Lesson 2.3

A Nanoscale View of Condensation
Lesson Overview

In this lesson, students focus on what happens at the nanoscale when water vapor condenses to form liquid water. Students first read a section in Water Encyclopedia about how water is made up of water molecules and how these water molecules are arranged differently in the different phases of water. Then, students use The Earth System Simulation to discover what happens to molecules when condensation occurs and raindrops form. Finally, students reflect on what they learned from reading in the reference book and investigating in the Sim as they create a model that shows raindrop formation in The Earth System Modeling Tool. The purpose of this lesson is for students to learn what happens at the nanoscale when raindrops form.

**Anchor Phenomenon:** One side of Ferris Island has a water shortage and the other does not.

**Everyday Phenomenon:** Raindrops fall from the sky.

**Students learn:**

- Water molecules are far apart in water vapor and close together in liquid water.
- Raindrops can form when enough water vapor gets cold and condenses into liquid water.
- When water vapor turns into liquid water, water molecules that were spread apart come together.
- Nanoscale is a scale that is much too small to observe directly with our eyes.
- A model is something scientists and engineers make to answer questions about the real world.
Reading About Phases of Water

Students read about how phases of water differ at the nanoscale and then draw what happens to water molecules when water condenses.

Instructional Guide

1. Review ideas about condensation.

   - What did we learn when we observed a cup of ice water in a plastic bag in Where the Water Drops Come From: Investigation 2? [Water drops come from water vapor in the air.]
   - Why did water vapor condense on the cups in our investigations? [Because they were cold.]
   - From our investigations, we know that water drops form on the cup when water vapor in the air gets cold and condenses from gas to liquid.

2. Refer to the Investigation Question and introduce today’s focus.

   - Today, we will continue investigating how raindrops form by zooming in to see what happens to water vapor when it condenses into liquid form. First, we’ll read a section of Water Encyclopedia.

3. Distribute books. Distribute one copy of Water Encyclopedia to each pair of students.

4. Project and introduce notebook pages 20–21. Have students turn to pages 20–21, Reading About Phases of Water, in the Investigation Notebook. Review the instructions with them.

   - Step 1: Read the “Phases of Water” section of Water Encyclopedia (pages 28–29).
   - Step 2: Answer the two questions below.
5. Circulate while students read, write, and draw. Encourage students to talk with their partners as they complete the notebook page.

6. Discuss ideas. Go through the questions and ask for volunteers to share their ideas. Explain that students will further investigate these ideas in the next activity.

7. Introduce and post the molecule vocabulary card. Have students turn to page 25 in Water Encyclopedia. Read the first paragraph aloud.

   As you read in the text, a molecule is a group of atoms joined together in a particular way.

   Post the molecule vocabulary card to the classroom wall.

8. Introduce the word nanoscale. Point out the image of water molecules on page 25 of Water Encyclopedia.

   The water drop is something you can see or observe but the individual molecules are at the nanoscale. What ideas do you have about what the nanoscale is?

   Accept all responses.

   From now on, we will be thinking about what is happening at the observable scale, which we can see, and what is happening with molecules at the nanoscale, which is much too small to observe directly.

Teacher Support

Instructional Suggestion

Providing More Experience: Today’s Daily Written Reflection

If you wanted to convince someone that the air is something and not nothing, what could you do? This prompt (on page 19 in the Investigation Notebook) allows students to reflect on the concepts they learned in the previous lesson.

Rationale

Pedagogical Goals: Diagramming Molecules During Condensation

The purpose of having students complete a diagram after reading about water in different phases is to provide them with an opportunity to relate what they’ve read to the hands-on activities they have done. Students may struggle with how to draw condensed water in this diagram because it requires them to synthesize what they know about
condensation with what they’ve read about water in different phases. At this point in the lesson, some students may not understand or articulate that molecules of water come together when water vapor condenses into drops of water on a cup. Even so, the activity allows students to generate initial ideas which they can then test in the Sim, where they will be able to observe molecules during the process of condensation.

Rationale

Pedagogical Goals: Particles vs. Molecules

In *The Earth System* unit we use the term *molecule* rather than using the more general term particle. The word *molecule* is introduced in this lesson so that students can use scientific language to describe what happens during condensation and evaporation at the nanoscale. In discussing these ideas with students, we have found that it is more straightforward to use the word *molecule*. However, it is not important that students understand the precise definition of the word at this point in the unit. For now, the important thing for students to understand is that water is made up of tiny particles called water molecules. If you would like to provide more support for students to make sense of the precise definition of *molecule*, you might spend more time discussing the representation of water molecules on page 25 of *Water Encyclopedia*. You can point out how the red and white circles that make up each water molecule represent atoms, which are even smaller than molecules.

