Systems and Scale Unit Front Matter

Tab 1: *Unit Home*

Download PDF of Unit Front Matter

Systems and Scale is the first of the six *Carbon TIME* units. If you are new to teaching *Carbon TIME*, read the *Carbon TIME* FAQ: Which Units Should I Teach.

The goal of the *Systems and Scale* unit is to introduce students to organic matter and chemical energy (in the context of combustion) using the tools for reasoning and environmental literacy practices that students will engage with in other units. Students develop required capacity to distinguish organic matter from inorganic matter, and to understand how differences in the chemical make-up of materials influences how materials and energy are transformed and moved between systems.

The *Systems and Scale Unit* supports students in using core disciplinary ideas, science practices, and cross-cutting concepts to develop scientific explanations of how *matter and energy are transformed* during combustion of different organic materials.

Follow these steps to get ready to teach the *Systems and Scale* Unit

Step 1	Step 2	Step 3	Step 4	Step 5
Read The Unit Overview	Choose Your Unit Sequence	Learn About The Instructional Model & Storyline	Prepare Unit Materials	Dig Into The Lessons

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This unit is also available online at http://carbontime.bscs.org/. Contact the MSU Environmental Literacy Program for more information: EnvLit@msu.edu.

Tab 2: Overview

The Driving Question and Research Base (accordion)

Download PDF of Unit Overview

The *Systems and Scale Unit* starts by asking students to express their ideas and generate questions about the driving question about an anchoring phenomenon: *What happens when ethanol burns*?

Carbon is the key! In the *Systems and Scale* Unit, students learn to tell the story of how matter and energy are transformed as they move through systems where combustion of organic materials is occurring, including open flames and internal combustion engines. A particularly powerful strategy for explaining how flames transform matter and energy involves *tracing carbon atoms*. For more information about the *Next Generation Science Standards* **disciplinary core ideas** included in this unit see the sections on the Matter Movement, Matter Change, and Energy Change Questions below and the Unit Goals.

Research base. This unit is based on learning progression research that describes the resources that students bring to learning about Systems and Scale and the barriers to understanding that they must overcome. It is organized around an instructional model that engages students in three-dimensional practices.

Students' Roles and Science Practices (accordion)

As students learn to answer the driving question by explaining how flames transform matter and energy, they play three different roles that encompass all of the *Next Generation Science Standards* science and engineering practices. (For more details on science and engineering practices, see the Unit Goals.)

- Questioners: Students explore the driving question, clarify, and generate more detailed questions.
- Investigators: Students conduct two matter-tracing investigations of (a) soda water fizzing and (b) ethanol burning. They develop evidence-based arguments about key observations and patterns.
- Explainers: Students construct model-based explanations of how matter and energy are transformed when organic materials burn.

The roles that students play are also embedded in the *Carbon TIME* Instructional Model and Discourse Routine. The Discourse Routine guides how classroom discourse aimed first at divergent thinking and then at convergent thinking should be sequenced through the unit.

Good Explanations Answer the Three Questions (accordion)

Students figure out how to answer the driving question by tracing the carbon-containing molecules in fuels through a series of movements and chemical changes inside flames. At each stage in these processes they answer **Three Questions** about what is happening: the *Matter Movement Question, the Matter Change Question,* and the *Energy Change Question*.

Below, we use the anchoring phenomenon of a flame burning as an example of how students learn to answer the Three Questions for different organic materials burning.

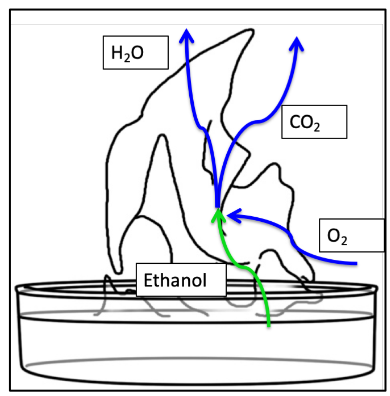
Note that, in *Carbon TIME*, **crosscutting concepts** serve as the "rules of grammar" for producing a scientific performance. With respect to organic materials burning, high quality explanations should attend to the following rules that are implied by crosscutting concepts. Explanations should attend to…

- *Scale* by explaining events and phenomena at the appropriate scale (see more in the structure and function bullets below).
- *Systems and system models and energy and matter* by following rules for tracing matter and energy through systems and system models. For example, neither energy nor matter should be created or destroyed as it moves into, through, or out of a system such as a flame.
- *Structure and function* by linking structures and functions in explanations at each scale.
    - Macroscopic scale (tracing matter and energy through processes occurring in flames)
    - Atomic-molecular scale (tracing matter and energy through a chemical process—combustion—involving molecules with different structures and properties)

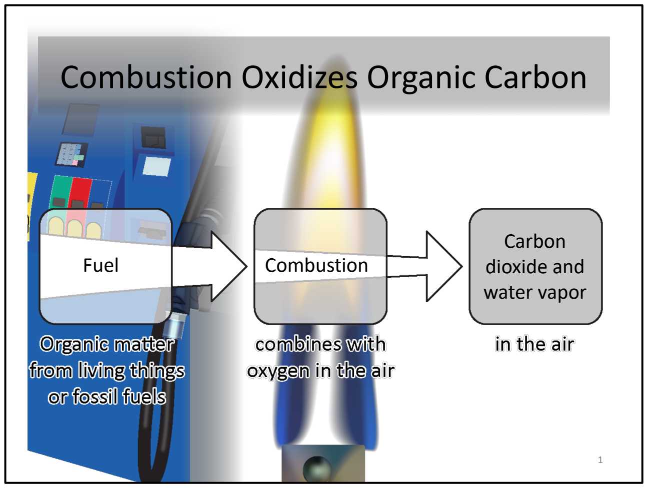
The Matter Movement Question: Tracing Molecules Through Flames (accordion)

Students learn to tell the following story of how carbon-containing molecules move through the flame in burning ethanol.

