Lesson 2 Foundations: Powers of Ten and Investigation Tools

Overview

Download PDF of Lesson 2 Teacher's Guide

Students view the Powers of Ten video and discuss how all systems can be described at multiple scales. Then students learn that atoms last forever in physical and chemical changes. Finally, students practice using a digital balance and BTB, key tools in *Carbon TIME* units.

Guiding Question

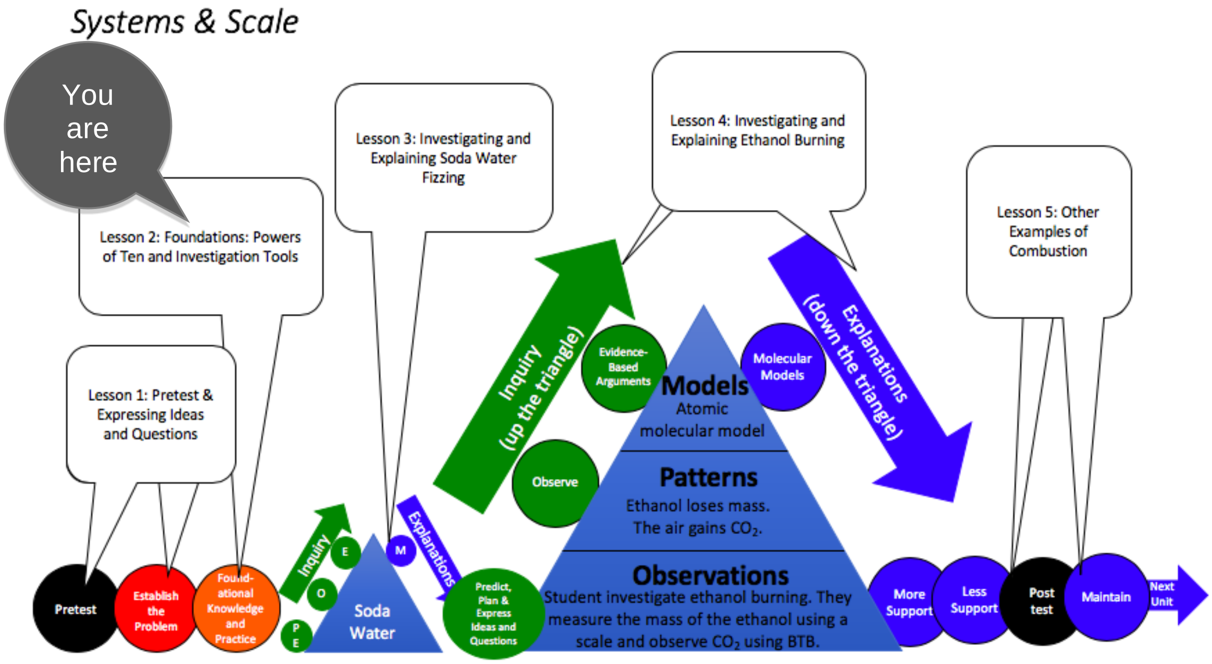
What do materials look like at smaller and smaller scales?

Activities in this Lesson

Note: Activity 2.2 is optional depending on the academic level of your students. See the Systems and Scale Unit Read Me file for more information to consider when making this choice.

- Activity 2.1: Powers of Ten Video and Discussion (30 min)
- (Optional) Activity 2.2: From Big to Small (30 min)
- Activity 2.3: Zooming into Air (30 min)
- Activity 2.4: Atoms and Molecules Quiz and Discussion (20 min)
- Activity 2.5: Using a Digital Balance and BTB (30 min)

Unit Map



Tab 2: Learning Goals

Target Performances

Activity	***Target Performance***
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: 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.

NGSS Performance Expectations

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.

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.

Background Information

Three-dimensional Learning Progression

Lesson 2 focuses on essential foundational knowledge that students will need to achieve the objectives for this unit. Although most students will be familiar with the words "atoms" and "molecules," they may not be able to use ideas about atoms and molecules to explain events in the world. This lesson introduces the hierarchy of scales and key facts about atoms that students will use in all future units. The activities in this lesson serve as the Foundational Phase of the Instructional Model, where students are introduced to key ideas and practices that they will use throughout the rest of the *Systems and Scale* unit.

