# Lesson 1.3

## Temperature and Motion

## Overview

Students are introduced to the particulate nature of matter. Students begin by exploring the *Thermal Energy* Simulation during the Warm-Up, and continue to use the Sim to model the hot and cold water from the hands-on investigation in the previous lesson. This Sim activity is meant to help students see how hot and cold things are different at the molecular scale. Finally, students learn more about what temperature is and how it is related to kinetic energy and molecular motion by reading "Absolute Zero" for homework. The purpose of this lesson is for students to understand the difference between hot and cool things at the molecular scale.

Anchor Phenomenon: Two different heating systems can heat Riverdale School.
Investigative Phenomenon: Food coloring disperses more quickly in warmer water.

Students learn:

- Things are made of molecules (or other types of atom groups).
- When a thing gets hotter, its molecules are moving faster.
- When a thing gets colder, its molecules are moving slower.
- Scientists use digital simulations to represent things that are too small to see with the naked eye.

## Lesson at a Glance

ACTIVITY

1

**Warm-Up** (10 min)
Students explore the *Thermal Energy* Simulation to familiarize themselves with its features and usage.

WARM-UP

2

**Simulating Hot and Cold Water** (25 min)
Students use the Sim to discover that food coloring spreads faster in warmer samples because the molecules are moving faster than the molecules in colder samples.

SIM

3

**Reflection** (10 min)
Students reflect on the evidence they gathered in the Sim and on how it helps them to answer the Investigation Question.

CLASS

4

**Homework**
Students read "Absolute Zero" to reinforce their understanding of temperature and its relation to molecular motion.

HOMEWORK

# Materials & Preparation

## Materials

### For the Classroom Wall

- vocabulary card: *molecule*
- key concept: *Things are made of molecules (or other types of atom groups).*
- key concept: *When a thing gets hotter, its molecules are moving faster.*
- key concept: *When a thing gets colder, its molecules are moving slower.*

### For the Class

- masking tape*

### For Each Student

- optional: printed copy of the "Absolute Zero" article*
- optional: *Thermal Energy* Investigation Notebook, pages 10–14*

### Digital Tools

- "Absolute Zero" article in the Amplify Library
- *Thermal Energy* Simulation
- optional: Scale Tool

*teacher provided

## Preparation

### Before the Day of the Lesson

1. Gather the following materials for the classroom wall:
    - vocabulary card: *molecule*

### VOCABULARY

- molecule
- temperature

### UNPLUGGED?

Digital Devices Required

It is highly recommended that students have access to digital devices for this lesson. If students do not have individual devices, print copies of the Investigation Notebook pages for this lesson and have students complete the Simulation activity in pairs. (A PDF file of the Investigation Notebook pages can be found in the Digital Resources.)

If students do not have access to Amplify Science at home, provide them with copies of page 14 from the Investigation Notebook and copies of the "Absolute Zero" article.

### DIGITAL RESOURCES

Absolute Zero

Printable article: "Absolute Zero"

Active Reading Guidelines

Thermal Energy Investigation Notebook, pages 10–14

- *Things are made of molecules (or other types of atom groups).*
- *When a thing gets hotter, its molecules are moving faster.*
- *When a thing gets colder, its molecules are moving slower.*

Thermal Energy Glossary

Thermal Energy Multi-Language Glossary

2. Familiarize yourself with the *Thermal Energy* Simulation activities in this lesson. Read Apps in This Unit (under Teacher References at the unit level) for more information. In each lesson where the Simulation is used, there is information about expected outcomes in the Possible Responses tab for that activity. Practice the activities that students will complete in Activities 1 and 2 of this lesson. Students will work with partners while they explore the Simulation. Students will each explore the Sim on their own devices, but partners should share interesting observations and show each other what they notice.
3. Familiarize yourself with the "Absolute Zero" article in the Amplify Library. This article is also located in the Digital Resources. Students will read and annotate this article for homework.
4. Locate and post the Active Reading Guidelines poster from a previous unit. Students will be reading an article for homework at the end of this lesson. If necessary, remind your students how to engage in Active Reading. If you do not have this poster from a previous unit, create it on chart paper using the Active Reading Guidelines (located in the Digital Resources) as a reference.