- Ethanol (C_5H_2OH) evaporates and enters the flame, along with O_2 molecules from the air.
- Carbon dioxide and water vapor leave the flame.



The Matter Change and Energy Change Questions: Explaining How Combustion Changes Organic Materials (accordion)



Matter movement is an essential part of the story, but not the whole story. To answer the driving question, students learn to explain chemical changes that occur inside flames:

- Matter Change: Students explain how the reactant molecules (ethanol and oxygen) break apart in the flame, and how their atoms then bond together to create new products (carbon dioxide molecules and water molecules).
- Energy Change: Students explain how the chemical energy in the reactant molecules, indicated by high-energy C-C and C-H bonds, is released when the products form lower-energy C=O and H-O bonds, releasing energy in the form of heat, light, and movement of air.

Students practice their explanations using multiple representations: (a) hands-on molecular models, (b) PowerPoint animations, (c) a chemical equation ($C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$), and (d) written paragraphs. They also practice on multiple examples of combustion, including combustion of methane, propane in a gas grill, octane in a gasoline engine, and wood.

How Much Detail? (accordion)

There are more complicated and more scientifically accurate ways of talking about chemical bonds and about changes in energy; we discuss some of those in detail in our educator resource: *Carbon TIME* Content Simplifications. But our learning progression research has shown that there is an important tradeoff here—many students get lost in the details and never learn a basic coherent story that answers the driving question. The *Next Generation Science Standards* take a clear position on this tradeoff; a coherent story based on principles such as matter and energy conservation is more important than the details. Consult the Unit Sequence tab to decide how much detail is appropriate for your students.

Tab 3: Unit Sequence

Before beginning the *Systems and Scale Unit*, you need to decide what to teach and importantly, what not to teach! Use this page to choose the unit sequence that's most appropriate for your students.

- Optional activities in the *Systems and Scale Unit* are designed to provide supportive learning opportunities for students who have not previously studied or who are still working to develop proficiency with regard to reasoning about scale and chemical change. Use your professional judgment to decide whether or not to teach each optional lesson or activity.

Unless otherwise noted in the table below, all activities in the unit should be taught.

Systems and Scale Unit Sequence and Decisions Table

Lesson	Activity Sequence	Make a Decision
1 (60 min)	1.1 Systems and Scale Unit Pretest (20 min)	

