethanol." AGREE/DISAGREE
   C) "The atoms in oxygen and ethanol were rearranged to make CO_2." AGREE/DISAGREE

6. **Work in your small groups to discuss your ideas.** Try to identify how your ideas are similar or different. Then work as a team to decide as a group whether each statement is correct or incorrect (and why). Be prepared to present your ideas to the class.

7. **Why do you think that levels of O_2 and CO_2 changed in these ways during combustion**? How can we explain these outcomes using what we know about combustion?

   ____

   ____

8. **Why did the ethanol eventually stop burning?** Why does sealing the container "snuff out" the flame?

   ____

   ____

9. **Sometimes water can be used to put out a fire. Both ethanol and water are clear liquids. Why does ethanol burn but water does not?**

   ____

   ____

Be prepared to discuss your ideas with other groups and/or as a class. If you have prior experiences or knowledge that can be helpful, please share this with when you are discussing your ideas.

Part 2: Core Ideas

Overview: In this activity, you will begin by watching a short video. This will help to clarify some of the questions you may have had yesterday.

Next, you will look at a short slideshow presentation. This will provide you with core ideas that will help you clarify your initial ideas. Your instructor will decide on how to implement this portion depending on your previous experience and capabilities with this content.

You will then work in small teams to answer the questions listed below. You should take notes in a notebook, on a dry erase board, or on scratch paper so that you are prepared to deliver your responses during the class discussion that will follow. *Note: your instructor may assign specific questions to your group if time is limited.*

Nutshell Video: https://study.com/academy/lesson/how-chemical-reactions-form-new-products.html

Core Ideas Presentation: https://bit.ly/WUHSBioMEW2

Driving Questions:

1. How can molecules contain energy if matter and energy are separate things?
2. What makes something a "fuel"? What primarily determines the amount of energy contained within a molecule?
3. What do gasoline, ethanol, and sugar molecules have in common that make them "high energy" molecules?
4. Can we directly use the energy contained within high energy molecules? What has to happen in order for this energy to become available for use?
5. When we see flames during combustion, what is it that we're actually seeing?
6. Both ethanol and water are clear liquids. Why does ethanol burn but water does not?
7. Explain combustion in a way that specifically addresses our "three rules" of matter and energy:
   1) All matter is made of atoms. 2) Atoms lasts forever. 3) Energy lasts for forever.

Revising Explanations: Return to your original explanation that you created at the end of Part 1. Based on this new information, how would you now respond to this question?

Why do levels of O_2 and CO_2 change during combustion?

____

____

Why did the ethanol eventually stop burning? Why does sealing the container "snuff out" the flame?

____

____

Both ethanol and water are clear liquids. Why does ethanol burn but water does not?

____

____

Part 3: Investigation

Overview: In this activity, you will be using Play-doh to create models of key molecules in biology.

Directions: Begin by answering the pre-investigation questions below. Then use the instructions on the following page to create each of your molecules out of Play-doh. Conclude by answering the post-investigation questions on this page. (*Note: your instructor may ask you to record your answers to questions using a different format, such as a whiteboard or online document*).

Pre-Investigation Questions: Answer these questions individually and in small groups before creating your Play-doh molecules. Your instructor will determine if/where you should record your answers (e.g., whiteboard, scratch paper, etc.). Your instructor may choose to assign specific questions to your group and/or may have you critique the responses of other groups for accuracy.

1. What is the difference between *matter* and *energy*? Provide examples of each in your response.
2. Can *matter* ever disappear or cease to exist? Can *energy* ever disappear or cease to exist?
3. What is an *atom*? Explain how *atoms* are different from *molecules*.
4. Carbon, oxygen, and hydrogen are different *elements*. What is an *element*?
5. Could a carbon atom become an oxygen atom through a process like combustion? Explain.
6. Can a molecule (which is *matter*) store *energy*? Explain.
7. Is it possible for the atoms found in fuel (like ethanol) to change into energy? Explain
8. Could atoms in a solid or liquid molecule be rearranged to form a gas molecule? Explain.
9. How are the carbon dioxide (CO_2) and water (H_2O) molecules that are released during combustion related to the molecules in the fuel and oxygen?
10. Record your answer below: **What do you think happens to the atoms in a combusted substance?**

I think…____

____

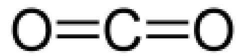
Creating Your Play-Doh Molecules: Use the instructions on the next page to create each of your molecules. Use your molecules as *scientific models* to help you improve and revise your answers to the questions above. In science, *models* are tools that help us clarify our thinking and make more accurate predictions. Models can be pictures, examples, scale models, or anything that helps us reason more accurately about a concept.