Key Ideas and Practices for Each Activity

In Activity 2.1, the Powers of Ten video introduces a fundamental scientific principle: Our world is organized into a hierarchy of systems at different scales, most of which are too small or too large for us to see directly. Powers of Ten is one way to step down or step up through the different scales so that students can make accurate comparisons between sizes and make connections between processes happening on one scale with processes happening on another. *Carbon TIME* focuses on the connections among systems and processes at four different scales:

- The large scale: ecosystems and Earth systems (roughly from about 1 km (10^3 m) to the size of the Earth: over 10,000 km (10^7 m))
- The macroscopic scale: systems and processes we can see with our naked eyes (roughly from about 1 mm (10^{-3} m) to one kilometer (10^3 m)).
- The cellular scale: systems and processes that happen inside cells, some of which we can observe with a microscope (roughly from about 10^{-4} m to 10^{-7} m)
- The atomic-molecular scale: Atoms and molecules (roughly from about 10^{-10} m to 10^{-8} m).

Note that between the atomic-molecular and the macroscopic scale there is another broad benchmark scale—the microscopic or cellular scale. While *Carbon TIME* does not emphasize the microscopic scale, students still need to understand that atoms and molecules are much smaller than this benchmark scale; even the best light microscopes cannot see atoms or molecules.

In Activity 2.2, an introductory and optional activity at the high school level, students sort a set of cards with images of systems into the four benchmark scales and talk about how a particular system at the macroscopic scale is part of a larger system, and also composed of smaller systems, including atoms and molecules. This activity will help students understand that processes and systems occur simultaneously on each scale.

In Activity 2.3, students discuss air at all four benchmark scales. Air is an especially important material that Level 2 students may not recognize as a material that has mass. Many Level 2 students think of air as ephemeral, weightless, and not necessarily composed of atoms or molecules. The 2.3 Zooming Into Air PPT and discussion in this activity will help students understand how air looks at multiple scales, from large scale down to atomic-molecular scale. Students will also learn that air contains four important molecules: N_2, O_2, H_2O, and CO_2, and the atoms that these molecules are made of are C, H, O, and N. These atoms are the key atoms in all carbon-transforming processes. Importantly, the student is introduced to three essential facts about atoms that they will be expected to remember and use throughout all *Carbon TIME* units:

- Atoms last forever (except in nuclear changes).
- Atoms make up the mass of all materials.
- Atoms are bonded to other atoms in molecules.

In Activity 2.4, the 2.4 Atoms and Molecules Quiz checks students understanding about the hierarchy of scales and the three key facts about atoms and molecules. The quiz requires students to apply these ideas to new situations that they have not yet discussed in class.

In Activity 2.5, students practice using two essential tools in *Carbon TIME* units:

- Digital balances are used in the units to detect movement of atoms (the Movement Question) by measuring differences in mass. This activity introduces students to the balances, allows every student to weigh something, and compares results.
- Bromothymol blue (BTB) is an indicator that changes from blue to yellow in response to high levels of CO_2. Students will see how blue BTB responds to a gas that most students know as a source of CO_2: their exhaled breath.

Key carbon-transforming processes: Combustion

Content Boundaries and Extensions

Talk and Writing

At this stage in the unit, the students will be learning **Foundational Knowledge and Practice** that is important for the rest of the unit. The table below shows specific talk and writing goals for this phase of the unit.

Talk and Writing Goals for the Foundations Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Treat this as background information.	*We want to talk about a few basic practices and some basic knowledge to prepare us for the unit.*	
Listen for student ideas about **matter** and	*What is happening to matter and energy at _______ scale? Who can explain?*	The **PPT** that “Zooms into” the macroscopic

energy at different **scales** and attend to wrong ideas.	*Are you in the macroscopic scale or the atomic-molecular scale?* *Who can explain that at a different scale?*	subjects of the unit: a leaf, a potato, air, fossil fuels, etc.
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** at different **scales**.	*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?* *Let's revisit our scale poster… what is happening to matter at a macroscopic scale?*	Powers of Ten Video Powers of Ten Poster Molecule Poster Three Questions Poster
Grade student ideas.		There is a **quiz** during this phase of the unit to help you decide if your students are ready to move on.

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

Overview and Preparation

Target Student Performance

Students discuss how all systems can be analyzed by “zooming in” and “zooming out” through a hierarchy of systems at different scales.