By using the term *molecule*, the unit enables students to begin developing a more precise understanding of matter at the nanoscale—differentiating between different kinds of molecules lays the groundwork for understanding chemical reactions at the nanoscale, which will become important in Chapter 5. In Chapter 5, students have a chance to explore chemical reactions at both the observable scale and the nanoscale, and gain the understanding that different substances are made of different molecules, which is key to making sense of chemical reactions. However, students are not expected to develop understanding of the specific arrangement of atoms within the molecules of each substance, the chemical formulas of molecules, the chemical bonds that hold atoms together, nor the difference between molecules and ionic compounds.

Background

Crosscutting Concept: What Is Meant by Scale, Proportion, and Quantity?

Scale, Proportion, and Quantity is a crosscutting concept called out by the Next Generation Science Standards. It is one of seven powerful ideas that are widely useful across scientific topics and subdisciplines. Making use of the crosscutting concept of Scale, Proportion, and Quantity involves assessing the relative dimensions of that which you can observe about the natural and designed worlds. Thinking about observations in quantitative ways enables a more powerful description of objects, organisms, events, and phenomena leading to deeper understanding. Scale, Proportion, and Quantity is applicable throughout science and engineering.

Background

Student Thinking: Scale, Proportion, and Quantity in This Unit

*The Earth System* unit focuses students on understanding how water moves between parts of the Earth system at both the observable scale and the nanoscale. Understanding what happens to water when it evaporates into water vapor or when it condenses from water vapor is easier when you can actually visualize water changing phase. Likewise, understanding how water vapor moves around the atmosphere and causes different amounts of rain in different places is much easier when you can visualize this movement. Reading about water at different scales in *Water Encyclopedia* and working with *The Earth System* Simulation helps students visualize water moving around Earth in different phases. Take opportunities in this lesson and across the unit to help students begin to understand the nanoscale.
Background

Crosscutting Concept: Scale, Proportion, and Quantity Across Chapter 2

In Chapter 2, students investigate the question *Why does more rain form over West Ferris than East Ferris?* This requires them to be able to describe how raindrops form and where the water in raindrops comes from. An essential aspect of explaining how raindrops form is developing an understanding of water vapor and how water vapor condenses into liquid water. A nanoscale understanding of water and what happens to water molecules as water changes phases is required to elevate a mysterious description of condensation or evaporation, in which water seems to appear or disappear, to a mechanistic explanation involving the movement of molecules. Chapter 2 begins with opportunities to explore condensation at the observable scale, then allows students to develop more sophisticated explanations of how raindrops form by investigating what happens at the nanoscale. Students investigate evaporation at both scales as well.

Instructional Suggestion

Providing More Experience: Acting Out Different Phases of Water

The idea of particulate matter is a very challenging concept for students to grasp. You may want to give them more experience with how molecules are arranged in the different phases of water that they learn about in this lesson (liquid and gas). You could have students act out the different phases of water through hand motions or by moving around the classroom. For a quick extension, you could show students how to model water vapor by making fists to represent water molecules and then moving your fists around erratically, like molecules of gas moving through the air. You could then model liquid water by bringing your fists together, and moving them as a pair more slowly. For a longer extension, you could have students stand in an open space in your classroom and have them meander around each other briskly, keeping some distance between themselves, to represent water vapor. To represent liquid water, you could have them huddle close together in a clump and move around each other, staying in a tight configuration.

Possible Responses

Investigation Notebook

Reading About Phases of Water (pages 20–21)

Describe water molecules when they are in water vapor.
Water molecules in water vapor are spread apart and moving fast.

Describe water molecules when they are in liquid water.
Water molecules in liquid water are close together and can move around each other.

In this diagram:

- Draw and label the molecules of liquid water in the cup.
- Draw and label the molecules of the water vapor outside the cup.
• Draw and label the molecules of water that condensed on the cup.

Representations of molecules may vary. However, drawings should show that molecules are closer together in liquid water and farther apart in water vapor.
Exploring The Earth System Simulation

Students are introduced to *The Earth System* Simulation and become familiar with its features.

**Instructional Guide**

1. **Introduce *The Earth System* Simulation.**

   Today, we’re going to use a digital simulation, or Sim, to learn more about how raindrops form, both at the observable scale and at the nanoscale. You will have time to explore the Sim in pairs, and you will then use the Sim to observe how raindrops form.

