Lesson 4: Investigating and Explaining Ethanol Burning

Overview

Students investigate changes in mass and CO_2 concentration for burning ethanol. Then they explain results using molecular models and chemical equations to answer the Three Questions.

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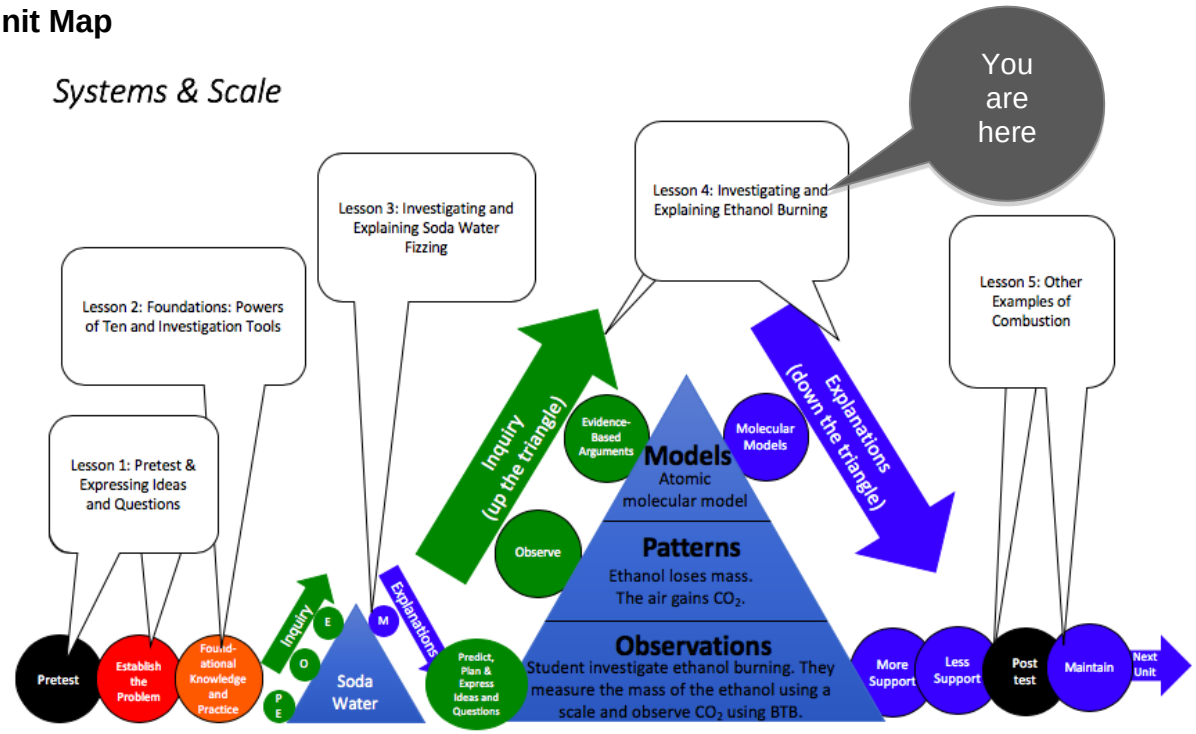
Guiding Question

What happens when ethanol burns?

Activities in this Lesson

- Activity 4.1: Predictions about Ethanol Burning (30 min)
- Activity 4.2: Observing Ethanol Burning (30 min)
- Activity 4.3: Evidence-Based Arguments about Ethanol Burning (50 min)
- Activity 4.4: Molecular Models for Ethanol Burning (50 min)
- Activity 4.5: Explaining Ethanol Burning (40 min)

Unit Map



Learning Goals

Target Performances

Activity	*Target Performance*
Lesson 4 – Investigating and Explaining Ethanol Burning (students as explainers)	
Activity 4.1: Predictions about Ethanol Burning (30 min)	Students develop hypotheses about how matter moves and changes and how energy changes when ethanol burns and make predictions about how they can use their investigation tools—digital balances and BTB—to detect movements and changes in matter.
Activity 4.2: Observing Ethanol Burning (30 min)	Students record data about changes in mass and BTB when ethanol burns and reach consensus about patterns in their data.
Activity 4.3: Evidence-Based Arguments about Ethanol Burning (50 min)	Students (a) use data from their investigations to develop evidence-based arguments about matter movements, matter changes, and energy changes when ethanol burns; and (b) identify unanswered questions about matter movement, matter change, and energy change that the data are insufficient to address.
Activity 4.4: Molecular Models for Ethanol Burning (50 min)	Students use molecular models to explain how carbon, oxygen, and hydrogen atoms are rearranged into new molecules during the oxidation of ethanol (the chemical change that happens when ethanol burns).
Activity 4.5: Explaining Ethanol Burning (40 min)	Students explain how matter moves and changes and how energy changes when ethanol burns (connecting macroscopic observations with atomic-molecular models and using the principles of conservation of matter and energy).

NGSS Performance Expectations

Middle School

- Structures and Properties of Matter. MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
- Chemical Reactions. MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- Chemical Reactions. MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

High School

- Chemical Reactions. 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.

- Chemical Reactions. HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Background Information

Three-dimensional Learning Progression

This lesson will be particularly helpful for students struggling to identify that mass of a burning fuel is lost to the air. Students observe a fuel source losing mass inside a chamber. They also observe an increase in CO_2 in the air using BTB. Students must explain where the carbon atoms in the CO_2 came from.

In this lesson the students return to the guiding question for the unit about what happens when ethanol burns. We will consistently focus on the idea that understanding carbon-transforming processes involves answering the Three Questions:

- **The Matter Movement Question: Where are molecules moving?** (How do molecules move to the location of the chemical change? How do molecules move away from the location of the chemical change?)
- **The Matter Change Question: How are atoms in molecules being rearranged into different molecules?** (What molecules are carbon atoms in before and after the chemical change? What other molecules are involved?)
- **The Energy Change Question: What is happening to energy? (**What forms of energy are involved? What energy transformations take place during the chemical change?)

Matter (the Matter Movement and Matter Change Questions). We find that even students who have learned how to balance chemical equations do not appreciate the meaning of the procedure:

- Conservation of atoms (the Matter Change Question): The numbers of atoms on the left and right side of a chemical equation have to be the same because they are THE SAME ATOMS! A chemical equation just shows how they are being rearranged into new molecules.
- Conservation of mass (the Matter Movement Question): ALL the mass of any material is in its atoms (and none of the mass is in the bonds, which are just attractive forces between atoms). So, the mass of the products is always the same as the mass of the reactants.