### Immediately Before the Lesson

1. Post the vocabulary card for *molecule* on the classroom wall.
2. Make sure the Investigation Question is still written on the board: "How is something different when it is warmer or cooler?" This question should remain on the board until the conclusion of the chapter.
3. Have on hand the following materials:
   - digital devices
   - optional: printed copies of the "Absolute Zero" article
   - optional: *Thermal Energy* Investigation Notebook, pages 10–14

### At the End of the Day

1. Post the following key concepts on the classroom wall:
   - *Things are made of molecules (or other types of atom groups).*
   - *When a thing gets hotter, its molecules are moving faster.*
   - *When a thing gets colder, its molecules are moving slower.*

## Differentiation

### Embedded Supports for Diverse Learners

Introducing vocabulary. Throughout the unit, vocabulary words and definitions are generally introduced when students need to use them, rather than before. This gives students a context for the words and allows them to integrate the words into the existing framework of their own prior knowledge. Respecting students' prior knowledge makes students feel more empowered in the classroom and helps them feel as though they are participating in their learning. In this lesson, students will use the Sim to see how molecules move differently depending on their temperature, and then will continue to think about molecular movement when they read the article "Absolute Zero" for homework.

### Potential Challenges in This Lesson

Recalling previous activities. This lesson re-introduces students to the idea that matter is made up of tiny pieces called molecules, which are made up of even smaller pieces called atoms. Students are likely to have some prior knowledge of the particulate nature of matter since these ideas are typically introduced in elementary school. However, abstract ideas about the particulate nature of matter are learned gradually, and students may not remember what they learned about molecules in previous units. If students have not yet internalized these ideas, it may be necessary to review them in a more substantial way before proceeding with the rest of the lesson.

Visual representations. This lesson introduces students to the *Thermal Energy* Simulation. The Sim will be used often throughout the unit. If you have students who might find working with this Sim challenging—for example, because it is dependent on clearly seeing the colors that denote various aspects of the Sim, or because your students have trouble processing information in this way—you may want to think ahead about how you can offer these students alternative ways of participating in this aspect of the unit.

Technology-focused. This lesson makes use of a great deal of technology, the bulk of this lesson involves using the *Thermal Energy* Simulation. This may be a challenge for students who have less experience using technology.

### Specific Differentiation Strategies for English Learners

*Thermal Energy* Glossary. Throughout this unit, you will find resources for supporting English learners in science, including a glossary in the Amplify Library that includes Spanish definitions for native Spanish speakers. If you have English learners in your class whose native language is Spanish, make sure to point out the glossary to them in the Digital Resources.

Vocabulary support. If there are students who need more support learning new vocabulary words, you may want to have them make flashcards or record new vocabulary words in a notebook or binder. You can ask students to draw a picture and write a sentence for each vocabulary word to help them remember the word's uses and to give them practice using the word in writing.

### Specific Differentiation Strategies for Students Who Need More Support

Additional teacher modeling with Sim exploration. Students will be working with the *Thermal Energy* Simulation many times in this unit. If needed, take time in this lesson to develop students' proficiency in working with the Sim. Visit with pairs who are working to discuss and model how to more carefully explore the Sim. Ask questions like, "What happens if I change the sample size but keep the temperature the same?" and "How do you think this graph relates to what I just observed in the Sim?"

Extended discussion. Students may be confused by the visual representations of molecules in the Simulation as the particulate nature of matter is not intuitive for everyone. Providing some extra discussion of the visual representation can help students to understand that the molecules depicted in the Sim represent smaller pieces of a visible, tangible, physical thing.

Exploring the Scale Tool. The Scale Tool provides an excellent opportunity for students to further explore scale and the relative size of things. Consider allowing time for students to explore the Scale Tool for a few minutes with their partner. Remind students that when they are considering scale, they are comparing the sizes of different things. Some things you could ask students to locate and compare include humans, marbles, ants, grains of salt, widths of human hair, skin cells, red blood cells, *E. coli* bacteria, DNA molecules, and water molecules.