Remember the following "rules" for energy and matter:

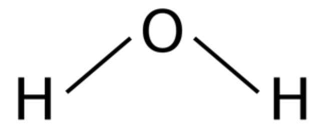
- **All solids, liquids, and gases are made of tiny particles called atoms**. Multiple atoms can bond together to form molecules (*e.g., water molecules consist of 1 oxygen atom & 2 hydrogen atoms*).
- In biology, **atoms last forever**. Atoms cannot be created or destroyed (*e.g., a carbon atom is always a carbon atom*). Atoms found on molecules can be rearranged to form new molecules.
- In biology, **energy lasts forever**. Energy cannot be created or destroyed. Energy can exist as light, heat, motion, or as chemical energy stored in the bonds of molecules. Energy in one form can be transferred into a different form (*e.g., light energy can be transformed into heat energy*).

1) To create your molecules, you will need the following:

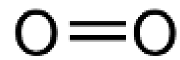
- **For carbon dioxide (CO_2)**
  - Two balls of the same color to represent oxygen atoms
  - One ball of a different color to represent a carbon atom



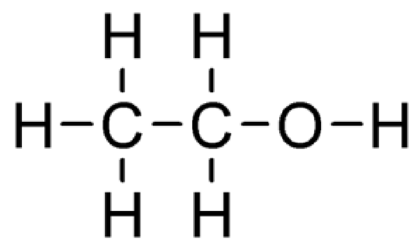
- **For water (H_2O)**
  - Two balls of a third color to represent hydrogen atoms
  - One ball of a different color to represent an oxygen atom (use the same color for oxygen as you did for carbon dioxide)



- **For oxygen (O_2)**
  - Two balls of the same color to represent oxygen atoms (use the same color for oxygen as you did for carbon dioxide).



- **For an ethanol molecule (C_2H_5OH)**
  - Using the same color as you used previously for oxygen, create one ball of that color for the oxygen molecule
  - Using the same color as you used previously for carbon, create two balls of that color for the carbon atoms
  - Using the same color as you used previously for hydrogen, create six balls of that color for the hydrogen atoms
  - *Hint: all carbon atoms should have 4 toothpicks attached. All oxygen atoms should have 2 toothpicks attached. .*



2) Using the pictures of each molecule as a guide, create each molecule out of the Play-doh atoms that you created. Use the toothpicks to represent the bonds between each atom in the molecule.

- Mark any **high energy bonds (C-C and C-H)** with a twist tie, piece of tape, string, or other physical marker (as determined by your instructor).

3) Based on the core ideas from this week, explain how each of these molecules relates to what happens when a substance is combusted.

When you think you are finished, **<u>raise your hand and show your instructor</u>**. While you are waiting for their approval and after they give their approval, complete the post-investigation questions on the next page.

This activity was successfully completed ____ (*instructor signature*)

Post- Investigation Questions: Answer these questions after creating your Play-doh molecules. Make a mental note of how your thinking about these questions changed after creating your molecular models.

1. **Based on our core ideas for this week, what do we know happens to most of the atoms in a substance when it is combusted**?

   ____

   ____

2. **How many carbon dioxide (CO_2) and water (H_2O) molecules could be made if you rearranged *all* the atoms found in ethanol (C_2H_5OH) and oxygen (O_2)? Show your work belo**w.

3. A**re there any high-energy bonds (C-C or C-H) in ethanol ($C_6H_{12}O_6$) and/or oxygen (O_2**)? ________

   Are there any high-energy bonds (C-C or C-H) in carbon dioxide (CO_2) or water (H_2O)? ________

   How do you think that this relates to what we can observe during combustion? (*Note: your thinking may still be changing about this question. That's ok – provide the best answer you can).*

   ____

   ____

4. **What do you think happens to the atoms in fuel when it is combusted?** (*Note: your thinking may still be changing about this question. That's ok – provide the best answer you can at this time*).

   ____

   ____

5. **What do you think happens to the chemical energy in fuel when it is combusted?** (*Note: your thinking may still be changing about this question. That's ok – provide the best answer you can at this time*).