Energy (the Energy Change Question). Chemists, physicists, and biologists have many different conventions for describing and measuring chemical energy. We have a deeper explanation of the conventions used in *Carbon TIME* units and how they relate to conventions used in different scientific fields on the BSCS website in a document called "*Carbon TIME* Content Simplifications." Here are some key points:

- All bond energies are *negative* relative to individual atoms. So, during a chemical reaction, it always takes energy (the activation energy) to break bonds. Then, energy is released when new bonds are formed.
- Whether a chemical reaction releases energy or not depends on the total energy of the reactants, compared with the total energy of the products. So, energy is released when the total bond energy of the products is lower (i.e., more negative relative to individual atoms) than the energy of the reactants.
- Weak bonds (like C-C and C-H) generally have MORE chemical energy than strong bonds (like C=O). The energy of the stronger bonds is more negative relative to individual atoms.

- In systems like our atmosphere, where excess oxygen is always present, the most abundant sources of chemical energy are substances that release energy when they are oxidized (e.g., substances with C-C and C-H bonds).

Our research has consistently showed that these ideas are extremely difficult for students who have not formally studied chemistry. We therefore use the convention of twist ties to identify bonds that release energy when they are oxidized.

The investigations in all units will make use of two essential tools:

- Digital balances. Students can detect movement of atoms (the Matter Movement Question) by measuring differences in mass. In this activity students will be able to observe changes when ethanol is burned.
- Bromothymol blue (BTB) is an indicator that changes from blue to yellow in response to high levels of CO_2. Thus, changes in BTB can partially answer the Matter Change Question by detecting whether there is a chemical change that has CO_2 as a reactant or product.

Key Ideas and Practices for Each Activity

Activity 4.1 is the **Predictions and Planning Phase** of the instructional model (beginning the climb up the triangle). During this phase, students record their predictions and express ideas about what happens to matter when ethanol burns. They use the **Predictions and Planning Tool** to do this.

Activity 4.2 is the **Observations Phase** of the instructional model (going up the triangle). During this phase, the students conduct the investigation for ethanol burning, record data, and try to identify patterns in their data and observations. The important practices students focus on in this activity are 1) making measurements and observations, 2) recording their data and evidence, and 3) reaching consensus about patterns in results. They use the **Observations Worksheet** and **Class Results Poster** to do this.

Activity 4.3 the **Evidence-Based Arguments Phase** of the instructional model (going up the triangle). During this phase, the students review the data and observations from their investigation of ethanol burning and develop arguments for what happened during the investigation. In this phase, they also identify unanswered questions: at this point they have collected data and observations about macroscopic scale changes (BTB color change and mass change), but they do not have an argument for what is happening at the atomic-molecular scale. They use the **Evidence-Based Arguments Tool** to record their arguments at this phase.

Activity 4.4 is the first part of the **Explanations Phase** of the instructional model (going down the triangle). Students construct molecular models of the chemical change they observed in the investigation to help them develop an atomic-molecular explanation for what happened.

Activity 4.5 the second part of the **Explanations Phase** of the instructional model (going down the triangle). Students use the **Explanations Tool** to construct final explanations of what happens when ethanol burns. Ideally, at this phase their explanations will combine evidence from macroscopic-scale observations during the investigation with their new knowledge of chemical change at the atomic-molecular scale.

Key carbon-transforming processes: combustion

Content Boundaries and Extensions

Talk and Writing

At this stage in the unit, students will complete the inquiry and application sequences for ethanol burning—they go both up and down the triangle. This means that they will go through the

Predictions Phase, the **Observations Phase,** the **Evidence-Based Arguments Phase,** and the **Explanations Phase** in one lesson. The tables below show specific talk and writing goals for these phases of the unit.

Talk and Writing Goals for the Predictions Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Treat this as elicitation and brainstorming (like the Expressing Ideas and Questions Phase), but with more directed questioning.	*Now that we have set up the investigation, we want to predict what we think will happen to matter and energy.*	Three Questions Handout **Predictions and Planning Tool**
Elicit a range of student ideas. Press for details. Encourage students to examine, compare, and contrast their ideas with the ideas of other students.	*Who can add to that?* *What do you mean by _____? Say more.* *So I think you said _____. Is that right?* *Who has a different idea?* *How are those ideas similar/different?* *Who can rephrase _____'s idea?*	Investigation Video (first half)
Encourage students to provide evidence that supports their predictions. .	*How do you know that?* *What have you seen in the world that makes you think that?*	
Have students document their ideas to revisit later.	*Let's record our ideas so we can come back to them and see how our ideas change.*	**Predictions and Planning Tool**

Talk and Writing Goals for the Observations Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Help students discuss data and identify patterns.	*What patterns do we see in our data?* *How do you know that is a pattern?* *What about _____ data. What does this mean?*	Class Results Poster Class Results Spreadsheet
Encourage students to compare their own conclusions about the data and evidence with other groups and other classes.	*What about this number? What does this tell us?* *How is group A's evidence different from Group B's data?* *How do our class's data differ from other classes' data?*	Class Results Spreadsheet Class Results Poster Investigation Video (second half).
Make connections between the observations and the data/evidence.	*It says here that our BTB turned colors. What does that mean?* *You recorded that your ethanol lost weight. What does that mean?*	
Have students consider how their predictions and results compare.	*Let's revisit our predictions. Who can explain the difference between our class predictions and our results?* *Who had predictions that were similar to our results? Has your explanation changed? How?*	

Talk and Writing Goals for the Evidence-Based Arguments Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Press for details. Encourage students to examine, compare, and contrast their ideas with the ideas of other students.	*Who can add to that argument?* *What do you mean by _____? Say more.* *So I think you said _____. Is that right?* *Who has a different argument?* *How are those arguments similar/different?*	Investigation Video (second half)

	Who can rephrase _____'s argument?	
Students provide evidence from the investigation (not just experiences in the world) to develop arguments.	*Does your argument include evidence from the investigation?* *What evidence is most important here?* *What does this evidence tell us about what happened?* *What evidence do we still need for a complete picture of what happened?* *How do you know that?*	**Evidence-Based Arguments Tool** Class Results Poster Class Results Spreadsheets Investigation Video (second half) Data from other classes
Focus on how matter and energy were transformed at different scales.	*What does this evidence tell us about how matter is changing?* *What does this evidence tell us about how energy is changing?*	**Three Questions Handout** **Evidence-Based Arguments Tool**
Revisit predictions and examine change in thinking.	*Let's revisit our Predictions and see how our thinking changed now that we know what happened.*	**Evidence-Based Arguments Tool** **Predictions and Planning Tool**
Encourage students to consider the questions they don't have answers to.	*This investigation told us many things about what happen to matter and energy during ____. But what questions do we still have?*	