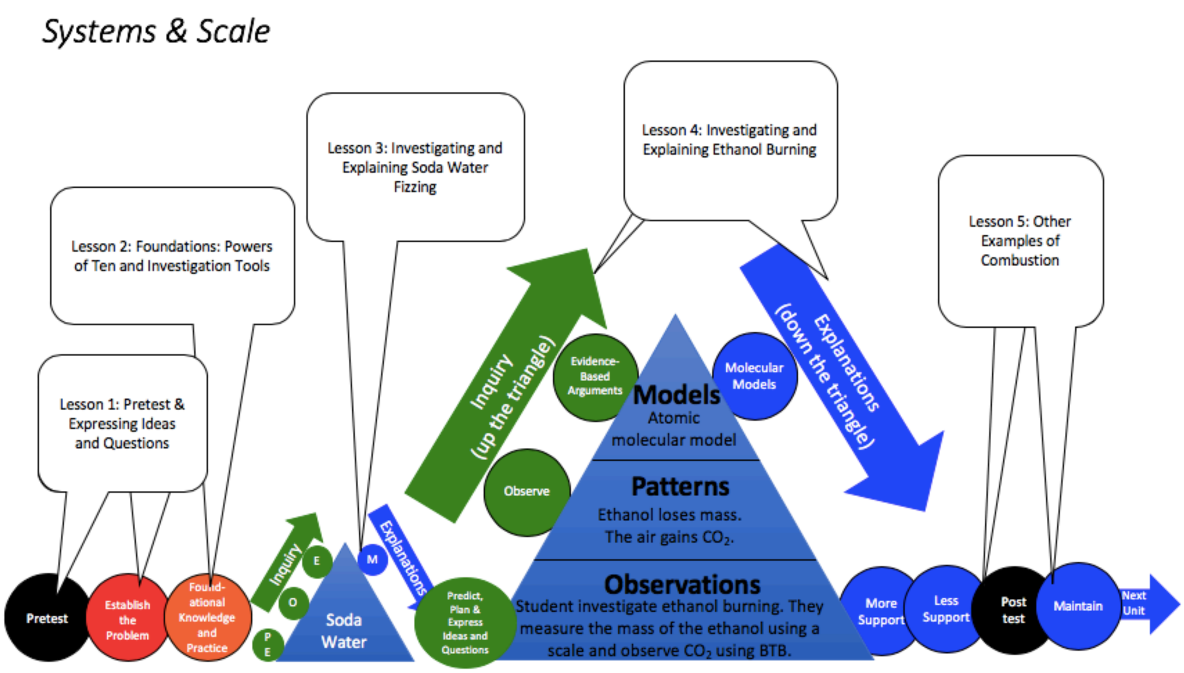
	1.2 Expressing Ideas and Questions About Ethanol Burning (40 min)	
2 (2 hr 30 min)	2.1 Powers of Ten Video and Discussion (30 min)	
	(Optional) 2.2 From Big to Small (30 min)	This activity provides students with a tactile opportunity to continue exploring scale. **Decide if this will be helpful for your students.**
	2.3 Zooming into Air (30 min)	
	2.4 Atoms and Molecules Quiz and Discussion (30 min)	
	2.5 Using a Digital Balance and BTB (30 min)	
(Optional) 3 (3 hr)	3.1 Predictions About Soda Water Fizzing (20 min)	For students with little experience of chemistry or chemical change, the complicated change in Lesson 4 (burning ethanol) is a heavy load. Lesson 3 provides an option to engage students with *Carbon TIME* activity structures (investigations, molecular modeling, chemical equations to explain chemical changes) in the simpler chemical change context of soda water fizzing. **Decide if this extra, simpler introductory experience will be helpful for your students.**
	3.2 Observing Soda Water Fizzing (30 min)	
	3.3 Evidence-Based Arguments about Soda Water Fizzing (45 min)	
	3.4 Molecular Models for Soda Water Fizzing (45 min)	
	3.5 Explaining Soda Water Fizzing (40 min)	
4 (3 hr 20 min)	4.1 Predictions about Ethanol Burning (30 min)	
	4.2 Observing Ethanol Burning (30 min)	
	4.3 Evidence-Based Arguments about Ethanol Burning (50 min)	
	4.4 Molecular Models for Ethanol Burning (50 min)	
	4.5 Explaining Ethanol Burning (40 min)	There are multiple scaffolds you can choose from including example explanations, the Three Questions Explanation Checklist and a reading. **Choose options that fit your students at this time.**
5 (3 hr 30 min)	**(Optional)** 5.1 Molecular Models for Methane Burning (40 min)	Students use molecular models to model the chemical change that occurs when methane burns. **They may not need to do this if their performances in Activity 4.4 (molecular models with ethanol burning) were already proficient.**
	(Optional) 5.2 Explaining Methane Burning (40 min)	**You may want to skip this activity if your students can already construct an atomic-molecular scale explanation of what happens to matter and energy when methane burns.**
	5.3 Preparing for Future Units: Organic vs. Inorganic (40 min)	
	5.4 Explaining Other Examples of Combustion (50 min)	Activity 5.4 involves explaining combustion of different fuels. **Consider a jigsaw format with different students becoming experts on different fuels and then sharing/comparing.** You may choose to scaffold the students with the Three Questions Explanations Checklist.
	5.5 Systems and Scale Unit Posttest (40 min)	

Tab 4: IM & Storyline

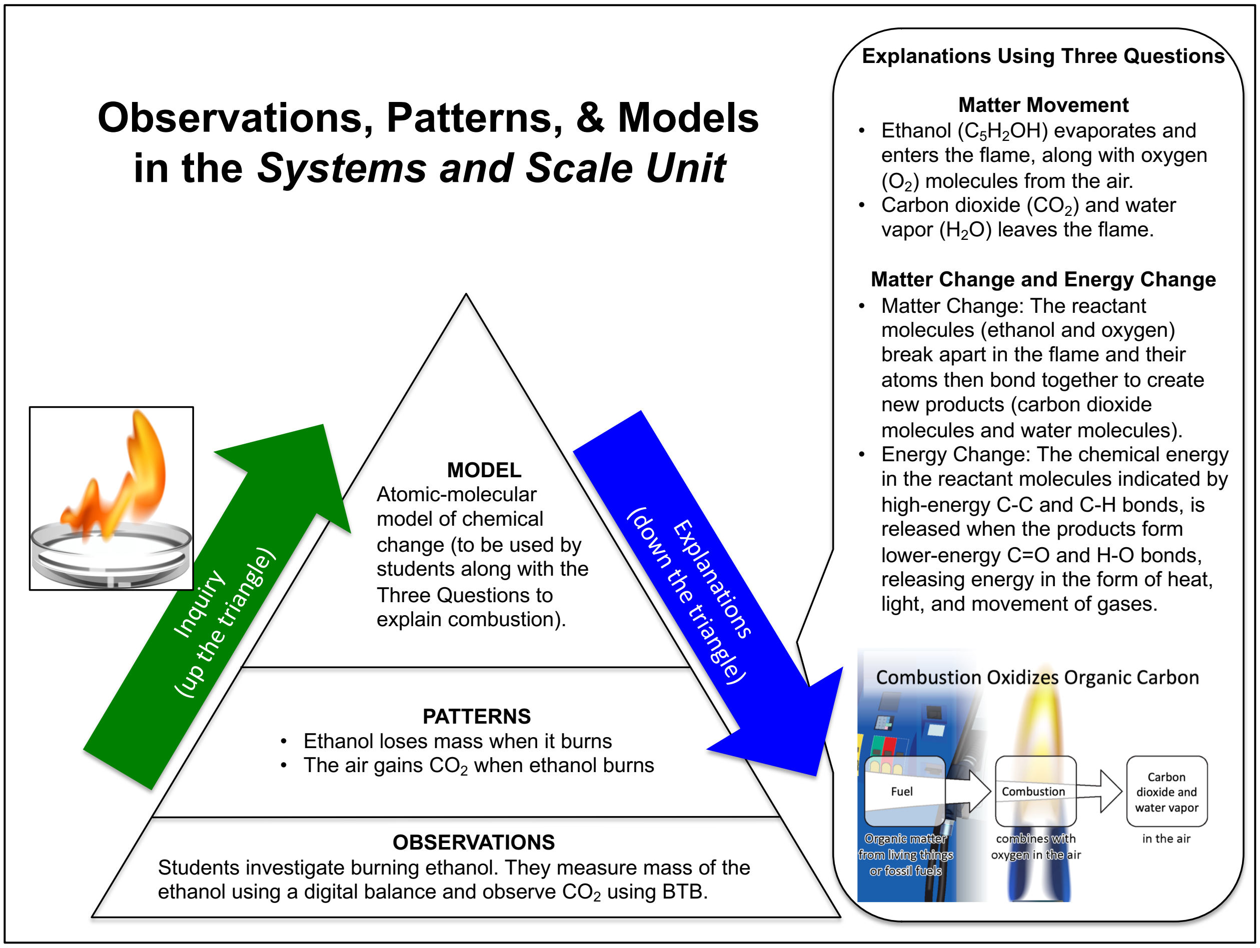
Here, we present two ways to think about how lessons are sequenced in the *Systems and Scale Unit*. The Instructional Model, immediately below, emphasizes how students take on roles of questioner, investigator, and explainer to learn and apply scientific models they can use to answer the driving question. Further below, the Unit Storyline Chart highlights the central question, activity, and answer that students engage with in each lesson of the *Systems and Scale Unit*.