Resources Provided

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

Recurring Resources

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

Setup

Print one copy of Powers of Ten 11 x 17 Poster display on your classroom wall. Prepare a computer with an Internet connection and a projector to watch the Powers of Ten video.

Directions

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

Show slide 2 of the 2.1 Powers of Ten PPT.

2. Introduce students to the Powers of Ten.

Explain to students that they will watch a short film looking at how the same location can have many different systems at different scales:

Post the Powers of Ten 11 x 17 Poster on a wall in your classroom where all students can see it. Alternatively, project slide 3 of the 2.1 Powers of Ten PPT so all students can see.

Lead a whole class discussion about the poster to help students become familiar with its key features. Here are suggested questions:

- Ask students to identify words that are familiar to them.
- Ask for students’ interpretations of the four benchmark scales across the top of the poster: atomic-molecular, microscopic, macroscopic, large scale.
- Ask students about what each scale means: “*What does macroscopic mean?”* (It means the size of things we can see easily around us). Have students offer examples of objects that go in each scale.
- Ask for students’ interpretations of the units of length in the ovals at the bottom.
- Ask students what they can measure with those units and have students give examples of distances around that size.

Point out that the numbers on the bottom use exponents—Powers of Ten—to give sizes in meters. Explain that the video they will watch will show them what this means.

3. Watch the Powers of Ten video.

Before they watch, divide students into four groups, one for each scale on the poster. As they watch the video, have each group note a different system or object from their designated scale.

Watch the Powers of Ten video (http://www.youtube.com/watch?v=0fKBhvDjuy0), which lasts about 10 minutes.

Accommodation: Stop the video periodically to allow students to discuss their notes with their group and/or ask questions.

4. Have students discuss the video.

Have students share their observations of the video. Ask student groups to report the systems they saw in the video at each of the four benchmark scales. Tell students that all systems are like the picnic in the video: they exist and can be explained at multiple scales. For example, explain that in order to understand what happens when ethanol burns, they will need to focus on two of the benchmark scales: the macroscopic and atomic-molecular scales.

5. Compare water and ethanol at the atomic-molecular scale.

Ask students for their ideas about what water and ethanol might look like at the atomic molecular scale. See whether students' responses illustrate a familiarity with the molecular formula for water: H_2O. Tell students that by the end of the unit they will investigate ethanol and a flame at the atomic-molecular scale.

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

Show slide 5 of the 2.1 Powers of Ten PPT.

- Pass out a Learning Tracking Tool for Systems & Scale to each student.
- 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 in the first column, "Powers of Ten."
- 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?
Zooming into Air	"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.	How can we use atoms and molecules to explain ethanol burning?

7. Have students complete an exit ticket.

Show slide 6 of the 2.1 Powers of Ten PPT.

- Conclusions: Why do scientists consider things and multiple scales?
- Predictions: What molecules would you expect to find in a drop of water?
- 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

Assessment takes place in Step 5 of the activity when students share ideas about what ethanol and water might look like at the atomic-molecular scale. Although many students will be familiar with the molecular formula for water, fewer students will understand what that means - that a water molecule has two hydrogen atoms and one oxygen atom. Very few students will know the formula for ethanol (C_2H_5OH). Even students who know the meaning of the formulas may not be able to connect atomic-molecular scale formulas with macroscopic-scale phenomena. For example, they may have trouble drawing what water molecules look like in a drop of water or as water vapor in the air.

Differentiation & Extending the Learning

Make sure that students are watching actively by assigning them to identify the systems at one of the four benchmark scales: atomic-molecular, microscopic, macroscopic, or large scale.

Differentiation

Modifications

Extending the Learning

Students can explore these Powers of Ten on interactive websites:

- Scale of Universe: http://htwins.net/scale2/
- Cell Size and Scale: http://learn.genetics.utah.edu/content/cells/scale/
- The Universe Within: http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/
- Cosmic Voyage with Morgan Freeman narration: https://www.youtube.com/watch?v=qxXf7AJZ73A

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

Overview and Preparation

Target Student Performance

Students organize images to “zoom in” and “zoom out” of six different systems at four different scales: atomic-molecular, microscopic, macroscopic, and large scales.

Accommodation: If you have a number of students with special needs in your class, it’s recommended to do this optional activity.