   ____

   ____

Part 4: Review & Assessment

Overview: you will begin by reviewing the driving questions below in your small groups. For each objective, rank it as a 1 (*completely unsure*), 2 (*somewhat unsure*), or 3 (*completely sure*) based on your comfort with that objective. Then work in teams to create responses to the questions (your instructor will determine if you will answer all the questions or only a portion).

After you have had time to create your responses, you will critique the responses of another group before coming together as a whole class. Be sure to use the "rules" for matter and energy as you do so. You will conclude by completing an assessment for this week's ideas.

Driving Questions

1. How can molecules contain energy if matter and energy are separate things?
2. What makes something a "fuel"? What primarily determines the amount of energy contained within a molecule?
3. What do gasoline, ethanol, and sugar molecules have in common that make them "high energy" molecules?
4. Can we directly use the energy contained within high energy molecules? What has to happen in order for this energy to become available for use?
5. When we see flames during combustion, what is it that we're actually seeing?
6. Both ethanol and water are clear liquids. Why does ethanol burn but water does not?
7. Explain combustion in a way that specifically addresses our "three rules" of matter and energy:
    a. All matter is made of atoms.
    b. Atoms lasts forever.
    c. Energy lasts for forever.

Remember the following "rules" for energy and matter:

- **All solids, liquids, and gases are made of tiny particles called atoms**. Multiple atoms can bond together to form molecules (*e.g., water molecules consist of 1 oxygen atom & 2 hydrogen atoms*).
- In biology, **atoms last forever**. Atoms cannot be created or destroyed (*e.g., a carbon atom is always a carbon atom*). If something gains mass, it gains atoms. If it loses mass, it loses atoms. Atoms found on molecules can be rearranged to form new molecules.
- In biology, **energy lasts forever**. Energy cannot be created or destroyed. Energy can exist as light, heat, motion, or as chemical energy stored in the bonds of molecules. Energy in one form can be transferred into a different form (*e.g., light energy can be transformed into heat energy*).

Part 5: Life Connections

Overview: For this activity, you will begin with a recap of the things that you learned in this packet. You will then have a discussion to see how this relates to your life in general. If time is limited, your instructor may decide to postpone some of these options.

<u>Weekly Recap (use a whiteboard, scratch paper, online document, etc.)</u>

1. Summarize everything that you have learned through this packet within your group. Try to identify the common themes, major ideas, and most important concepts from the content you have learned.
2. Is there anything that anyone still doesn't completely understand? Is there anything that anyone maybe disputes or disagrees with? Did anything seem particularly surprising or noteworthy?
3. What you think are the most important ideas and concepts that you have learned so far. Aim to have at least 5 or 6 ideas written down. It is ok to have more than this.

Overview: For this activity, you will begin with a recap of the things that you learned in this packet. You will then take part in one of two activities. If possible, you will interview a local professional whose work involves the ideas we discussed this week. If this is not possible you will take part in a separate activity. If time is limited, your instructor may decide to postpone some of these options.

<u>Combustion in our Community</u>

Adapted from Carbon TIME (carbontime.bscs.org). Used with permission.

Combustion of fossil fuels plays an important role in our society. The reaction produces heat that we use to make electricity, heat homes, cook, and much more. As we have seen from our study of the combustion of ethanol, combustion of hydrocarbons also produces carbon dioxide. The carbon dioxide is a greenhouse gas. This means that it can absorb and reflect heat energy in the earth's atmosphere. This can lead to changes in the earth's climate.

You will be invesitage the usefulness and the environmental impact of combustion of fossil fuels.

Gathering Information for your graphic

A. Fossil fuel combustion as a source of heat

Natural gas is a mixture of gases found underground in places where ancient plants and animals have decayed. It is a fossil fuel. It is about 95% methane (CH4) with small amounts of other gases such as ethane (C2H6) and propane (C3H8) mixed in. It is commonly used in home heating and cooking. It can also be used to heat dryers and water in homes. Your school labs may be equipped with natural gas outlets for Bunsen burners. Some power plants burn natural gas to produce electricity.

The main component in natural gas is methane, CH4. Like ethanol, it undergoes combustion.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Address the following questions in small groups. Your instructor will determine how to record your answers.