Instructional Model [accordion]

Like all *Carbon TIME* units, this unit follows an instructional model (IM) designed to support teaching that helps students achieve mastery at answering the driving question through use of disciplinary content, science practices, and crosscutting concepts. To learn more about this design, see the *Carbon TIME* Instructional Model.



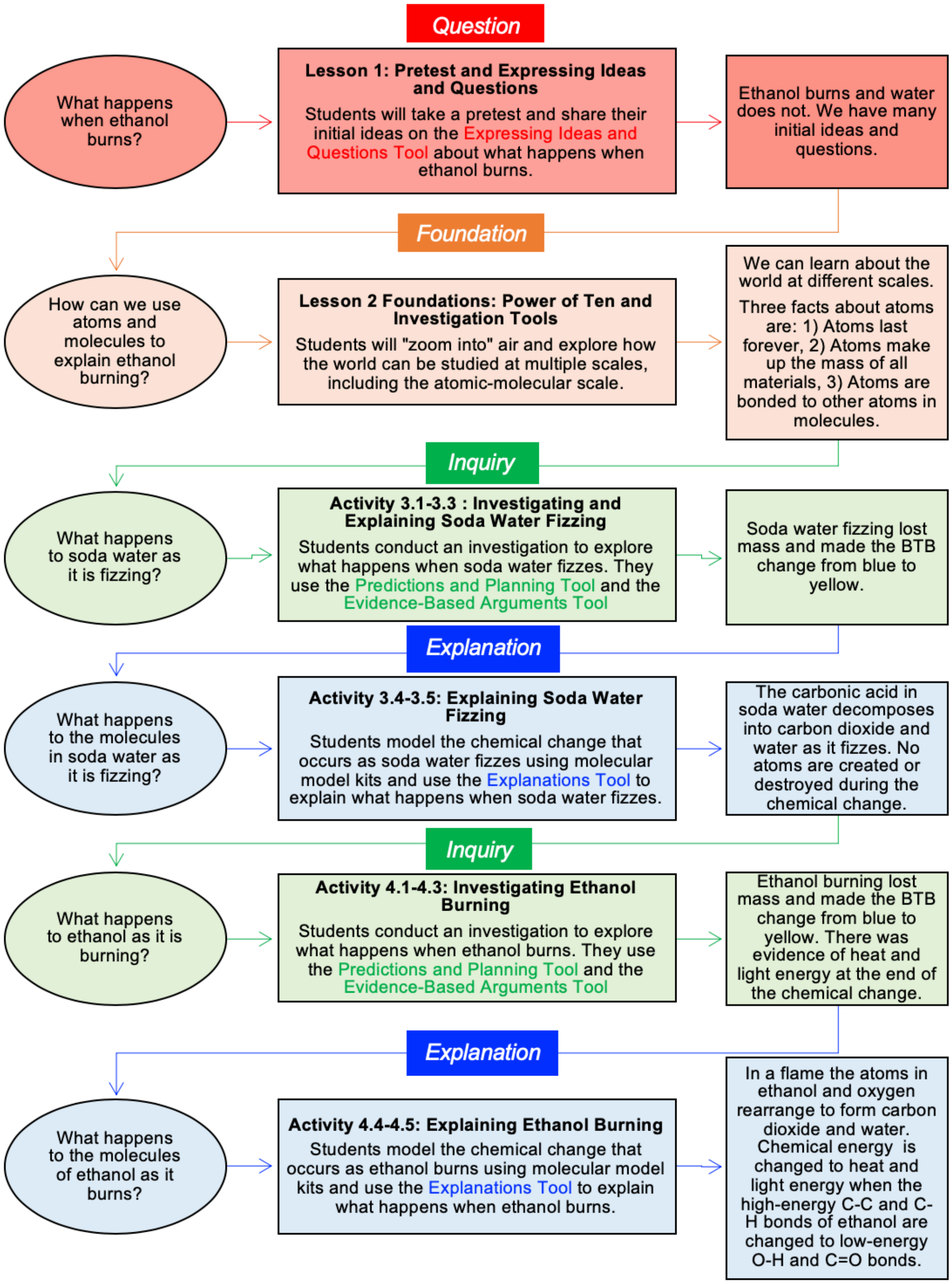
The core of the *Carbon TIME* IM is the Observation, Patterns, Models (OPM) triangle, which summarizes key aspects to be attended to as the class engages in unit inquiry and explanation. The OPM triangle for the *Systems and Scale* Unit, shown below, articulates the key observations students make during the unit investigation, the key patterns they identify through analyzing their investigation data, and the central scientific model that can be used to answer the unit's driving question. During the inquiry portions of the unit (Lessons 3 and 4), the class moves from making observations to identifying patterns, eventually using these patterns to make evidence-based arguments. During the explanation portion of the unit (Lessons 4 and 5), the class learns the atomic-molecular model, makes connections across scales, and uses atomic-molecular model to explain combustion. Across the unit, classroom discourse is a necessary part of 3-dimensional *Carbon TIME* learning. The Carbon TIME Discourse Routine document provides guidance for scaffolding this discourse in lessons.