Consider using the following prompts to support student discussion:

- *What objects might be the same scale as an ice cube? A building? A lake? A moon?*
- *Is a glucose molecule smaller than a water molecule? How do you know?*
- *Which objects can be seen easily by the human eye? Which objects cannot be seen solely by the human eye?*

### Specific Differentiation Strategies for Students Who Need More Challenge

Critique the model. Students who need more challenge can be directed to produce a written critique of the model in the Sim. To help students structure this critique, you may wish to prompt them with some of the following questions:

- *What is unrealistic about the model?*
- *What is difficult to understand about the model?*
- *How could the model be made more realistic or easier to understand?*

## Standards

**Key**

Practices Disciplinary Core Ideas Crosscutting Concepts

### 3-D Statement

Students use a digital model to investigate differences between the warm water and cold water samples they observed at the molecular scale in the previous lesson (scale, proportion, and quantity).

### Next Generation Science Standards (NGSS)

NGSS Practices

- Practice 2: Developing and Using Models
- Practice 3: Planning and Carrying Out Investigations
- Practice 6: Constructing Explanations and Designing Solutions
- Practice 8: Obtaining, Evaluating, and Communicating Information

NGSS Disciplinary Core Ideas

- PS3.A: Definitions of Energy:
  - Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3),(MS-PS3-4)

NGSS Crosscutting Concepts

- Scale, Proportion, and Quantity
- Stability and Change

### Common Core State Standards for English Language Arts (CCSS-ELA)

- CCSS.ELA-LITERACY.RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
- CCSS.ELA-LITERACY.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics
- CCSS.ELA-LITERACY.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic

### Common Core State Standards for Mathematics (CCSS-Math)

CCSS-Math Practices

- CCSS.MATH.PRACTICE.MP1: Make sense of problems and persevere in solving them.
- CCSS.MATH.PRACTICE.MP2: Reason abstractly and quantitatively.
- CCSS.MATH.PRACTICE.MP4: Model with mathematics.
- CCSS.MATH.PRACTICE.MP5: Use appropriate tools strategically.
- CCSS.MATH.PRACTICE.MP7: Look for and make use of structure.

CCSS-Math Content

- CCSS.MATH.CONTENT.6.SP.5: Summarize numerical data sets in relation to their context.
- CCSS.MATH.CONTENT.7.RP.2: Recognize and represent proportional relationships between quantities.
- CCSS.MATH.CONTENT.7.RP.2a: Decide whether two quantities are in a proportional relationship.

1 WARM-UP
Warm-Up

# Warm-Up

Students explore the features of the *Thermal Energy* Simulation.

10 MIN

## Instructional Guide

1. Project Warm-Up; students work independently. Collapse the instructional guide and project the student screen, or have students turn to page 11 in their Investigation Notebooks. Allow a few minutes for students to respond individually to the Warm-Up.

2. Prompt students to discuss the questions on their screens or on page 11 in the Investigation Notebook with a partner. After about five minutes, have pairs discuss what they found about the Sim.

## Teacher Support

**Rationale**

Technology Note: Free Explore in the Simulation
The first time students use a Simulation, they need a few minutes to freely explore its features. Students are quick to learn on their own and will have more fun if they can discover and share some aspects of the Simulation's functionality. Giving students this time initially reduces distraction in later activities that have more focused goals.

## Possible Responses

What students should do and notice in the Sim:
By exploring and sharing what they notice in the Sim, students become familiar with its features.

2 SIM
**Simulating Hot and Cold Water**

# Simulating Hot and Cold Water

25 MIN

Students use the Sim to investigate the relationship between temperature and the movement of molecules.

## Instructional Guide

1. Introduce the purpose of the Simulation.

Throughout this unit, we will be using the *Thermal Energy* Simulation that you just explored. This Sim is a digital model that will help us learn about how temperature can change. Today, we will use it to learn more about the differences between hot and cold things.

2. Have students help you demonstrate the Sim features. Project the *Thermal Energy* Simulation. Invite students to share what they noticed about the Sim in their free exploration during the Warm-Up. Ask them to answer the questions from the Warm-Up to help guide the class discussion.