1. Explain the energy transformations involved in the combustion of methane. Why does this reaction and the combustion of other fossil fuels generate heat?
2. How is natural gas used in your home or school?
3. Are any other fuels burned in your home or school? List the fuel(s) and their uses.

B. Hidden uses of fossil fuels. How much of your electricity comes from fossil fuel combustion?
Most of the electricity used in this country is generated by burning a fossil fuel like coal or natural gas. The heat produced is used to turn water into steam that turns a turbine. The energy sources used to generate electricity vary widely from state to state.

What fuels and sources of energy are used in your state? Use the Energy Information Association website (https://www.eia.gov/state/) to complete the questions below.

1. Based on this website, what are the top 4 energy sources for your state?

_______________________________________ _______________________________________

_______________________________________ _______________________________________

2. Do any of these energy sources involve combustion? Circle any that do.

3. If time allows, you can learn more about how electricity is generated from steam produced by combustion at the following web sites:
   https://www.youtube.com/watch?v=ouWOhk1INjo
   https://en.wikipedia.org/wiki/Thermal_power_station

4. What are the advantages and drawbacks of using these nergy sources? Work in small groups to develop as many ideas as you can. Be prepared to discuss your ideas as a class. Use the space below to record similarities and differences across your ideas as a class. Using evidence, try to achieve consensus in areas where there may be disagreement.

Similarities	Differences

Matter & Energy Unit, Week 2 Assessment

Name: ____Hour______Date:________Score:________/___

Directions: A 3x5 notecard with *handwritten* notes can be used to guide your answers.

Background: A class was trying to determine what happens to ethanol when it combusts. The teacher asks, "What happens to the molecules in the ethanol as it is combusting?" Three students shared their ideas.

1. **Do you agree or disagree with what each student claims? Circle "Agree" or "Disagree" for each of the three claims below.**

a) Daryll: "The atoms in the molecules of ethanol are being destroyed." Agree / Disagree

b) Marisol: "The ethanol and oxygen molecules are being converted into energy." Agree / Disagree

c) Bai: "The atoms in ethanol & oxygen are reorganized into different kinds of molecules." Agree / Disagree

2. **Provide an explanation. Why did you agree or disagree with each student's claim?**

a)____

b)____

c)____

The teacher then asks, "What happens to the energy in the ethanol as it is combusting?" Three students shared their ideas.

3. **Do you agree or disagree with what each student claims? Circle "Agree" or "Disagree" for each of the three claims below.**

a) Daryll: "The chemical energy in the bonds of ethanol is changed to heat and light energy." Agree / Disagree

b) Marisol: "The ethanol and oxygen molecules are being converted into energy." Agree / Disagree

c) Bai: " Ethanol cannot contain energy because matter and energy are different things." Agree / Disagree

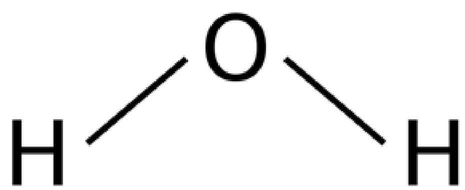
4. **Provide an explanation. Why did you agree or disagree with each student's claim?**

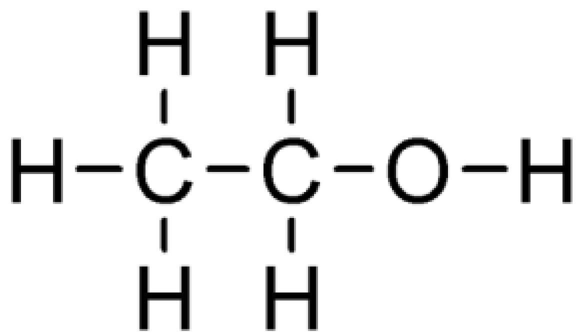
a)____

b)____

c)____

5. **Both ethanol and water are clear liquids. Why does ethanol burn but water does not? Be sure to include the following in your response: *molecules; energy chemical bond; C-C and C-H bonds, high-energy bonds.* You can also use the images below to support your responses.**





Appendix: Data Dive

Overview: Data Dives are exercises in which students are presented with data from experiments or scenarios and are asked to identify trends and develop explanatory models in a process that is very similar to what actual scientists do on a regular basis.