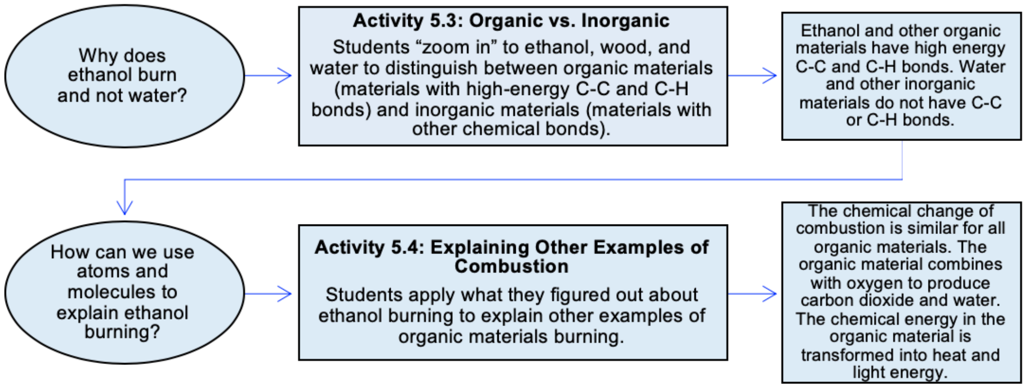


Unit Storyline Chart [accordion]

Another way to familiarize yourself with the sequence of lessons in the *Systems and Scale Unit* is with the Unit Storyline Chart depicted below. The Unit Storyline Chart summarizes a unit phenomenon-based driving question associated with each lesson, what classes will do in each lesson to address the question, what conclusions they will come to, and how they will transition to a subsequent lesson.

Download PDF of Unit Storyline Chart


Question
What happens when ethanol burns?
Lesson 1: Pretest and Expressing Ideas and Questions
Students will take a pretest and share their initial ideas on the Expressing Ideas and Questions Tool about what happens when ethanol burns.
Ethanol burns and water does not. We have many initial ideas and questions.
Foundation
How can we use atoms and molecules to explain ethanol burning?
Lesson 2 Foundations: Power of Ten and Investigation Tools
Students will "zoom into" air and explore how the world can be studied at multiple scales, including the atomic-molecular scale.
We can learn about the world at different scales.
Three facts about atoms are: 1) Atoms last forever, 2) Atoms make up the mass of all materials, 3) Atoms are bonded to other atoms in molecules.
Inquiry
What happens to soda water as it is fizzing?
Activity 3.1-3.3 : Investigating and Explaining Soda Water Fizzing
Students conduct an investigation to explore what happens when soda water fizzes. They use the Predictions and Planning Tool and the Evidence-Based Arguments Tool
Soda water fizzing lost mass and made the BTB change from blue to yellow.
Explanation
What happens to the molecules in soda water as it is fizzing?
Activity 3.4-3.5: Explaining Soda Water Fizzing
Students model the chemical change that occurs as soda water fizzes using molecular model kits and use the Explanations Tool to explain what happens when soda water fizzes.
The carbonic acid in soda water decomposes into carbon dioxide and water as it fizzes. No atoms are created or destroyed during the chemical change.
Inquiry
What happens to ethanol as it is burning?
Activity 4.1-4.3: Investigating Ethanol Burning
Students conduct an investigation to explore what happens when ethanol burns. They use the Predictions and Planning Tool and the Evidence-Based Arguments Tool
Ethanol burning lost mass and made the BTB change from blue to yellow. There was evidence of heat and light energy at the end of the chemical change.
Explanation
What happens to the molecules of ethanol as it burns?
Activity 4.4-4.5: Explaining Ethanol Burning
Students 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.



Tab 5: *Unit Goals*

The tables below show goals for this unit in two forms. A table showing specific target performances for each activity is followed by a list of the *Next Generation Science Standards (NGSS)* addressed by this unit.