3. Highlight the following Sim features if students don't bring them up during discussion:

- You can select the size of the sample.
- You can have one, two, or three samples.
- You can push samples together so they are in contact.
- In Run, you can add energy to or remove energy from the sample.
- Using controls in the upper right, you can pause or reset the Sim or change the speed at which it runs.
- You can toggle on and off visualizations of kinetic energy and energy transfer.
- In Analyze, you can track changes in temperature over time.

4. Ask students to turn and talk to their partners about what they think the small circles in the Sim represent.

5. Have a brief class discussion about the small circles in the Sim. Ask for student volunteers to share what they think the small circles in the Sim represent.

*If using devices, ask students to press NEXT to continue this activity.*

6. Introduce the vocabulary word *molecule* and project the definition. Collapse the instructional guide and project the student screen. Read (or ask a student to read) the word and definition aloud. Point out that the vocabulary word is also posted on the wall. Clarify that students will use the term *molecule* to describe the particles that make up larger materials. Remind students to look at the glossary if they need more support.

Remember that the Simulation is a model of the real world that helps us understand thermal energy. In this unit and in the Sim, we will describe the smaller pieces that make up stuff by using the word *molecule*. In the Sim, each circle represents one molecule.

The Sim portrays molecules on a much larger scale than their size in real life. Molecules actually are so small that scientists can only see them using some of the most powerful microscopes in the world. Molecules are made up of even smaller pieces called atoms.

We are only focusing on molecules in this unit, so to help us think about those, the circles in the Sim represent molecules, not atoms. Sometimes you will hear the word *molecular* used in the unit. That's just a way to describe anything related to molecules.

7. Discuss the number of molecules in the Sim. Point out that the Sim shows only a relatively small number of molecules so that we can easily observe what is happening to them. Remind students that the things around us—even very small things—are made up of billions upon billions of molecules.

8. Project and introduce key concept 1. Read (or ask a student to read) the key concept aloud. Remind students that even things that might not seem to be made of anything, like air, are actually also made of atoms and molecules. Remind students that we'll be focusing on molecules in this unit, and that they will learn more about other types of atom groups in later units.

**Key Concept**

Things are made of molecules (or other types of atom groups).

*Ask students to press NEXT (or to turn to page 12 in their Investigation Notebooks) to continue this activity.*

9. Introduce the Sim activity. Remind students about the hot and cold water samples from the food coloring investigation in the previous lesson.

- Ask for volunteers to review what they saw in the hot and cold water food coloring investigation. [They observed that food coloring spreads out faster in warmer water than in colder water.]
- Ask for initial ideas about what could have caused the difference between the way the food coloring moved in the hot and the cold water. If no students bring it up, make a connection to molecules.

We just learned a key concept about molecules. Could molecules be involved? How do you think the molecules of the hot water might be different from the molecules of the cold water?

- Pause for student responses and accept all ideas.

Normally, we can't see molecules because they are too small, but the Sim allows us to visualize what is happening on this very small scale.

- Explain that they will now use the Sim to model the food coloring investigation. This will help them find evidence to help explain why the food coloring spread out differently in the warm and cold water samples.

10. Review the Sim instructions and set expectations for partner work. Collapse the instructional guide and project the student screen, or have students turn to page 12 in their Investigation Notebooks. Explain that students will work with partners while they explore the Simulation. They will each explore the Sim on their own devices, but partners should share interesting observations and show each other what they notice. If partners are sharing one device, they can take turns running the Sim. Review the Sim instructions as needed.

11. Direct students to begin the Sim activity. Circulate as students complete this activity, reminding them that they have to gather evidence about the differences between the hot water sample and the cold water sample.

12. After a few minutes, encourage students to discuss their findings or questions with a partner.

13. Lead a class discussion of the Sim activity. Have students share the evidence they found with the class.

14. Revisit the Investigation Question: *How is something different when it is warmer or cooler?* Help students shift their thinking about each sample as a single thing to thinking about the samples as made up of molecules. Prompt students to use evidence that they gathered from the Sim to explain their answers to the Investigation Question. As needed, help students see that when something is warmer it has faster molecules than when it is colder. If necessary, project the Simulation to highlight the difference in molecular speed.