Directions: Students should consider the data in their assigned groups. They should work with their group members to make sense of the graph, identify trends, and try to determine the conclusions that can be drawn from that data. Students may struggle with this, especially in their first attempts and particularly if your students have limited experience reading graphs and data tables. It may be necessary for you to project the data onto a large screen and guide students by explaining the steps that you would use to make sense of what is being reported. This may be difficult; just like explaining the steps of tying your shoes can be challenging because you rarely have to think about it, it can be exceptionally challenging for someone who is scientifically literate to identify the thought processes that they use to make sense of data. It may be helpful to jot down your ideas in advance and have them ready prior to the start of this class.

Students are likely to struggle to varying extents. That is ok! Be sure to float from group to group to assist. Be sure to remind group members to help each other out. It might ideal to assign groups with a mix of abilities. Encouraging struggling students to work with their better-prepared peers, and conversely, encouraging high performing students to advance their abilities by working with individuals with different skill sets helps to prepare students for the kinds of situations they will encounter in their careers and personal lives.

Plan to allow for about 15-20 minutes to introduce the activity and review how to read a graph with your students. About a third to half of the class period should be reserved for allowing students to work in their individual groups. The remaining time should be reserved for intergroup or whole-class discussion so that students can engage in scientific debate and argumentation.

It would a good idea to remind students that the term *argumentation* is used differently between scientists and the general public. While argumentation generally has a negative connotation (such as a “heated argument”), argumentation among scientists is generally very good-natured and polite. The goal is not to “win” an argument but rather to expand the understanding of the phenomenon by all involved. Often scientists on opposing sides of an issue will both change their stance as a result of the improved understanding that results from engaging in argumentation. Similarly, students should not be trying to disprove each other or prove that they have the “right” answer. Rather, students should be examining the differences in their conclusions, the manner in which each conclusion was reached, and the similarities and agreements that exist among different conclusions.

Students may reach a conclusion that is not entirely supported by evidence. The temptation may be to point out errors in their reasoning. However, when students are struggling, they are also likely improving their abilities in evidence-based reasoning, which is one of the most important goals of this kind of instruction. Try to resist the urge to correct student errors; rather, try to probe their understanding and challenge them to re-examine the evidence to check the validity of their conclusions and the conclusions of other groups. Consider using the 9 Talk Moves (next page) to support productive classroom dialogue.

Remember – students should re-visit their explanations and models repeatedly over the course the week. If they don’t get it right on the first try, they will have more opportunities to do so.

Goals for Productive Discussions and Nine Talk Moves

Goal: Individual students share, expand and clarify their own thinking

1. Time to Think:

Partner Talk

Writing as Think Time

Wait Time

2. Say More: “Can you say more about that?” “What do you mean by that?” “Can you give an example?”

3. So, Are You Saying…?:
“So, let me see if I’ve got what you’re saying. Are you saying…?” (always leaving space for the original student to agree or disagree and say more)

Goal: Students listen carefully to one another

4. Who Can Rephrase or Repeat?

“Who can repeat what Javon just said or put it into their own words?” (After a partner talk) “What did your partner say?”

Goal: Students deepen their reasoning

5. Asking for Evidence or Reasoning:

“Why do you think that?” “What’s your evidence?” “How did you arrive at that conclusion?” “Is there anything in the text that made you think that?”

6. Challenge or Counterexample:

“Does it always work that way?” “How does that idea square with Sonia’s example?”
“What if it had been a copper cube instead?”

Goal: Students think with others

7. Agree/Disagree and Why?:

“Do you agree/disagree? (And why?)” “Are you saying the same thing as Jelya or something different, and if it’s different, how is it different?” “What do people think about what Vannia said?”
“Does anyone want to respond to that idea?”

8. Add On:

“Who can add onto the idea that Jamal is building?”
“Can anyone take that suggestion and push it a little further?”

9. Explaining What Someone Else Means:

“Who can explain what Aisha means when she says that?” “Who thinks they could explain in their words why Simon came up with that answer?” “Why do you think he said that?”

Source: https://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf

Appendix: Play-Doh Molecule Modeling

Introduction: this lab was designed to provide students with a kinesthetic and conceptual means of visualizing the fundamental components of the carbon cycle at the cellular and molecular level. While the overall premise of the lab is quite simple, the ideas inherent in this activity are quite complex. Often students are surprised to find that the products of cellular respiration are identical to the inputs of photosynthesis (and vice versa) despite having learned this the previous day. This lab is often the moment that these ideas finally 'click' with students.