Target Performances for Each Activity [accordion]

Download PDF of Unit Target Performances

All *Carbon TIME units* are organized around a common purpose: *assessing and scaffolding students' three-dimensional engagement with phenomena.* Every *Carbon TIME* activity has its specific expectation for students' three-dimensional engagement with phenomena, what we call its **target performance**. Each activity also includes tools and strategies that teachers can use to asses and scaffold the target performance in rigorous and responsive ways.

The target performances for each activity in the *Systems and Scale* unit are listed in the table below.

Activity	***Target Performance***
Lesson 1 – Pretest and Expressing Ideas and Questions (students as questioners)	
Activity 1.1: Systems and Scale Unit Pretest	Students show their initial proficiencies for the overall unit goal: Questioning, investigating, and explaining how matter and energy changed during combustion of organic materials.
Activity 1.2: Expressing Ideas and Questions about Ethanol Burning (40 min)	Students ask and record specific questions about changes in matter and energy in response to the unit driving question: What happens when ethanol burns?
Lesson 2 – Foundations: Powers of Ten and Investigation Tools (students developing foundational knowledge and practice)	
Activity 2.1: Powers of Ten Video and Discussion (30 min)	Students discuss how all systems can be analyzed by "zooming in" and "zooming out" through a hierarchy of systems at different scales.
(Optional) Activity 2.2: From Big to Small (30 min)	Students organize images to "zoom in" and "zoom out" of six different systems at four different scales:

Activity	***Target Performance***
	atomic-molecular, microscopic, macroscopic, and large scales.
Activity 2.3: Zooming into Air (30 min)	Students describe air at atomic-molecular, microscopic, macroscopic, and large scales, identifying specific molecules in air.
Activity 2.4: Atoms and Molecules Quiz and Discussion (30 min)	Students apply the principle of matter conservation to atoms and molecules in different phenomena.
Activity 2.5: Using a Digital Balance and BTB (30 min)	Students (a) practice using two key tools for investigation—digital balances and BTB—with accuracy and precision and (b) describe how they can use these tools to detect matter movement and matter change.
(Optional) Lesson 3 – Investigating and Explaining Soda Water Fizzing (students as investigators and explainers)	
Activity 3.1: Predictions about Soda Water Fizzing (20 min)	Students develop hypotheses about how matter moves and changes when soda water loses its fizz and make predictions about how they can use their investigation tools—digital balances and BTB—to detect movements and changes in matter.
Activity 3.2: Observing Soda Water Fizzing (30 min)	Students record data about changes in mass and BTB when soda water fizzes and reach consensus about patterns in their data.
Activity 3.3: Evidence-Based Arguments about Soda Water Fizzing (45 min)	Students (a) use data from their investigations to develop evidence-based arguments about matter movements and matter changes when soda water fizzes, and (b) identify unanswered questions about matter movement and matter change that the data are insufficient to address.
Activity 3.4: Molecular Models for Soda Water Fizzing (45 min)	Students use molecular models to explain how carbon, oxygen, and hydrogen atoms are rearranged into new molecules during the decomposition of carbonic acid (the chemical change that happens when soda water fizzes).
Activity 3.5: Explaining Soda Water Fizzing (40 min)	Students explain how matter moves and changes when soda water loses its fizz (connecting macroscopic observations with atomic-molecular models and using the principle of conservation of matter).

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 and matter changes when ethanol burns, and (b) identify unanswered questions about matter movement and matter 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).
Lesson 5 – Other Examples of Combustion (students as explainers)	
(Optional) Activity 5.1: Molecular Models for Methane Burning (40 min)	Students use molecular models to explain how carbon, oxygen, and hydrogen atoms are rearranged into new molecules during the oxidation of methane (the chemical change that happens when methane burns).
(Optional) Activity 5.2: Explaining Methane Burning (40 min)	Students explain how matter moves and changes and how energy changes when methane burns (connecting macroscopic observations with atomic-molecular models and using the principles of conservation of matter and energy).
Activity 5.3: Preparing for Future Units: Organic vs. Inorganic (40 min)	Students distinguish between organic and inorganic materials on the basis of both their functions (organic materials include foods, fuels, and the bodies of living things) and the chemical structure of

Activity	***Target Performance***
	their molecules (organic materials contain high-energy C-C and C-H bonds).
Activity 5.4: Explaining Other Examples of Combustion (50 min)	Students explain how matter moves and changes and how energy changes when other organic fuels burn, including (a) wood burning in a fireplace, (b) propane burning in a gas grill, and (c) octane burning in an internal combustion engine.
Activity 5.5: Systems and Scale Unit Posttest (40 min)	Students show their end-of-unit proficiencies for the overall unit goal: Questioning, investigating, and explaining how matter and energy changed during combustion of organic materials.

Next Generation Science Standards [accordion]

The *Next Generation Science Standards* (*NGSS*) performance expectations that middle and high school students can achieve through completing the Systems and Scale Unit are listed below. To read a discussion of how the *Carbon TIME* project is designed to help students achieve the performances represented in the NGSS, please see Three-dimensional Learning in *Carbon TIME*.