Talk and Writing Goals for the Explanations Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Examine student ideas and correct them when there are problems. It's ok to give the answers away during this phase! Help students practice using **precise language** to describe **matter and energy**.	*Let's think about what you just said: Air molecules. What are air molecules?* *Are you talking about matter or energy?* *Remember: atoms can't be created. So that matter must have come from somewhere. Where did it come from?* *Let's look at the molecule poster again… is carbon an atom or a molecule?*	Molecule Poster Three Questions Poster
Focus on making sure that explanations include multiple **scales**.	*The investigation gave us evidence for what was happening to matter and energy at a macroscopic sale. But what is happening at an atomic-molecular scale?* *What is happening to molecules and atoms?* *How does energy interact with atoms and molecules during chemical change?* *Why doesn't the macroscopic investigation tell us the whole story?* *Let's revisit our scale poster… what is happening to matter at the molecular scale?*	Molecular Models Molecular Modeling Worksheets **Explanations Tool** PPT Animation of chemical change Powers of Ten Poster
Encourage students to recall the investigation.	*When did this chemical change happen during our investigation?* *How do we know that? What is our evidence?* *What were the macroscopic indicators that this chemical change took place?*	**Evidence-Based Arguments Tool** Investigation Video
Elicit a range of student explanations. Press for details. Encourage students to examine,	*Who can add to that explanation?* *What do you mean by _____? Say more.* *So I think you said _____. Is that right?* *Who has a different explanation?* *How are those explanations similar/different?*	**Explanations Tool**

compare, and contrast their explanations with others'.	*Who can rephrase _____'s explanation?*	

Activity 4.1: Predictions about Ethanol Burning (30 min)

Overview and Preparation

Target Student Performance

Students develop hypotheses about how matter moves and changes and how energy changes when ethanol burns and make predictions about how they can use their investigation tools—digital balances and BTB—to detect movements and changes in matter.

Resources You Provide

- (From previous activity) Students' ideas and questions they shared in Activity 1.2 Expressing Ideas and Questions Tool for Ethanol Burning
- (From previous activity) 1.2 Expressing Ideas and Questions Tool for Ethanol Burning
- Video or demonstration of ethanol burning

Resources Provided

- 4.1 Predictions about Ethanol Burning PPT
- 4.1 Predictions and Planning Tool for Ethanol Burning (1 per student)
- 4.1 Assessing the Predictions and Planning Tool for Ethanol Burning
- 4.1 Good Explanations of Chemical Change Reading (1 per student)

Recurring Resources

- Three Questions 11 x 17 Poster (1 per class)
- Three Questions Handout (1 per student)
- Questions, Connections, Questions Student Reading Strategy
- (Optional) Investigation Planning Tool
- Burning Ethanol Video

Setup

Print one copy of 4.1 Predictions and Planning Tool for Ethanol Burning, 4.1 Good Explanations of Chemical Change Reading, and Three Questions Handout for each student. Prepare a computer and projector to display the PPT and the video. Print one copy of the Three Questions 11 x 17 Poster and display it on your classroom wall. Retrieve the materials from Activity 1.2. This may include a PPT slide from the lesson in which you typed students' responses or a photograph of their sticky notes as well as the students' completed 1.2 Expressing Ideas and Questions Tool for Ethanol Burning.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.1 Predictions about Ethanol Burning PPT.

2. Revisit students' ideas from Activity 1.2.

Display slide 3 of the 4.1 Predictions about Ethanol Burning PPT.

- Remind students of the ideas and questions they had in Activity 1.2.
- Return students' completed 1.2 Expressing Ideas and Questions Tool for Ethanol Burning and ask them to review their ideas from the first lesson.
- You may have typed and saved students' ideas and questions on the 1.2 Expressing Ideas and Questions Tool About Ethanol Burning PPT, or you may have taken a picture of students' sticky notes. Display the visual and review what students shared.
- Tell students that in this lesson, they will be investigating what happens when ethanol burns to learn more about what happens to matter *and energy* during chemical changes.

3. Have students read the Good Explanations of Chemical Change Reading

Show slide 4 of the 4.1 Predictions about Ethanol Burning PPT. Give each student a copy of 4.1 Good Explanations of Chemical Change Reading and a copy of the Three Questions Handout (or have them take out their existing copies). Have students read 4.1 Good Explanations of Chemical Change Reading using the Questions, Connections, Questions Student Reading Strategy. See the Question, Connections, Questions Reading Strategy Educator Resource document for information about how to engage students with this strategy. After the students read, ask them to define combustion in their own words. Place a copy of the Three Questions 11 x 17 Poster on the wall for reference if it is not there already.

- As students read each section, have them stop and highlight or underline the following rules about matter and energy on their handout.
  - Atoms are bonded together in molecules.
  - Atoms last forever.
  - Energy lasts forever, and energy can be transformed.

4. Watch the first half of the Burning Ethanol Video.

Display slide 5 of the PPT.

- Watch the *Burning Ethanol Video* until the first intermission where Darryl and Nina ask the students to make predictions about what happens when ethanol burns.
- Pause the video at 03:10 to discuss the questions posed on the screen before students complete the predictions and planning tool.

5. Have students complete Part A of the Predictions and Planning Tool for Ethanol Burning.

Show slide 6 of the PPT. Pass out one copy of 4.1 Predictions and Planning Tool for Ethanol Burning to each student and ask them to record their ideas as individuals for what happens when ethanol burns under part A.

- Remind students that these are just *predictions*, and that there are no wrong answers at this point. Encourage them to write down all of their ideas on the tool.

6. Discuss the Matter Movement Question as it relates to a digital balance

Show slides 7 and 8 of the 4.1 Predictions about Ethanol Burning PPT. Discuss with students how a digital balance can be used to measure matter moving into or out of a system. Highlight that the mass of the system can be measured before and after a change happens in a system. Discuss the two possible conclusions students can draw from their observations:

- If the mass of the system increases, then matter *must* have moved into the system (remember the facts about atoms)
- If the mass of the system decreases, then matter *must* have moved out of the system.

7. Discuss Matter Change Question as it relates to BTB

Show slide 9 of the 4.1 Predictions about Ethanol Burning PPT. Discuss with students how BTB can be used to measure matter change in a system. Highlight that the BTB in a closed container can be observed before and after a change happens in the system. Discuss the two possible conclusions students can draw from their observations:

- If the BTB changes from blue to yellow, then a chemical change may be producing CO_2
- If the BTB changes from yellow to blue, then a chemical change may be using CO_2 as a reactant.

8. Have students complete their predictions for Ethanol Burning: Part B of the Predictions and Planning Tool.

Show slide 10 of the PPT. Have students find Part B on 4.1 Predictions and Planning Tool for Ethanol Burning and ask them to record their ideas as individuals for the matter movement, matter change, and energy change questions.

Remind students that these are just *predictions*, and that there are no wrong answers at this point. Encourage them to write down all their ideas on the tool.

Divide students into pairs and tell them to compare and contrast their predictions with each other and to look for differences and similarities. Give students 2-3 minutes to compare their predictions**.**

9. Save the Predictions and Planning Tools for later.

Display slide 11.