Materials Needed: 3 colors of Play-doh per group; toothpicks; tape or string; lab activity sheet; pen/pencil

Tips: for the sake of time, it is easiest to have students determine the number of balls they need to make of each color and then make them in advance. Encourage students who feel more comfortable with this to take on the challenge of producing glucose while students who are less confident should try the simpler molecules. Be sure to point out that some molecules have double bonds, requiring two toothpicks instead of one.

Guidance for Learning: there are three main objectives for learning in this lab.

1. Students should be guided in observing that the atoms in glucose and O_2 are the same as those found in CO_2 and H_2O.

2. Students should be guided in observing that the atoms in glucose and oxygen can be rearranged to form carbon dioxide and water.

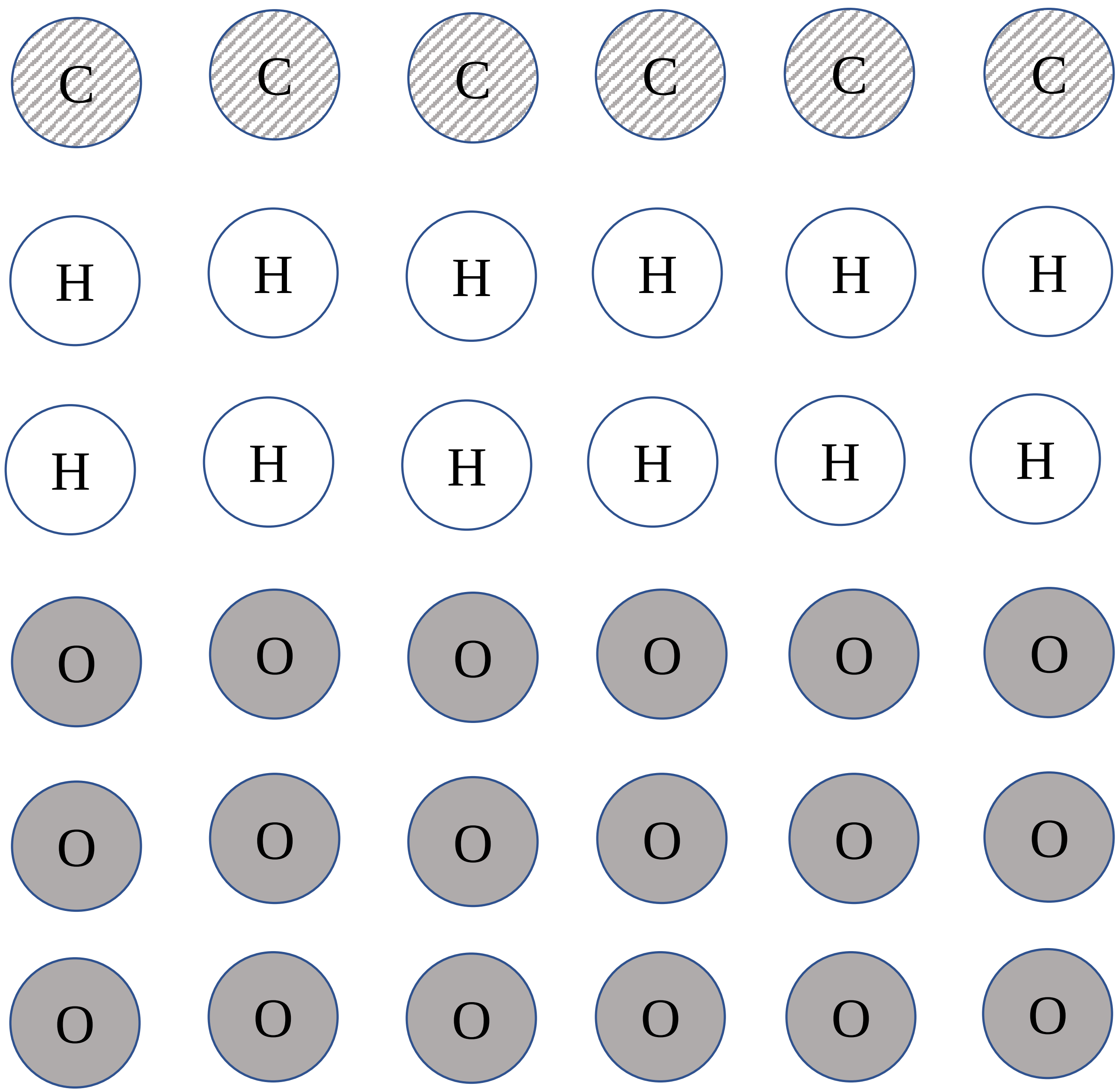
3. Students should observe that glucose is able to store large amounts of chemical energy (that was formerly light energy) in its high-energy C-C and C-H bonds.
    a. This should help students to understand that energy can be transferred from different forms (light energy to chemical bond energy) and that while matter and energy are separate entities, matter can store energy within chemical bonds.
    b. It may be helpful to explicitly ask students if CO_2 and H_2O have any high energy bonds, and when they observe they don't, ask them to reason about what happened to that energy.