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: http://www.nextgenscience.org/hsps-cr-chemical-reactions
- Chemical Reactions. HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction: http://www.nextgenscience.org/hsps-cr-chemical-reactions

Middle School

- Structures and Properties of Matter. MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures: http://www.nextgenscience.org/msps-spm-structure-properties-matter
- 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: http://www.nextgenscience.org/msps-cr-chemical-reactions
- 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: http://www.nextgenscience.org/msps-cr-chemical-reactions

Tab 6: Materials

Materials You Provide [accordion]

Activity 1.1: Systems and Scale Unit Pretest (20 min)

- Pencils (1 per student, for paper version)

- Computer with an Internet connection (1 per student, for online version)

Activity 1.2: Expressing Ideas and Questions about Ethanol Burning (40 min)

- Sticky notes (1 per student)
- ethanol, 95% (10-15 ml)
- water (10-15 ml)
- lighter (1)
- Petri dish, glass (1)
- Petri dish, plastic (1)

Activity 2.3: Zooming Into Air (30 min)

- Piece of paper (1 per student)

Activity 2.4: Atoms and Molecules Quiz and Discussion (30 min)

- Pencils (1 per student)

Activity 2.5: Using a Digital Balance and BTB (30 min)

- BTB, blue (1 cup per group of four students)
- Clear plastic cups (1 per group of four students)
- Digital balance (1 per group of four students)
- Paper clips (10 per group of four students)
- Safety glasses (1 per group of four students)
- Straws (1 per group of four students)

Activity 3.1: Predictions about Soda Water Fizzing (20 min)

- Petri dish, plastic (1 per class)
- Soda water (1 cup per class)

Activity 3.2: Observing Soda Water Fizzing (30 min)

- BTB, blue (less than 1 cup per group of four students)
- Digital balance (1 per group of four students)
- Petri dish, plastic (2 per group of four students)
- Sealable, 9.5-Cup container (1 per group of four students)
- Soda water (less than 1 cup per group of four students)
- (From previous activity) 3.1 Predictions Tool for Soda Water Fizzing

Activity 3.3: Evidence-Based Arguments for Soda Water Fizzing (50 min)

- (From previous activity) 3.2 Observing Soda Water Fizzing Worksheet
- (From previous activity) 3.2 Soda Water Fizzing Class Results 11 x 17 Poster (or spreadsheet)

Activity 3.4: Molecular Models for Soda Water Fizzing (40 min)

- Molecular model kit (1 per pair of students)

Activity 3.5: Explaining Soda Water Fizzing (40 min)

- (From previous activity) 3.3 Evidence-Based Arguments Tool for Soda Water Fizzing

Activity 4.1: Predictions about Ethanol Burning (30 min)

- (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 of demonstration of ethanol burning

Activity 4.2: Observing Ethanol Burning (30 min)

- 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)
- Large plastic container with aluminum foil taped inside to protect the bottom from the ethanol flame (1 per group of four students)
- Ethanol, 95% (10-15 ml per group)
- 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 Tool for Ethanol Burning with student answers

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

- (From previous activity) 4.2 Observing Ethanol Burning Worksheet
- (From Previous Activity) 4.2 Ethanol Burning Class Results 11 x 17 Poster (or spreadsheet) (1 per class)

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

- Molecular model kit (1 per pair of students)
- Scissors (1 per pair of students)
- Twist ties (at least 12 per pair of students)

Activity 4.5: Explaining Ethanol Burning (40 min)

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

(Optional) Activity 5.1: Molecular Modeling for Methane Burning (40 min)

- Molecular modeling kit (1 per pair of students)
- Scissors (1 per pair of students)
- Twist ties (12 per pair of students)

Activity 5.3: Preparing for Future Units – Organic vs. Inorganic (40 min)

- (From previous activity) 1.2 Expressing Ideas and Questions about Ethanol Burning with student ideas

Activity 5.5: Systems and Scale Unit Posttest (20 min)

- Pencils (1 per student, for paper version)
- Computer with an Internet connection (1 per student, for online version)

Materials Available on the Website [accordion]

Recurring Resources

- Powers of Ten 11 x 17 Poster (1 per class)
- Powers of Ten with Pictures 11 x 17 Poster (1 per class)
- Learning Tracking Tool for Systems and Scale
- Assessing the Learning Tracking Tool for Systems and Scale

- (Optional) Big Idea Probe: Fill 'Er Up
- (Optional) Assessing the Big Idea Probe: Fill 'Er Up
- Example Systems and Scale Explanations Handout (1 per student or per group)
- Burning Ethanol Video
- Using Big Idea Probes
- Three Questions Handout
- Three Questions 11x17 Poster
- Molecular Models 11 x 17 Placemat (1 per pair of students)
- Molecule 11 x 17 Poster (1 per class)
- Forms of Energy Cards (1 set per pair of students)
- BTB Color Handout
- BTB Instruction and Information Handout
- Engaging Students with Readings and the Questions, Connections, Questions Reading Strategy Educator Resource
- Questions, Connections, Questions Student Reading Strategy

Activity 1.1: Systems and Scale Unit Pretest (20 min)

- Systems and Scale Unit Pretest (1 per student or online)
- Assessing Systems and Scale Unit Pretest

Activity 1.2: Expressing Ideas and Questions about Ethanol Burning (40 min)

- 1.2 Expressing Ideas and Questions Tool for Ethanol Burning (1 per student)
- 1.2 Assessing the Expressing Ideas and Questions Tool for Ethanol Burning
- 1.2 Expressing Ideas and Questions about Ethanol Burning PPT
  1.2 Systems and Scale Storyline Reading: Learning from the Work of Elizabeth Fulhame (1 per student)

Activity 2.1: Powers of Ten Video and Discussion (30 min)