- Tell students that tomorrow they will discuss their predictions together as a class.
- Also, they will revisit their ideas after the investigation to see how their ideas changed over time

10. Have students share ideas about planning the investigation: Part C of the Predictions and Planning Tool.

Show slide 12 of the PPT and describe the instruments and materials necessary for carrying out the investigation. Have students begin planning their investigation. There are two main variations in how much control students can have over this planning process:

- Minimal student control: Discuss student ideas for how an investigation could be set up. Then have students follow the lab instructions for lesson 4.2
- Maximal student control: Students in the class develop their own consensus plans that will replace the lab instructions in lesson 4.2. (They may use the Investigations Planning Tool for making their plans. Note the importance of having different student groups following the same plan so that they can come to a consensus about patterns in data in lesson 4.2 Some possible ideas of using lab materials are below.
    - Students might choose to add controls to the experiment, for example including both a Petri dish of yellow bromothymol blue (BTB) (made from blowing into the blue BTB with a straw) and a Petri dish of blue BTB to the chamber.
- Students might also choose to set up a chamber with a Petri dish of blue BTB alone without the ethanol.

Assessment

The **Three Questions** will be new to students, and Level 2 students will find the questions themselves hard to understand. In particular, they will initially be unable to connect the three columns in the Three Questions 11 x 17 Poster:

- The question itself: Note whether students use the “Facts about atoms and molecules” that they studied in Lesson 2 as they try to answer the Matter Movement and Matter Change Questions.
- Rules to follow: The most important rule (and the first Fact about Atoms) is: Atoms last forever. Do they follow that rule when they try to answer the questions?
- Evidence to look for: Students will address this column in more depth when they do the investigation. One thing to note for now: Do students connect the ethanol losing mass with atoms leaving the ethanol?
- During the class, listen to the idea’s students offer in the final step of the activity. At this point, do students’ predictions follow the rules? At this point, do not correct student ideas, but listen for what they say about matter and energy in the context of combustion. After class, use the 4.1 Assessing the Predictions and Planning Tool for Ethanol Burning to compare your students’ what we would expect to see in Level 4 responses.

This discussion will show that some students are still at Level 2 with respect to both their ideas about energy and their understanding of the questions. For example, do students have a sense of necessity about the connections between mass changes and movement of atoms? Do they recognize that if the ethanol loses mass, then atoms must be moving out of the ethanol? Do students account for energy separately from matter, or do they suggest that some of the matter in the ethanol might be converted to energy? You do not need to correct any problems now; they will be addressed through the investigation and Modeling in the Activities to come.

Differentiation & Extending the Learning

Differentiation

Modifications

Tips

- Have a designated place in the classroom where students store their 4.1 Predictions and Planning Tool for Ethanol Burning so they can easily refer back to their ideas at the end of the lesson.
- Expect many students to make the right predictions for the wrong reasons. Note in particular whether they say that changes in the mass of the ethanol indicate that atoms are moving.

Extending the Learning

Students may want to consider controls or other conditions (e.g., seeing what happens to mass and CO_2 when the ethanol is not burning.)

Activity 4.2: Observing Ethanol Burning (30 min)

Overview and Preparation

Target Student Performance

Students record data about changes in mass and BTB when ethanol burns and reach consensus about patterns in their data.

Resources You Provide

- BTB, blue (less than 1 cup per group)
- (optional) BTB, yellow (less than 1 cup per group)
- digital balance (1 per group of four students)
- ethanol, 95% (10-15 ml per group)
- large plastic container with aluminum foil taped inside to protect the bottom from the ethanol flame (1 per group of four students)
- lighter (1 per group of four students)
- Petri dish, glass (1 per group of four students)
- Petri dish, plastic (1 per group of four students)
- safety glasses (1 per student)
- (Optional) Molecular modeling kits
- (From previous activity) 4.1 Predictions and Planning Tool for Ethanol Burning with student answers

NOTE: Some classrooms have access to CO_2 probes. We designed this investigation with BTB because it is less expensive than probes, but if you have them available, they are more sensitive than BTB and show changes more quickly.

Resources Provided

- 4.2 Ethanol Burning Class Results 11 x 17 Poster (1 per class)
- 4.2 Ethanol Burning Class Results Spreadsheet (1 per class)
- 4.2 Observing Ethanol Burning Worksheet (1 per student)
- 4.2 Grading the Observing Ethanol Burning Worksheet
- 4.2 Observing Ethanol Burning PPT

Recurring Resources

- Three Questions Handout (1 per student)
- (Optional) BTB Color Handout
- (Optional) BTB Instructions and Information Handout
- Burning Ethanol Video

Setup

Prepare the BTB, Petri dishes, ethanol, lighter, digital balances, plastic containers, aluminum foil, and safety glasses for students to retrieve for their groups. If you plan to use the poster to record student data, print one copy of the poster before class and post it on the wall. Print one copy of 4.2 Observing Ethanol Burning Worksheet for each pair of students. Prepare a computer with an overhead projector to display the PPT and video. You may want to review the BTB Instructions and Information Handout and/or print a few color copies of the BTB Color Handout for students.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.2 Observing Ethanol Burning PPT.

2. Have students set up the investigation.

Display slide 3 of the 4.2 Observing Ethanol Burning PPT. Divide students into groups of four.

- Pass out one copy of 4.2 Observing Ethanol Burning Worksheet to each student. Walk through the steps in Part A of the worksheet that overview how to set up and conduct the investigation.

3. Have students conduct the investigation.

Display Slide 4 while students are conducting the investigation. The students will need to wait 20 minutes to see color change in the BTB.

4. Have students discuss their predictions about the Matter Movement Question as a class.

While waiting for the ethanol to burn, display slide 5 of the PPT. Ask students to retrieve their completed tools from the previous activity: 4.1 Predictions and Planning Tool for Ethanol Burning.

- Ask pairs of students to share their ideas for the Matter Movement Question. Ask students what they expect to see in the investigation and what that might mean.
- Use the Three Questions Handout to check if students' predictions follow the rules. If they don't, ask students why they don't. At this stage, students' ideas do not yet need to be corrected.
- Record students' ideas on the slide.
- Help the students look for similarities and differences in the predictions in the class. Try to get a range of ideas on the slide.

5. Have students discuss their predictions about the Matter Change Question as a class.

While continuing to wait for the ethanol to burn, display slide 6 of the PPT and ask pairs of students to share their ideas for the Matter Change Question.

- Lead a discussion by asking students what they expect to see in the investigation and what that might mean.
- Use the Three Questions Handout to check if students' predictions follow the rules. If they don't, ask students why they don't. At this stage, students' ideas do not yet need to be corrected.
- Record students' ideas on the slide.
- Help the students look for similarities and differences in the predictions in the class. Try to get a range of ideas on the slide.