Resources Provided

- 2.2 Powers of Ten Cards (1 per group)

Recurring Resources

- Powers of Ten 11 x 17 Poster (1 per class)
- Powers of Ten with Pictures 11 x 17 Poster (1 per class)

Setup

Print one copy of the Powers of Ten 11 x 17 Poster for each group. Print one copy of 2.2 Powers of Ten Cards for each group. Either cut the cards apart before class, or have the students cut the cards in their groups.

Directions

1. Have students explore the Powers of Ten websites.

This activity has introductory materials that make it optional at the high school level. Show students websites that illustrate the Powers of Ten (see links in the **Extending the Learning** section below).

2. Have students sort cards according to scale.

Divide students into groups of four. Pass out one copy of the Powers of Ten 11 x 17 Poster to each group, or a smaller version as a handout. Give one copy of 2.2 Powers of Ten Cards to each group. Each individual student should get about six cards.

- Ask students to place their cards on the correct scale on the poster—large scale, macroscopic scale, microscopic scale, or atomic-molecular scale. Tell students they can use the interactive websites and discuss among themselves to determine the scale each card should go on.
- Have students work in groups for about 10-20 minutes, placing each card into one of the four categories.

Ask students to think of examples of similar systems or objects (plant, people, water, fuel, fire, pollen) at different scales (large, macro, micro, atomic-molecular).

3. Have students discuss the sorting process.

Ask each group of students to share with their classmates where they placed one or two cards. Have students in each group reveal any questions they had about cards they were not sure of.

- Discuss their questions with the class as a whole.

- If they don't notice on their own, point out that the cards are organized into groups: plants, people, water, fuel, fire, and pollen systems.

4. Discuss why scientists think about scales.

Tell students that scientists try to understand systems at many different scales. Ask students why they think scientists might use scale as a tool to interpret the world.

In the next activity they will be looking at a very important system at different scales—air.

Place a copy of the Powers of Ten with Pictures 11 x 17 Poster on the wall in the classroom for future reference. This version has examples of objects and systems at each scale.

Assessment

Notice students' successes and difficulties in placing images at the appropriate Powers of Ten benchmark scales.

Modifications & Extending the Learning

Differentiation

Modifications

- Use this optional activity for students who are less experienced with systems at different scales.
- Have students use the microscope to look at cells to get a better sense of scale.

Tips

- Focus on the four benchmark scales (e.g., atomic-molecular) rather than the exact Power of Ten (e.g., 10^{-8} m) for each picture.
- The Powers of Ten with Pictures 11 x 17 Poster has images on the poster that are only to be referenced after this activity is completed, so make sure to wait until the end of the activity to post this version of the poster.

Extending the Learning

Have students explore these websites about scale on their own:

- Scale of Universe: http://htwins.net/scale2/
- Cell Size and Scale: http://learn.genetics.utah.edu/content/begin/cells/scale/
- The Universe Within: http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/
- Cosmic Voyage with Morgan Freeman narration: https://www.youtube.com/watch?v=qxXf7AJZ73A

Activity 2.3: Zooming into Air (30 min)

Overview and Preparation

Target Student Performance

Students describe air at atomic-molecular, microscopic, macroscopic, and large scales, identifying specific molecules in air.

Resources You Provide

- piece of paper (1 per student)

Resources Provided

- 2.3 Zooming Into Air PPT

Recurring Resources

- Learning Tracking Tool for Systems and Scale (1 per student)
- Assessing the Learning Tracking Tool for Systems and Scale

Setup

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 2.3 Zooming Into Air PPT.

2. Elicit students' ideas about air.

Show students Slide 2 of the 2.3 Zooming Into Air PPT. Ask students to discuss what is air made out of, and vote on whether air has mass, and whether air is made of atoms. Note students' ideas and discuss them as they go through the activity.

3. Discuss what students see when they are zooming into air.

View slides 4-8 to zoom into air from large scale down to the smallest droplets so students can see air at the macro and micro scales. While zooming in, discuss how each scale is measured, and if you can see each scale with the naked eye. Use Slides 8-9 to continue to zoom down to the atomic-molecular scale. Ask students if this matched their initial ideas about what air is made out of.

- Note: Slides 4-10 use animations. View in "Presentation Mode" to see the animations.