2. **Students think about water molecules during condensation.** Have students briefly discuss condensation on the nanoscale with their partners.

   What do you think happens to water molecules when water vapor condenses into raindrops in the atmosphere?
3. **Project Guidelines for Using Apps.** Introduce students to the expectations for using apps and digital devices in the classroom.

**Guidelines for Using Apps**

- Only one person “drives” at a time.
- Anyone can make suggestions about how to use the app.
- Talk about what you observe.
- Rotate the role of “driver.”

4. **Project The Earth System Simulation.** Project the Student Apps Page and select *The Earth System* and then the Simulation. Choose any landscape.

5. **Organize students into pairs and distribute digital devices.** Distribute one digital device to each pair of students and have them go to *The Earth System* Simulation. Let students know they will have a few minutes to explore the Sim.

6. **Give pairs several minutes of free exploration time.** Circulate as students explore the Sim, encouraging them to discuss what they are observing with their partners. Listen for student questions or alternate conceptions as they relate to the basic components of the Sim. Halfway through the free exploration time, provide a signal for students to switch “drivers.”

7. **Discuss observations.** Have students to share their observations with the class.

What did you observe while exploring the Sim?

8. **Discuss features of the Sim.** Students are very quick to learn on their own and will be more engaged if they can discover and share some of the Sim’s features. Demonstrate, or allow students to demonstrate, what they discovered about how the Sim works. Point out the following features if students don’t bring them up in the discussion:

- **Landscape:** In the landscape screen, students can choose one of twelve landscapes.
- **Wind:** Students can turn wind off or designate its direction.
- **Water Molecules toggle:** Students can toggle water molecules on to show what is happening to water molecules. When water molecules are visible, a key appears that labels liquid water and water vapor molecules.
9. **Discuss how the Sim allows students to observe at the nanoscale.** On your projection of the Sim, point out the Water Molecules toggle and turn it ON. Explain that this allows students to see what is happening to water molecules at the nanoscale, which is too small to observe otherwise. Point out that blue molecules represent liquid water and pink molecules represent water vapor, as shown in the key in the lower right corner of the landscape.

10. **Introduce the idea of the Sim as a model.**

    The Sim is a model. A model is something scientists and engineers make to answer questions about the real world.

11. **Discuss the globe as a model.** Hold up the inflatable globe and explain that it is a model too. Have students identify ways that a globe is an accurate or inaccurate model of Earth.

    How is the globe an accurate model of Earth? How is it inaccurate?
    [Accurate: shaped like a ball, has oceans and land in the right shapes. Inaccurate: smaller than real Earth, filled with air, has words written on it.]

12. **Discuss diagrams as models.** Refer to the diagrams students made of water molecules on or around a cup on page 18, Where the Water Drops Come From: Investigation 2, in the Investigation Notebook.

    Your drawings of molecules and the pictures of molecules in *Water Encyclopedia* are models too. Molecules don’t actually look like this and they are not this large, but these models make it easier for us to make sense of water at the nanoscale.

13. **Discuss inaccuracies in the Sim.** Emphasize that models can be accurate in some ways and inaccurate in other ways.

    Depending on what scientists and engineers are using them for, models show some aspects of the real world accurately but are inaccurate in other ways.

Point out accurate aspects, such as water flowing down the mountain or into the ground, where it is stored as groundwater. Have pairs discuss inaccurate aspects, then have students share what they have noticed with the class. Highlight the following:

- Liquid water and water vapor are depicted with two different colors: blue and pink, respectively. The color distinction in the model enables students to distinguish between liquid water and water vapor. In reality, this is not what the molecules really look like. The molecules in water vapor and liquid water are the same. The difference between liquid and vapor is the arrangement and behavior of the water molecules. Molecules in water vapor are spread apart; molecules in liquid water are close together.
Some areas in the atmosphere in the Sim do not show any water vapor molecules. In reality, water vapor is present in all parts of Earth’s atmosphere, even indoors.

**Teacher Support**

**Background**

**Technology Note: About The Earth System Simulation**

The Earth System Simulation allows students to study condensation and evaporation at both the observable scale and the nanoscale. The Sim is a dynamic model that shows how molecules evaporate from the surface of bodies of water as water vapor, come together to form liquid water in the atmosphere, and fall as rain. The Sim also enables students to explore how features of the environment (e.g., the wind, mountains) can affect the movement of water vapor and, subsequently, differential patterns in rainfall. Open exploration in the Sim enables students to get an initial sense of the behavior of molecules at the nanoscale during condensation and evaporation. This will prepare students to gather information in the Sim about why one place might get more rain than another.