6. Have students discuss their predictions about the Energy Change Question as a class.

While continuing to wait for ethanol to burn, display slide 7 of the PPT and ask pairs of students to share their ideas for the Energy Change Question.

- Lead a discussion by asking students what they expect to see in the investigation and what that might mean.

- Use the Three Questions Handout to check if students' predictions follow the rules. If they don't, ask students why they don't. At this stage, students' ideas do not yet need to be corrected.
- Record students' ideas on the slide.
- Help the students look for similarities and differences in the predictions in the class. Try to get a range of ideas on the slide.

7. Have students record data and observations.

Display slide 8 of the PPT. Have students record their group's data and observations about the mass change and BTB color on their worksheet.

- Have students select a recorder to input their group's results on the 4.2 Ethanol Burning Class Results 11 x 17 Poster, or in the 4.2 Ethanol Burning Class Results Spreadsheet.

8. Have students' groups compare and identify patterns in BTB Color.

Display slide 9 of the PPT

- Lead a discussion to help students compare results across groups and identify patterns in the data. Have students discuss how BTB has a gradient of colors depending on how much CO_2 is absorbed.
- Optionally, give each group or pair of students a BTB Color Handout to use as a reference guide.

9. Have students' groups discuss patterns in class results.

Show students slide 10 to discuss patterns that students see in the class results.

- Ask students to identify patterns in the data for both the mass change and also the BTB color change and discuss any outliers or unexplained data points.
- If you input data into the spreadsheet, the software will construct a graph of the students' data. Use the graph to elicit more interpretation of their observations.

10. Watch the end of the Burning Ethanol Video.

Show slide 11 of the PPT

- Have students watch the Burning Ethanol Video starting from 3:10 to observe Darryl and Nina's results to the burning ethanol investigation. Ask the class to compare their own results to Darryl and Nina's results, pausing the video when the data are shown.

11. Have students compare their class's data with data from another class.

Show slide 12 of the PPT to view data from Ms. Angle's class.

- Ask students to compare the patterns they observed with the patterns from Ms. Angle's class. What similarities or differences do they notice? What patterns do they see?

The remainder of the unit is based on the assumption that your class results are similar to those of Ms. Angle's class and the Ethanol Burning video. If your class results are significantly different for any reason, after a conversation about why that may have happened, decide whether to have students conduct the investigation again or to refer to Ms. Angle's data as they work through the remainder of the unit.

12. Have students compare their class's BTB color with data from another class.

Show slide 13 of the PPT to view BTB from Ms. Angle's class.

- Ask students to compare the colors they observed with the colors from Ms. Angle's class. What similarities or differences do they notice?

13. Revisit predictions from the previous activity.

Use slide 14 to revisit students' predictions from Activity 4.1.

- Have them compare the predictions they made with the results of the investigation.
- Which predictions were correct? Which predictions were incorrect? What questions to they still need to answer?

14. Have students complete an exit ticket.

Show slide 15 of the 4.2 Observing Ethanol Burning PPT.

- Conclusions: What did you observe during the investigation?
- Predictions: What do you think is one conclusion you can make from the investigation?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead into the next activity.

Assessment

Use the class discussion to interpret how successful your students are at identifying patterns in the class data. Use the 4.2 Grading the Observing Ethanol Burning Worksheet to determine if your students had any trouble with data collection.

During this Activity, note students' success in measuring changes in mass and BTB. Also note students' ability to reach a consensus about patterns in data and how they interpret results.

Differentiation & Extending the Learning

Differentiation

Modifications

- Have students develop the experimental design on their own using the tools provided. For example, students may choose to set up a control treatment as a chamber with BTB and no ethanol.
- If you have a hygrometer, consider measuring water content in the air after the ethanol burns.

Tips

Addressing problems at this point as students try to find patterns in data will support their learning in future investigations. This is the first investigation, so it is likely to expose challenges that may come up again.

Extending the Learning

Students can explore conditions under which the ethanol burns for longer or shorter periods, and the relationship between how long the ethanol burns and how much mass it loses.

Activity 4.3: Evidence-Based Arguments for Ethanol Burning (50 min)

Overview and Preparation

Target Student Performance

Students (a) use data from their investigations to develop evidence-based arguments about matter movements, matter changes, and energy changes when ethanol burns; and (b) identify unanswered questions about matter movement, matter change, and energy change that the data are insufficient to address.

Resources You Provide

- (From Previous Activity) 4.2 Observing Ethanol Burning Worksheet
- (From Previous Activity) 4.2 Ethanol Burning Class Results 11 x 17 Poster (or spreadsheet)

Resources Provided

- 4.3 Evidence-Based Arguments Tool for Ethanol Burning (1 per student)
- 4.3 Assessing the Evidence-Based Arguments Tool for Ethanol Burning
- 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT

Recurring Resources

- Three Questions Handout (1 per student)
- Learning Tracking Tool for Systems & Scale (1 per student)
- Assessing the Learning Tracking Tool for Systems and Scale

Setup

Print one copy of 4.3 Evidence-Based Arguments Tool for Ethanol Burning for each student. Make sure that the 4.2 Ethanol Burning Class Results 11 x 17 Poster (or spreadsheet) from the previous activity is available.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT.

2. Have students review their results from the investigation.

Display slide 3 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT. Draw students' attention to the 4.2 Ethanol Burning Class Results 11 x 17 Poster from the investigation and students' own 4.2 Observing Ethanol Burning Worksheet, section D, "results for the whole class." Ask the students to find a partner, and in their own words, review what happened during the investigation. Tell them to discuss:

- What patterns they observed in the mass change
- What patterns they observed in the BTB color change

Tell students that when scientists construct arguments for what happened, using evidence from observations is important, so today's activity is designed to help them use the evidence from the investigation to construct an argument for "What happens when ethanol burns" and come to class consensus.

3. Have students share ideas about the chemical change with ethanol burns

Display slide 4 of the 4.3 Evidence Based Arguments Tool. Pass out the 3.3 Evidence Based Arguments Tool Worksheet. Have students complete and discuss part A of the tool. Have students discuss how their ideas have changes since they wrote about ethanol burning on the predictions and planning tool.

4. Have students develop arguments for what happened as individuals.

Display slide 5 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT. Pass out one copy of 4.3 Evidence-Based Arguments Tool for Ethanol Burning to each student. Review Tool directions. Also, have students take out their Three Questions Handout and be ready to refer to their class results.

- Instruct students to complete their evidence, conclusions, and unanswered questions as individuals for the Three Questions.
- Give students about 5-10 minutes to complete the process tool.

5. Have students compare and revise arguments in pairs.

Display slide 6 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT. Divide students into pairs.

- Have each pair compare their **evidence, conclusions,** and **unanswered questions** for the Matter Movement Question.
- Have partners discuss how their ideas are alike and different. Have students change or add to their responses, based on partner input.
- Have students repeat this step for the Matter Change Question and the Energy Question.
- Pay attention to patterns in students' ideas. You will want to begin moving towards class consensus in this activity.
- Partner work should take about 10 minutes.