4. Have students discuss atoms and molecules in air.

Show students Slides 11-14, which are about atoms and molecules in air.

- Show students slide 11 and compare percentages of gases in air. Explain to students that even though they are very important, CO_2 and water vapor make up only a very small portion of the molecules in air. Tell students that Argon (Ar) is an inert gas - one of the few elements whose atoms do not bond to other atoms in molecules. Ask students if this matches their ideas about what air is made out of.

5. **Have students make a T-chart with atoms and molecules.**

Have students make two columns on a piece of paper—a T-chart. Instruct them to label one column "atoms" and the second column "molecules."

- Display slide 12. Ask students to write the number of each image in the either the "atoms" or "molecules" column. Then have them check their answers with a neighbor.

Accommodation: Do this activity as a class discussion. Ask students what they think and place the number into the two categories.

- Check for understanding. Ask students if the word "nitrogen" refers to an atom, molecule, or both.
- Ask students: *"What is the difference between a nitrogen atom and a nitrogen molecule?"*

Use slide 13 to discuss the four key molecules in air: N_2, O_2, H_2O, and CO_2, explaining both structures and formulas. Tell students that the four key atoms that are involved in carbon-transforming processes are: C (carbon), H (hydrogen), O (oxygen), and N (nitrogen). Describe how each of the key molecules in air is made of atoms bonded together.

Accommodation: Use the Molecule 11 x 17 Poster to help students visualize the difference between atoms and molecules.

6. **Introduce three facts about atoms.**

Show students Slide 14 and tell students that they will need to remember these three facts about atoms in all *Carbon TIME* units.

- Tell students that nuclear changes include reactions at nuclear power plants and changes that occur in the interior of the sun, but do not happen to common atoms on the Earth's surface. In *Carbon TIME* units we treat "weight" and "mass" as equivalent.

Use slides 15-17 to ask students to apply the facts about atoms to air. Ask students to write down their answers to the questions on the back of their T-chart, and then discuss their ideas in groups.

7. **Have students apply the facts about atoms to other materials.**

Use Slide 18 to ask students questions to make sure they understand that the facts about atoms apply to all materials, including the materials that people and other living organisms are made of.

- Ask students whether they think that people are made of atoms.
- Ask whether the three facts about atoms apply to the atoms that we are made of. Many students believe that living things in general and people in particular are "special," not made of just ordinary atoms like non-living materials.
- Ask students if they think that ethanol is made of atoms. Have students recall the lesson where they watched ethanol burn.
- Ask students if the three facts about atoms apply to the atoms that ethanol is made of.
- Ask students if these facts apply to ethanol when it is burned.
- Ask students whether they think that flames contain atoms. (note: flames do contain atoms, as well as forms of energy)
- Ask students if the three facts about atoms apply to the atoms in flames. Use this question to assist students in making the connection between matter and energy.

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

Show slide 19 of the 2.3 Zooming Into Air PPT.

- Have students take out their Learning Tracking Tool for Systems and 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 in the first column, "Zooming Into Air."
- 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.
- Example Learning Tracking Tool

Activity	What We Figured Out	What We are Asking Now
2.3 Zooming Into Air	Three facts about atoms are: 1. Atoms last forever (except in nuclear changes). 2. Atoms make up the mass of all materials. 3. Atoms are bonded to other atoms in molecules.	How can we use atoms and molecules to explain ethanol burning?

8. Have students complete an exit ticket.

Show slide 20 of the 2.3 Zooming into Air PPT.

- Conclusions: What are three facts about atoms?
- Predictions: Why do we study atoms and molecules even though they are too small to see?
- 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

Formative assessment takes place in steps 3 and 7 of the activity. When students are asked about whether air has mass, Level 2 students, in particular, may not believe that air has mass or is made of atoms. They probably think of air as insubstantial—not a material like solids or liquids. Some Level 2 students and virtually all Level 3 students say that air has mass and is made of atoms, but they often fail to consider the mass of gases or the atoms and molecules in gases when they explain carbon transforming processes, like combustion or plant growth.

When students are asked questions about atoms in ethanol, most students will confirm that ethanol contains atoms, but many of them will not be able to apply the facts about atoms to the atoms in ethanol. For example, saying that the ethanol is “burned up” or “turned into energy” is in conflict with the first fact: Atoms last forever. When questioned about atoms in flames, students may have difficulty because in a flame we see both materials: glowing gases and white-hot particles of soot, which are made of atoms; and forms of energy, heat and light, which are not made of atoms.