Limitations: for the sake of time, each group can usually only produce one of each molecule. However, six molecules of CO_2 and six molecules of water can be produced from one molecule of glucose and six molecules of oxygen. It is important to point this out in order for students to understand that matter is conserved. Verbally acknowledging this is important for student clarification and comprehension.

Appendix: Molecule Modeling Alternatives

Introduction: if you need an alternative to Play-doh, a number of options are available.

- Usually high school chemistry courses have chemistry modeling kits on hand and may be able to loan them to you if you do not have access to these within your own program. You can also purchase these online (e.g. the Organic Chemistry Model Kit (239 Pieces) *via Amazon*).
- Loose change can also be an option if you have sufficient quantities, or you can have students bring in loose change in advance. Quarters can serve as carbon atoms, pennies can serve as oxygen atoms, and dimes can serve as hydrogen atoms. Students can draw molecular bonds between atoms on scratch paper or dry erase boards.
- You can also have students use the images of atoms below. You can either print this page and have students cut them out, or you can provide a digital space for students to arrange these atoms (such as in a Word or PowerPoint document, or on a shared Google doc).



Appendix: Review and Assessment

Introduction: In this section, we will discuss strategies to guide your students during review and assessment for a vocabulary-intensive unit.

While recent reforms to science education (as outlined by the NRC's *K12 Framework* and NGSS) minimize the emphasis on having students learn vocabulary, we have found that we cannot completely eliminate vocabulary from ecological instruction for a number of reasons. Most importantly, we have found that in order for students to sufficiently engage in reasoning and sense-making about ecological phenomena, they need to have an appropriate language with which to develop explanations and solutions.

However, in this curriculum, we view vocabulary as a *means to an end* and not as a central objective to the curriculum. In other words, we don't care very much whether students have memorized the definitions of terms, but whether they can accurately use those terms to describe and understand phenomena, and ultimately create evidence-based arguments, explanations, and solutions. We view vocabulary as part of a "sense-making toolkit" that enables students to organize their reasoning and argumentation.

As such, we recommend that you provide students with opportunities to practice mastering the vocabulary in this course while also recognizing that mastery of vocabulary is a secondary objective in these units. This means that assessing vocabulary can work as a formative assessment but is not ideal by itself as a summative assessment. The primary goal of this curriculum is to enable valid evidence-based reasoning and sense-making, and your summative assessments should reflect this.

There are a few strategies you might considering adopting to support these objectives:

- While multiple-choice assessments are provided in the weekly packets, we take the stance that these options should not be used by themselves as a final summative assessment.
    - You might consider assigning this as optional homework, allowing students to use a 3x5 card with handwritten notes, and/or assigning completion points in lieu of scores based on the percent correct.
- Teachers have also created hybrids of the multiple choice and short answer assessments, selecting some questions from each option. Their experiences suggest that the multiple-choice assessments help to prepare students for the more intellectually rigorous short answer questions.
- You might also consider having a space on a chalkboard/dry-erase board for publicly posting course vocabulary or hanging a large sheet of paper and adding vocabulary and definitions if students start to struggle.
- Teachers have also used vocabulary practice as an option for a bell-ringer activity, using options such as short, ungraded online quizzes to start class.

You as the instructor are best positioned to decide what will be most effective for your classroom. Feel free to use or disregard these suggestions as you see fit. However, we do strongly recommend that you avoid positioning memorization of vocabulary as one of the primary objectives of this course, and instead emphasize valid reasoning and sense-making about ecological phenomena as your top priority.