6. Have a class discussion of the Matter Movement Question; move toward class consensus.

Display slide 7 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT.

- Have students/pairs share their evidence and conclusions for the Matter Movement question. Keep a class record, using the PPT slide or board. Ask students to update their answers by using a different colored writing utensil. Discussions should move toward class consensus. Use class conversation to correct student ideas. Use the Three Questions Handout to help guide towards consensus by following the established rules.
- Have students share unanswered questions. Discussions should move toward class consensus. Use the 4.3 Assessing the Evidence-Based Arguments Tool for Ethanol Burning to guide your goals for consensus. Note that students may contribute unanswered questions that align with rules on the Three Questions Handout but may not closely align with those on the Assessing worksheet. You may still choose to record those unanswered questions. These may be answered in other parts of this unit or even in other units during the school year. However, at this point in this unit, though there may be several viable paths of inquiry moving forward, you will begin to more closely guide the path of inquiry in one direction – in this case towards molecular modeling of ethanol burning.
- Class discussion should take about 10 minutes.

7. Repeat step 5 with the Matter Change Question; move toward class consensus.

Display slide 8 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT.

- Class discussion may take another 10 minutes.

8. Repeat step 5 with the Energy Change Question; move toward class consensus.

Display slide 9 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT.

- Class discussion may take another 10 minutes.

9. Discuss how the Unanswered Questions shape our next steps, and the transition from inquiry to application.

Display slide 10 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT.

- Use the Unanswered Questions to set the stage for students' next steps, specifically the need to know what's happening at the atomic-molecular scale.

Take a moment to show students that you have arrived at the "top of the triangle" on the instructional model. This means they will be making a transition. When they went "up the triangle," they conducted an investigation and collected evidence based on what they could observe using their own eyes and also tools (e.g., macroscopic observations). Now they are preparing to go "down the triangle," when they will figure out how to explain what happened in the investigations at an atomic-molecular scale by being provided and practicing with a model for scientifically accurate thinking.

10. Save the Evidence-Based Arguments Tools for later.

Display slide 11. Tell students that they will revisit their unanswered questions later in the unit to see which questions they can now answer.

11. Have a discussion to complete the Learning Tracking Tool for this activity.

Show slide 12 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT.

- Have students take out their Learning Tracking Tool for Systems and Scale.
- Have students write the activity name, "Investigating Ethanol Burning" and their role "investigator" in the first column.
- Have a class discussion about what students did during the activity. When you come to consensus as a class, have students record the answer in the second column of the tool.
- Have a class discussion about what students figured out during the activity that will help them in answering the unit driving question. When you come to consensus as a class, have students record the answer in the third column of the tool.
- Have a class discussion about what students are wondering now that will help them move towards answering the unit driving question. Have students record the questions in the fourth column of the tool.
- Have students keep their Learning Tracking Tool for future activities.
- Example Learning Tracking Tool

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Investigating Ethanol Burning Investigating	Conduct an investigation to explore what happens when ethanol burns and use the Predictions and Planning Tool	Ethanol burning lost mass and made the BTB change from blue to yellow. There was evidence of heat and light energy at	What happens to the molecules of ethanol as it burns?

	and the Evidence-Based Arguments Tool.	the end of the chemical change.	

12. Have students complete an exit ticket.

Show slide 13 of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning PPT.

- Conclusions: What is our conclusion for the energy change question from the investigation?
- Predictions: Where do you think the CO_2 that turned the BTB yellow came from?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead into the next activity.

Assessment

During the class discussion, listen for students making connections to the investigation and their arguments. Are they drawing on observations from the investigation, or from other sources of knowledge and experience? Use the 4.3 Assessing the Evidence-Based Arguments Tool for Ethanol Burning to assess your students' thinking at this point in the unit. At this point they have concluded their "up the triangle" inquiry journey and are headed "down the triangle" for the application sequence.

Differentiation & Extending the Learning

Differentiation

Modifications

Tips

Have the students store their 4.3 Evidence-Based Arguments Tool for Ethanol Burning in the same place as their Expressing Ideas and Questions and Predictions and Planning Tools so they can be easily revisited.

Extending the Learning

- Students can use their investigation tools to collect data on changes in mass and CO_2 for other fuels (e.g., candle, butane lighter, can of Sterno, paper, matches or wood).
- Use cobalt chloride indicator paper to test for the presence of water after ethanol burning.
- Burn steel wool (which gains mass) to help students conceptualize movement of matter/mass changes.

Activity 4.4: Molecular Models for Ethanol Burning (50 min)

Overview and Preparation

Target Student Performance

Students use molecular models to explain how carbon, oxygen, and hydrogen atoms are rearranged into new molecules during the oxidation of ethanol (the chemical change that happens when ethanol burns).

Resources You Provide

- molecular model kit (1 per pair of students)
- scissors (1 per pair of students)
- twist ties (at least 12 per pair of students)

Resources Provided

- 4.4 Molecular Models for Ethanol Burning Worksheet (1 per student)
- 4.4 Grading the Molecular Models for Ethanol Burning Worksheet
- 4.4 Molecular Models for Ethanol Burning PPT
- 4.4 Molecular Models for Ethanol Burning Reading (1 per student)
- (Optional) 4.4 Alternative Flame Molecular Model Placemat
- Carbon TIME Molecular Modeling Ethanol Video

Recurring Resources

- Learning Tracking Tool for Systems & Scale (1 per student)
- Assessing the Learning Tracking Tool for Systems and Scale
- Questions, Connections, Questions Student Reading Strategy
- Forms of Energy Cards (1 set per pair of students)
- Molecular Models 11 x 17 Placemat (1 per pair of students)

Setup

Prepare one model kit, one Molecular Models 11 x 17 Placemat, one pair of scissors, and one Forms of Energy Cards for each pair of students. Print one copy of the 4.4 Molecular Models for Ethanol Burning Worksheet and 4.4 Molecular Models for Ethanol Burning Reading for each student. Prepare a computer and a projector to display the PPT.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.4 Molecular Models for Ethanol Burning PPT.

2. Have students read Molecular Models for Ethanol Burning Reading.

Display slide 3 of the 4.4 Molecular Models for Ethanol Burning PPT. Give each student a copy of 4.4 Molecular Models for Ethanol Burning Reading.

- Remind students that the investigation left them with unanswered questions (students can refer back to 4.3 Evidence-Based Arguments Tool for Ethanol Burning).
- Have students read 4.4 Molecular Models for Ethanol Burning Reading to learn about modeling using the Questions, Connections, Questions Student Reading Strategy. See the Engaging Students with Readings and the Question, Connections, Questions Reading

Strategy Educator Resource document for information about how to engage students with this strategy.