Remember that these questions are particularly difficult and especially challenging for Level 2 students who are just learning to connect atomic models with macroscopic phenomena.

Differentiation & Extending the Learning

Differentiation

Modifications

Less experienced students may benefit from experiences helping them to see that air is really a form of matter that has weight and occupies space.

Tips

The Three Facts about Atoms are important. Make sure students understand them and can apply them to the gases in air.

Extending the Learning

Have students mass an empty balloon and a balloon filled with air (or conduct this as an investigation). This will allow students to see that air is matter and has mass.

Students can explore other materials in air, including common gases such as argon, particles such as dust or smoke, or polluting gases such as methane or nitrous oxide.

Have students experiment with the molecular model kits before the quiz in Activity 2.4. Have them construct simple molecules that they will use throughout the Unit: H_2O, O_2, CO_2, and ethanol.

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

Overview and Preparation

Target Student Performance

Students apply the principle of matter conservation to atoms and molecules in different phenomena.

Resources You Provide

- pencils (1 per student)

Resources Provided

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

Recurring Resources

- Molecule 11 x 17 Poster (1 per class)

Setup

Print one copy of 2.4 Atoms and Molecules Quiz for each student.

Directions

1. Review for the quiz. Ask your students if they remember the three facts about atoms and molecules they learned in the previous activity: atoms last forever (except in nuclear changes), atoms make up the mass of all materials, and atoms are bonded to other atoms in molecules.
2. Have students take the quiz. Pass out one copy of the 2.4 Atoms and Molecules Quiz to each student and give them 10-20 minutes to take the quiz. Tell students that they will be graded for their answers on this quiz.
3. Discuss their answers to the quiz. Ask students to partner or divide into groups and share what they thought were the best answers to each question. Give the students feedback on areas of the quiz that were difficult to them.
4. Introduce the Molecule 11 x 17 Poster. Post one copy of the Molecule 11 x 17 Poster on the wall. Tell students that they can use this as a reference in future lessons if they are having trouble remembering the difference between an atom and a molecule.

Assessment

Assessment takes place in Step 3 of the activity when students share their answers from the quiz. Use this time to assess which items were more difficult for the class than others. If the students stumbled on any of them, you may want to revisit the material again before moving on. Patterns in student responses can be found in 2.4 Grading the Atoms and Molecules Quiz.

Differentiation & Extending the Learning

Differentiation

Modifications

Tips

If students are struggling with the vocabulary words from the quiz, consider making a vocabulary wall, having the students keep vocabulary notebooks, or giving them personal copies of the poster.

Extending the Learning

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

Overview and Preparation

Target Student Performance

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.

Resources You Provide

- 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)

Resources Provided

- 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)
- 2.5 Investigation Tools PPT

Recurring Resources

- Learning Tracking Tool for Systems and Scale (1 per student)
- Assessing the Learning Tracking Tool for Systems and Scale
- (Optional) BTB Color Handout
- BTB Information and Instructions Handout

Setup

Prepare the materials listed above for each group, including diluted BTB solution. Use the instructions on the BTB Information and Instructions Handout for details about how to prepare the BTB. Print one copy of the 2.5 Class Results for Investigation Tools 11 x 17 Poster and post it to the wall in an accessible location or prepare to display the 2.5 Class Results for Investigation Tools Spreadsheet. You may want to print one copy of the BTB Color Handout for each group, but this is optional.

Directions

1. Use the instructional model to show students where they are in the course of the unit.
Show slide 2 of the 2.5 Investigation Tools PPT.
2. Introduce students to the two investigation tools.
Introduce the investigation tools to students and explain that since atoms are too small to see, scientists have developed special methods to investigate things about the world they can’t know from using their eyes only. Today they will explore two of these tools: a digital balance and Bromothymol Blue (BTB).
3. Have students practice using the digital balance in small groups.
Show students slide 3 of the PPT.

- Divide students into groups of four. Tell students to follow the instructions on the slide, and to determine the mass of at least four different items: a paper clip, a straw, a cup of BTB, and a pencil.

Accommodation: Print out slide 3 so each group has a copy of the instructions.