15. Ask students to connect the Investigation Question to the hands-on investigation from the previous lesson and to the Sim activity from this lesson.

Now we can revisit our question from the food coloring investigation with a more complete explanation of what is happening to the water molecules. After using the Sim today, why do you think the food coloring spread faster in the hot water?
[The hot water molecules moved faster and moved the food coloring around.]

# Teacher Support

### Instructional Suggestion

Discussion: Using Models in Science
It may be useful to discuss the importance and limitations of using models to study science. Ask students to share what kinds of models they have seen or used before. Point out that scientists develop and use models to help them conceptualize, investigate, and communicate ideas about the natural world. A model can be a physical setup that is smaller or larger than what it represents, a diagram that depicts the invisible, or a computer simulation that represents salient features of a phenomenon, system, or process. Throughout the unit, students will use several types of models, including the *Thermal Energy* Simulation and the Modeling Tool. The *Thermal Energy* Simulation is a scientific model that shows thermal energy and energy transfer at the molecular scale. The Simulation accurately models many aspects of thermal energy transfer, including the relationships between kinetic energy of molecules, temperature and thermal energy, the conservation of energy during transfer in a closed system, the way in which mass affects thermal energy transfer, and the way in which objects reach equilibrium. Of course, like any model, it is inaccurate in other ways, such as by showing a very small number of molecules in an object and by not showing any phase changes. Refer to Apps in this Unit (under Teacher References at the unit level) for more information. Helping students understand the ways in which the Sim mimics and is different from the natural world can be useful for students as they construct an understanding of the Sim and its features.

### Instructional Suggestion

Vocabulary: Using the Term *Sample* in the Sim
Throughout the unit, we use various terms to refer to an object or material in question. The Sim uses the term *sample*, whereas *thing* and *object* are more often used in other parts of the unit. If needed, clarify the meaning of the term *sample* for your students as you introduce them to the Sim features.

### Rationale

Pedagogical Goals: Look For and Make Use of Structure
The Common Core State Standards for Mathematical Practice states that mathematically proficient students look closely to discern a pattern or structure. Students should be able to see complicated things as single objects or as being composed of several objects. In the Sim, students see that objects are composed of molecules and observe the behavior of the molecules when energy is transferred to the object. They observe how each molecule changes in kinetic energy at the micro level and connect that to how the object changes on the macro level by seeing a change in temperature. Using the Sim, students will also learn about the pattern of energy transfer when two objects that have different temperatures are placed into contact. They observe that energy gets distributed throughout the molecules of the object as molecules transfer kinetic energy when they collide.

### Rationale

Instructional Rationale: Science Vocabulary
Our approach to building a strong base of disciplinary vocabulary is multifaceted and based on the idea that words are concepts. The idea that words represent larger concepts is especially relevant in a science class, where complex and novel words are often introduced. Our aim is to have all students build a conceptual network of understanding about each of the central words from the unit, rather than a simple, definitional understanding. To achieve this deeper level of

understanding, we offer many opportunities to use each word and to think about it in a variety of contexts. We also focus more closely on a smaller set of words, choosing to focus on those that are most relevant to the subject matter, and then provide many opportunities to encounter the words as well as opportunities to produce them.

### Rationale

Scientific Language: How and Why the Term *Molecule* Is Used
All matter is made up of atoms that are too small to see. These atoms are joined together in different configurations that use different types of chemical bonds. For the purposes of this unit, *molecule* is used to mean all subunits that make up substances, regardless of the type of bond joining the atoms together. This is not entirely accurate, as *molecule* is traditionally reserved exclusively for a group of atoms joined together by covalent bonds. By this definition, subunits of ionic substances, pure metals, and metal alloys are not molecules. However, differentiating between the types of chemical bonds and the types of atom groups is beyond the scope of this unit. Therefore, a simplified version of the term *molecule* is used so that other content may be emphasized instead. While other curricula use the more general term particle to teach these ideas, this term can be confusing, as it is often used to refer to units at the molecular, atomic, and subatomic levels. The ambiguity of the term particle, coupled with students' familiarity with the term *molecule*, makes *molecule* the preferred term in this unit. The term molecular is also used throughout the unit. If needed, you can review this term and how it is related to *molecule* with your students. Students will be exposed to a more specific conception of the particulate nature of matter in other units.