- Have a class discussion about why scientists use molecular models and about why they need to use molecular modeling to answer their unanswered questions.

3. Zoom into a flame.

Display slides 4 the 4.4 Molecular Models for Ethanol Burning PPT to explain molecular bonding to students.

- Pose the question: "*What's the hidden chemical change when ethanol burns?"* Explain to students that both ethanol and O_2 enter the flame at the bottom. Ethanol enters the flame through evaporation. Define or review the word evaporation with your students. Emphasize that evaporation is a physical change and not a chemical change. Write the chemical formula for ethanol on the board, "C_2H_5OH". This means each ethanol molecule has two carbons, six hydrogens and one oxygen atom.
- Show slides 5 and 6 to contrast the molecules at the bottom and top of a flame.

4. Have students use the molecular model kits to make one ethanol and three oxygen molecules.

Divide the class into pairs and give each pair a molecular model kit, a set of Forms of Energy Cards, and a Molecular Models 11 x 17 Placemat. Pass out one copy of 4.4 Molecular Models for Ethanol Worksheet to each student.

- Show students slide 7 to remind them of how atoms bond in molecules. These rules apply to all molecules that they will make in all *Carbon TIME* units.
- Use slide 8 to show instructions to construct oxygen and ethanol molecules. Students can also follow instructions in Part B of their worksheet.
- Use slide 9 to instruct students to compare their own molecule with the picture on the slide.
- Slide 10 shows an **important message**: after students create their reactant molecules, make sure they put away all unused pieces of their molecule kits. This helps reinforce that the matter and energy in the reactants are conserved through the chemical change, and that only the materials from the reactants are used to build the products.

Accommodations: Arrange the molecules along with students so they have a step-by-step model of what the molecules should look like.

Use the Carbon TIME: Molecular Modeling Ethanol Video if doing in-person molecular modeling is not possible, or to support absent students.

5. Have students construct a model of the chemical change.

Tell students to follow the instructions the worksheet to construct their products.

- Show slide 11 of the PPT and have students re-arrange the atoms to make molecules of CO_2 and H_2O. To do this, they will need to move their molecules from the reactants side to the products side of the 11 x 17 Placemat. Explain to students that atoms last forever, so they should not add or subtract atoms when they change the reactant molecule into product molecules.
- Show students Slide 12 to make a comparison between the reactants and the products.
- Show students Slide 13 to make a comparison between the reactants and the products.

Accommodations: *Arrange the molecules along with students so they have a step-by-step model of what the molecules should look like.*

Use the Carbon TIME: Molecular Modeling Ethanol Video if doing in-person molecular modeling is not possible, or to support absent students.

6. Have students watch an animation of the chemical change.

Show slides 14-19 in the PPT to help students make connections between what is happening in the animation and the molecular models they made.

- For each slide, focus on different atoms and forms of energy and how they change. The animation draws attention to where they atoms begin and end in the reaction.

7. Have students record their results.

Show slide 20 in the PPT.

- Tell students to complete Part C of their worksheet to trace the atoms during the chemical change.

8. Have students record their results.

Show slide 21 in the PPT.

- Tell students to complete Part D of their worksheet to trace the energy during the chemical change.

9. Discuss results with the class.

Show slide 22 in the PPT.

- Complete the "check yourself" questions with the class in Part E.

10. Help students write a balanced chemical equation on the worksheet.

After the discussion, tell students that now that they have represented a chemical change using molecular models and in animations, they will represent chemical change by writing the chemical equation.

- Show Slide 23 of the presentation to guide students through the process of writing a balanced chemical equation for the combustion of ethanol. Tell students that these rules apply to all chemical reactions.
- Tell students to write their equations in Part F of their worksheet.
- Have students write their own chemical equations before comparing them with the one on Slide 24.

Assessment

Listen for the students' sense of necessity to make sure that atoms last forever during chemical changes. Asking them about the "atoms are forever" rule during the molecular modeling and animation may give you a sense of how committed they are to conserving matter.

Differentiation & Extending the Learning

Differentiation

- Instead of the Molecular Models 11 x 17 Placemats, provide your students with the 4.4 Alternative Flame Molecular Model Placemat to use as the placemat for their molecular

modeling. Have students place the models in the appropriate locations on the flame system placemat before, during and after the chemical change.

Modifications

Tips

- Laminate the Molecular Models 11 x 17 Placemats. These will be used multiple times in each unit.
- During the molecular modeling activity and animation, focus on how matter and energy are conserved through the chemical change. This is the main goal of the activity!

Extending the Learning

Lesson 5 will include opportunities for students to learn about the combustion of other fuels, including methane, propane, and octane. Curious students can look up the formulas for these fuels and make molecular models of them.

Activity 4.5: Explaining Ethanol Burning (40 min)

Overview and Preparation

Target Student Performance

Students explain how matter moves and changes and how energy changes when ethanol burns (connecting macroscopic observations with atomic-molecular models and using the principles of conservation of matter and energy).

Resources You Provide

- (from previous activity) 4.3 Evidence-Based Arguments Tool for Ethanol Burning

Resources Provided

- 4.5 Explanations Tool for Ethanol Burning (1 per student)
- 4.5 Explaining Ethanol Burning PPT
- 4.5 Grading the Explanations Tool for Ethanol Burning Worksheet
- (Optional) 4.5 What Happens When Ethanol Burns? Reading (1 per student)
- (Optional) 4.5 Matter Tracing Tool
- (Optional) Grading the 4.5 Matter Tracing Tool

Recurring Resources

- Three Questions Handout (1 per student)
- Questions, Connections, Questions Student Reading Strategy
- (Optional) Big Idea Probe: Fill 'Er Up
- (Optional) Assessing the Big Idea Probe: Fill 'Er Up
- (Optional) Example Systems and Scale Explanations Handout (1 per student or per group)

Setup

Print one copy of the 4.5 Explanations Tool for Ethanol Burning for each student. Return students' completed versions of the 4.3 Evidence-Based Arguments Tool for Ethanol Burning for review. In this activity, your students will need to use the Three Questions Explanation Checklist on the back of the Three Questions Handout. Be sure to have this available to students, and see the notes in the Modifications at the end of the Activity for ideas about how to use it. Decide if you will use the Big Idea Probe: Fill 'Er Up, Example Systems and Scale Explanations Handout and/or 4.5 What Happens When Ethanol Burns? Reading. Print copies of the ones you decide to use.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.5 Explaining Ethanol Burning PPT.

2. Revisit students' arguments about what happens to ethanol when it burns.

Show slide 3 of the 4.5 Explaining Ethanol Burning PPT.

- Tell students that this activity's purpose is to develop explanations for what happens when ethanol burns.
- Return each student's copy of 4.3 Evidence-Based Arguments Tool for Ethanol Burning and have them review their arguments before they completed the molecular modeling activity.
- Ask them to think about what they know now that they didn't know then.