- Tell students to record their results on the 2.5 Class Results for Investigation Tools 11 x 17 Poster or the 2.5 Class Results for Investigation Tools Spreadsheet.
- Have students compare their results across groups for the digital balance.

4. Have students practice using BTB in small groups.

Show students slide 4 of the PPT and tell one student in each group to use the soda straw to blow through BTB while the other students watch and record their observations.

- Have each group record results on the 2.5 Class Results for Investigation Tools 11 x 17 Poster or the 2.5 Class Results for Investigation Tools Spreadsheet.
- Have students compare their results across groups for the BTB using the (optional) BTB Color Handout as a reference guide.

5. Have students look for patterns and sources of error in their measurements.

Show students slide 5 to help students compare results of mass and color from different groups. Have them answer the questions on the slide. Have students compare and discuss the results from different groups, look for patterns, and identify possible sources of error. This activity will be the first time they do this, and you can judge the sophistication of their thinking.

If students are discussing…

- …how the last digit on the balance (.01 g) is sensitive to slight movements and wind currents, and therefore it may not be reliable, then students are discussing levels of **precision**.
- …the differences between the objects that are similar for all groups (paper clip and straw) and the objects that vary from one group to another (pencil and cup of BTB), then the students are discussing real **variation in objects**.
- …that the balances themselves may be inconsistent, then they are discussing **variation among balances**. One way to check this is to mass the same object on different balances.
- …variations in BTB color depending on how long and how hard different students blew through the solution, then they are discussing **time dependence**.

Accommodation: Create a slide with the discussion points and descriptions mentioned above to help facilitate the discussion about error.

6. Discuss key conclusions about digital balances and BTB

Discuss key conclusions about using digital balances and BTB for investigations:

- Digital balances measure mass very accurately. The last decimal place (.01 g) shows tiny differences that can be affected even by air currents.
- Use Slide 6 and the optional BTB Color Handout to remind students that BTB detects concentrations of CO_2 in the air. They can keep the handout to use in future investigations.

7. Discuss matter movement question as it relates to a digital balance

Show slide 7 of the 2.5 Investigation Tools 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.

8. Discuss matter change question as it relates to BTB

Show slide 8 of the 2.5 Investigation Tools 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.

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

Show slide 9 of the 2.5 Investigation Tools PPT.

- Have students take out their Learning Tracking Tool for Systems and Scale.
- Have students write the activity name in the first column, "Zooming Into Air."
- 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 Systems & Scale for future activities.
- Example Learning Tracking Tool
-

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Zooming Into Air	"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.	How can we use atoms and molecules to explain ethanol burning?

10. Have students complete an exit ticket.

Show slide 10 of the 2.5 Investigation Tools PPT.

- Conclusions: What information can BTB provide?
- Predictions: How do you think you could use a digital scale and BTB to figure out what happens when ethanol 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 into the next activity.

Assessment

We expect that individual students, and the class as a whole, will often have difficulty identifying sources of error and finding patterns in the data. Yet these skills are essential if they are to interpret the results of their investigations meaningfully. In particular, you will be working with students to identify patterns across multiple replications - for example, when different groups in your class all conduct the same investigation. The students will have to decide what claims about patterns are justified. Listen for their responses to the discussion in the final step to determine if they need more support in identifying sources of error or finding patterns.

Differentiation & Extending the Learning

Differentiation

Modifications

Have students figure out that BTB is an indicator for CO_2 by having them compare what happens to blue BTB when they blow bubbles in BTB through a straw, compared to making bubbles with a turkey baster. Ask students what the difference is between the air they exhale and the air in the bubbles from the turkey baster.

Tips

Collect results from the different groups and compare their measurements. Discuss threats to accuracy of measurement. Make sure that each student in every group has a chance to find the mass of something on the digital scales.

Extending the Learning

If students have questions about how or why the BTB changes color, show the first 6.5 minutes of the Colorful Indicators: MIT Chemistry Behind the Magic video (https://www.youtube.com/watch?v=nAhIrh9vM4A&t=2sO). This video provides an accessible explanation as to why CO_2 causes the BTB to change color.

Have students see how long it takes the BTB to change colors for a resting student and for that same student after exercising.

Have students weigh other objects and use BTB to look for evidence of CO_2 (or other acidic materials) in other liquids.