- Powers of Ten video (http://www.youtube.com/watch?v=0fKBhvDjuy0)
- 2.1 Powers of Ten PPT

(Optional) Activity 2.2: From Big to Small (30 min)

- 2.2 Powers of Ten Cards (1 per group)

Activity 2.3: Zooming into Air (30 min)

- 2.3 Zooming Into Air PPT

Activity 2.4: Atoms and Molecules Quiz and Discussion (30 min)

- 2.4 Atoms and Molecules Quiz (1 per student)
- 2.4 Grading the Atoms and Molecules Quiz

Activity 2.5: Using a Digital Balance and BTB (30 min)

- 2.5 Investigation Tools PPT
- 2.5 Class Results for Investigation Tools 11 x 17 Poster (1 per class)
- 2.5 Class Results for Investigation Tools Spreadsheet (1 per class)

Activity 3.1: Predictions about Soda Water Fizzing (20 min)

- 3.1 Predictions about Soda Water Fizzing PPT

- 3.1 Predictions Tool for Soda Water Fizzing (1 per student)
- 3.1 Assessing the Predictions Tool for Soda Water Fizzing

Activity 3.2: Observing Soda Water Fizzing (30 min)

- 3.2 Soda Water Fizzing Class Results 11 x 17 Poster (or spreadsheet) (1 per class)
- 3.2 Observing Soda Water Fizzing Worksheet (1 per student)
- 3.2 Assessing the Observing Soda Water Fizzing Worksheet
- 3.2 Observing Soda Water PPT

Activity 3.3: Evidence-Based Arguments for Soda Water Fizzing (50 min)

- 3.3 Evidence-Based Arguments Tool for Soda Water Fizzing (1 per student)
- 3.3 Assessing the Evidence-Based Arguments Tool for Soda Water Fizzing
- 3.3 Evidence-Based Arguments Tool for Soda Water Fizzing PPT

Activity 3.4: Molecular Models for Soda Water Fizzing (40 min)

- 3.4 Molecular Models for Soda Water Fizzing Worksheet (1 per student)
- 3.4 Grading the Molecular Models for Soda Water Fizzing Worksheet
- 3.4 Molecular Models for Soda Water Fizzing PPT

Activity 3.5: Explaining Soda Water Fizzing (40 min)

- 3.5 Explanations Tool for Soda Water Fizzing Worksheet (1 per student)
- 3.5 Explaining Soda Water Fizzing PPT
- 3.5 Grading the Explanations Tool for Soda Water Fizzing

Activity 4.1: Predictions about Ethanol Burning (30 min)

- 4.1 Predictions about Ethanol Burning PPT
- 4.1 Predictions Tool for Ethanol Burning (1 per student)
- 4.1 Assessing the Predictions Tool for Ethanol Burning
- 4.1 Good Answers to Scientific Questions Reading (1 per student)

Activity 4.2: Observing Ethanol Burning (30 min)

- 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

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

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

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

- 4.4 Molecular Models for Ethanol Burning PPT
- 4.4 Molecular Models for Ethanol Burning Worksheet (1 per student)
- 4.4 Grading the Molecular Models for Ethanol Burning Worksheet (1 per student)
- 4.4 Molecular Models for Ethanol Burning Reading (1 per student)

Activity 4.5: Explaining Ethanol Burning (40 min)

- 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) 4.5 Grading the Matter Tracing Tool

(Optional) Activity 5.1: Molecular Modeling for Methane Burning (40 min)

- 5.1 Molecular Models for Methane Burning PPT
- (Optional) 5.1 Molecular Models for Methane Burning Worksheet (1 per student)
- (Optional) 5.1 Grading Molecular Models for Methane Burning Worksheet

(Optional) Activity 5.2: Explaining Methane Burning (40 min)

- 5.2 Explanations Tool for Methane Burning (1 per student)
- 5.2 Explaining Methane Burning PPT
- 5.2 Grading the Explanations Tool for Methane Burning

Activity 5.3: Preparing for Future Units – Organic vs. Inorganic (40 min)

- 5.3 Organic vs. Inorganic PPT
- 5.3 Materials Cards (1 set per pair of students)
- 5.3 Organic vs. Inorganic Worksheet (1 per student)
- 5.3 Grading the Organic vs. Inorganic Worksheet
- (Optional) 5.3 More About Chemical Energy Reading (1 per student)

Activity 5.4: Explaining Other Examples of Combustion (50 min)

- 5.4 Other Examples of Combustion PPT
- 5.4 Other Organic Materials Reading: Octane, Gasoline, and Internal Combustion Engines
- 5.4 Other Organic Materials Reading: Propane, and Propane Combustion
- 5.4 Other Organic Materials Reading: Cellulose, and Combustion of Wood
- 5.4 Explaining Combustion of Octane Worksheet
- 5.4 Explaining Combustion of Propane Worksheet
- 5.4 Explaining Combustion of Cellulose Worksheet
- 5.4 Grading the Explaining Combustion of Octane Worksheet
- 5.4 Grading the Explaining Combustion of Propane Worksheet
- 5.4 Grading the Explaining Combustion of Cellulose Worksheet
- (Optional) 5.4 Digging Deeper Gasoline Reading

Activity 5.5: Systems and Scale Unit Posttest (20 min)

- 5.5 Grading the Systems and Scale Unit Posttest
- 5.5 Systems and Scale Unit Posttest