### Rationale

Reviewing Prior Knowledge: Particulate Nature of Matter
Students should begin this unit with some elementary experiences that brought them to the understanding that the things all around us are made of smaller pieces called atoms. This includes the knowledge that matter can exist in different states: solid, liquid, and gas. This unit will build on that basic understanding to include the idea that these particles are always in motion, and that atomic motion can change with temperature. The fact that matter is made of molecules will be stated in this lesson and related vocabulary (*molecule*) will be presented in this lesson. Students' success in this unit is dependent on them knowing that things are made of smaller pieces. The questions and discussions in this lesson should give you an idea of your students' familiarity with the particulate nature of matter. If you notice that your students are not at least somewhat familiar with this concept you may want to take some time to teach more about it before moving forward. If you wish to utilize it, the Scale Tool may be helpful in helping your students to understand this concept. See the Differentiation Brief for more on using the Scale Tool.

While you are discussing molecules, if students mentioned cells, discuss how these are different from molecules. Students may have learned that living things are made of cells, and that even cells are made of smaller particles (atoms). Emphasize that in this unit, students will only need to think about molecules.

## Possible Responses

What students should do and notice in the Sim:
Students add two samples that are the same size. They add energy to one of the samples by pressing the plus button, making this sample hot. They remove energy from the other sample by pressing the minus button, making this sample cold. Students should notice that the molecules in the hot sample move faster than the molecules in the cold sample.

What do you notice about the movement of the molecules of the two samples?
I noticed that the molecules move faster in the warmer thing and slower in the cooler thing.

Explain what you discovered from the Simulation about why food coloring spreads faster in warmer water.
Since molecules in warmer water move faster than molecules in cooler water, the food coloring spread faster in the warmer water. The faster molecules moved the food coloring around.

3 CLASS
Reflection

# Reflection

10 MIN

Students reflect on what they have learned over the last two lessons.

## Instructional Guide

1. Review the key and visual representations in the reflection. Collapse the instructional guide and project the student screen, or have students turn to page 13 in their Investigation Notebooks. Be sure students read and understand the key and what each option (A, B, C, and D) is showing.

2. Students work independently to complete the reflection. Allow students a few minutes to complete the reflection and answer the questions.

3. Direct students to choose the answer they think is most accurate by selecting their choices on their devices or by raising their hands as you read the answers to the reflection question. If students are raising their hands, tally up the votes for each claim on the board. If students are using devices, briefly project the poll results, using the graph icon, and invite students to share their responses with the class.

4. Project the new key concepts and read them aloud. Remind students that they saw evidence of this in the Sim. Also let students know that they will continue to learn more about how molecule motion and temperature are related.

### Key Concepts

- When a thing gets hotter, its molecules are moving faster.
- When a thing gets colder, its molecules are moving slower.

5. Point out the homework assignment to students (Activity 4 or page 14 in the Investigation Notebook). If students do not have access to Amplify Science at home, provide them with copies of page 14 from the Investigation Notebook and copies of the "Absolute Zero" article. Inform students that they will read an article called "Absolute Zero" about an interesting phenomenon that scientists discovered that will help them think more about temperature at the molecular level.

## Possible Responses

Explain your answer choice.
Option B shows the difference between the speed of the molecules in water when it is hot and when it is cold because according to the key, yellow is high-molecule speed, and molecules move faster in hotter things than in colder things.

4 HOMEWORK
Homework

# Homework

Students read an article about absolute zero to learn more about temperature and molecular speed.

## Instructional Guide

1. If needed, make additional time to explain the homework. If students do not have access to Amplify Science at home, provide them with copies of page 14 from the Investigation Notebook and copies of the "Absolute Zero" article.

## Possible Responses

1. Which of the following would be true if something was at absolute zero?
The molecules that make up a sample wouldn't be moving.

2. If the molecules of a sample speed up, what else happens?
The temperature of the sample increases.