3. Have students complete the front of the Explanations Process Tool.

Show slide 4 of the 4.5 Explaining Ethanol Burning PPT. Give each student one copy of 4.5 Explanations Tool for Ethanol Burning.

Make sure students understand that they will use the information from the front of the explanations tool help them construct their explanations paragraphs on the back.

Give students about 10 minutes to complete the front of the Explanations Process Tool.

Display slide 5. Then, have students compare their responses with the class, with the goal of confirming that their responses are the same.

4. Have students check the front of the explanations tool using the PPT.

Display slides 6-8 of the PPT. Have students compare their answers to the Matter Movement Question with the answers on the slide. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.

- Display slide 9-10 of the PPT for the Matter Change Question and repeat the process above.
- Display slide 11 of the PPT for the Energy Change Question and repeat the process above.

5. Have students write paragraph explanations of the process of ethanol burning.

Display slide 12. Ask students to write paragraphs explaining the process of ethanol burning on the second page of the 4.5 Explanations Tool for Ethanol Burning.

- Refer student to the checklist and questions on the Three Questions Handout for reminders about what to include in their paragraph
- Remind students that they have the information they need in their responses to the questions on the front of the Explanations Tool.
- Remind students that the graphic organizer on the front has the information they need to write their explanations paragraphs.
- Remind students to refer to their Three Questions Handout and Explanations Checklist to review what should be included in a good explanation.

6. Have students share explanations with each other.

- Show slide 13 of the 4.5 Explanations Tool for Ethanol Burning PPT. Divide students into pairs and have them compare explanations for the Three Questions and the final explanation on the process tool.
- Have students use the Three Questions 11 x 17 Poster (or Handout) as a reference. Have students check their explanations with the middle and right-hand columns of the poster to make sure they are following the "rules."

7. (Optional) Have students critique example explanations

Display Slide 14 of the PPT. Have students look at two handouts: (a) the Three Questions Handout, and (b) the Systems and Scale Example Explanations Handout.

- Ask students to evaluate the two example explanations of ethanol burning on the Systems and Scale Example Explanations Handout: Which explanation is better? Why?
- Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to justify their critiques of the explanations.

8. Have students critique and improve their full explanations.

Display slide 14 of the PPT for the full explanation. Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to check that their story includes each of the parts (matter movement, matter change, energy change, and matter movement) and answers the prompt in a cohesive way.

- If students don't have all four parts in their explanation, instruct them to add to their explanation using a different colored writing utensil.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

9. Lead a discussion about how student ideas have changed over time.

Display slide 15 of the 4.5 Explanations Tool for Ethanol Burning PPT. Have students look back over their process tools for this unit. Have students consider how their ideas changed with regard to scale, movement, and carbon. What do they know about ethanol burning now that they didn't know before the investigation?

10. (Optional) Have student read about combustion.

Pass out 4.5 What Happens When Ethanol Burns? Reading. The reading provides a summary explanation of the combustion of ethanol and additional information about ethanol.

Have students read 4.5 What Happens When Ethanol Burns? Reading using the Questions, Connections, Questions Student Reading Strategy. See the Engaging Students with Readings and the Question, Connections, Questions Reading Strategy Educator Resource document for information about how to engage students with this strategy.

Then, have the students use the 4.5 What Happens When Ethanol Burns? Reading to complete the 4.5 Matter Tracing Tool.

11. (Optional) Have students complete the Big Idea Probe: Fill 'Er Up for the second time.

If you decided to use the Big Idea Probe: Fill 'Er Up, have students complete it and share their ideas for a second time. See Using Big Idea Probes and Assessing the Big Idea Probe: Fill 'Er Up for suggestions about how to use the Big Idea Probe.

12. Have a discussion to complete the Learning Tracking Tool for this activity.

Show slide 16 of the 4.5 Explanations Tool for Ethanol Burning PPT.

- Have students take out their Learning Tracking Tool for Systems & Scale.
- Explain that students will add to the tool after activities to keep track of what they have figured out that will help them to answer the unit driving question.
- Have students write the activity name "Explaining Ethanol Burning" and their role "Explainer" in the first column,
- Have a class discussion about what students figured out during the activity that will help them in answering the unit driving question, "What happens when ethanol burns?" When you come to consensus as a class, have students record the answer in the second column of the tool.
- Have a class discussion about what students are wondering now that will help them move towards answering the unit driving question. Have students record the questions in the third column of the tool.
- Have students keep their Learning Tracking Tool for future activities.

- Example Learning Tracking Tool

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Explaining Ethanol Burning Explainer	Model the chemical change that occurs as ethanol burns using molecular model kits and use the Explanations Tool to explain what happens when ethanol burns.	In a flame the atoms in ethanol and oxygen rearrange to form carbon dioxide and water. Chemical energy is changed to heat and light energy when the high-energy C-C and C-H bonds of ethanol are changed to low-energy O-H and C=O bonds.	Why does ethanol burn and not water?

13.

13. Have students complete an exit ticket.

Show slide 17 of the 4.5 Explaining Ethanol Burning PPT.

- Conclusions: How do matter and energy change when ethanol burns?
- Predictions: What do you think happens when natural gas (methane or CH_4) burns?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead in to the next activity.

Assessment

During the class, circulate while students are comparing their explanations. Listen to see if they are able to explain ethanol burning at both the macroscopic and atomic-molecular scales. Use 4.5 Grading the Explanations Tool for Ethanol Burning Worksheet to grade your students' work on the 4.5 Explanations Tool for Ethanol Burning. At this point in the lesson, students should be held accountable for correct answers.

Differentiation & Extending the Learning

Differentiation

Modifications

If time allows, have students revisit their initial predictions and planning tools from Activity 4.1. Comparing their early predictions to their final explanations may show a greater change in their thinking over time.

The Three Questions Explanation Checklist on the back of the Three Questions Handout can be used to scaffold students' explanations in many ways.

- Students refer to the checklist as they are constructing their explanations.
- Students use the checklist as they are sharing and revising their explanations with a partner.
- Students use the checklist to critique and revise their final explanations.
- Students use the checklist to critique the example explanations for each unit.
- Students use the checklist to create and/or evaluate a whole-class consensus explanation.

We recommend using this checklist with a gradual release. As students improve in their ability to write their own explanations, they may rely on the checklist less.

Tips

- Make sure students understand that the chemical energy in ethanol (not ethanol itself) is converted to heat and light energy.
- Make sure that students discuss and understand all three columns of the Three Questions 11 x 17 Poster or Handout. They play a central role in all *Carbon TIME* units.

Extending the Learning

If students still have unanswered questions about flames, show the Alda Kavlie Learning Center 'What is a Flame?' video challenge winner (https://www.aldacenter.org/practice/flame-challenge/what-is-a-flame).