**Background**

**Science Note: About Rainfall in the Sim**

In the Sim, if wind is turned off, water molecules will only move vertically and will not blow over the land. This means that the Sim will not show rain forming over land unless wind is turned on. This is generally consistent with the natural phenomenon: the wind causes water in the atmosphere to move to other parts of the atmosphere, including areas over land. However, this visual (of rain forming only over water) may be confusing for students, as it is misaligned with their experiences with rain (which occurs on land). If students question why the rainfall occurs only over bodies of water, you might point out that factors like the wind allow rain to happen on land. However, note that the unit is intentionally designed so that students do not use the wind feature in the Sim until Chapter 4 when they investigate what factors cause water vapor to move to different parts of the atmosphere.

**Instructional Suggestion**

**Technology Note: Sharing Devices with a 1:2 Ratio**

Throughout this unit, pairs share digital devices. We recommend that instead of working individually, students work with partners so they can engage and talk to each other while investigating molecules in the Sim. Try to establish clear expectations for the use, handling, and storage of digital devices in order to decrease transition time between activities and minimize any potential conflict that could come from sharing a limited number of devices.

**Background**

**Science Practices: About Models**

Scientists develop and use models to help them conceptualize, investigate, and communicate ideas about how the natural world works. Scientists create models to portray structures and processes that are thought to exist in the real world but are not readily observable. A model can be a physical setup that is smaller or larger than what it represents; a diagram that depicts things that are not visible; or a computer simulation that represents salient features of a phenomenon, system, or process. Models are used to describe tentative ideas to be tested, substitute for situations that are hard to investigate directly, clarify ideas for oneself, or communicate ideas to others. In all cases, scientific models approximate whatever is being modeled in an intentional way, simplifying some aspects in order to clearly focus on others.
Rationale

Pedagogical Goals: Discussing Inaccuracies in the Sim

Discussing the inaccuracies of the Sim ensures that students do not come away with false ideas and provides an opportunity for students to learn about the scientific practice of modeling. Approximations and simplifications are inherent in models, and it is important to acknowledge them to understand the limitations of what conclusions can be made from the models. Discussing inaccuracies of the Sim calls out how it is a useful tool, but not an exact replica of the real world.

Background

Science Note: Inaccuracies in the Sim

The Earth System Simulation is intended to provide students with a model for investigating the phenomena of evaporation, condensation, and interactions of Earth’s spheres. However, some simplifications of content are necessary to support students with this key content. Note the following important simplifications:

- Liquid water and water vapor are depicted with two different colors: blue and pink, respectively. The color distinction in the model enables students to distinguish between liquid water and water vapor. In reality, this is not what the molecules really look like. The molecules in water vapor and liquid water are the same. The difference between liquid and vapor is the arrangement and behavior of the water molecules. Molecules in water vapor are spread apart; molecules in liquid water are closer together.

- Some areas in the atmosphere in the Sim do not show any water vapor molecules. In reality, water vapor is present in all parts of Earth’s atmosphere, even indoors.

- The size of the molecules in the Sim is much larger than their actual size. This inaccuracy is intentional to allow students to see how molecules behave; however, it could lead a student have a skewed understanding of the scale of molecules or the quantity of molecules that come together during condensation.

- The rocks in the landscapes have very large cracks that water can flow through. In reality, the rocks that groundwater flows through often look solid, without large, visible cracks. Water can flow through tiny cracks and small spaces within rocks that may be too small to see at the observable scale.

- In the Sim, it takes a few minutes for water vapor to evaporate, move through the atmosphere, and condense. In reality, this process is much slower (i.e., hours rather than minutes). The Sim speeds this process up so that we can observe the entire cycle.

- When water vapor condenses into liquid water in the Sim, just three molecules come together; in reality, many, many water molecules come together during condensation.

Possible Responses
What students should do and notice:
Students should have a chance to explore the different features of the Sim with their partners and discuss what they notice. By exploring and discussing what they notice in the Sim, students become familiar with the features of the Sim.
Investigating Condensation in the Sim

Students use the Sim to investigate what happens to water molecules when raindrops form.

Instructional Guide

1. Set a purpose for the Sim investigation. Explain that students will now use the Sim to observe molecules at the nanoscale to better understand how raindrops form.

2. Introduce notebook page 22. Have students turn to page 22, Investigating Condensation, in the Investigation Notebook. Review the instructions.

Your goal is to use the Sim to investigate condensation, then answer the questions.

- Step 1: Choose any landscape.
- Step 2: In RUN, check that the Wind is OFF and the Water Molecules toggle is ON.
- Step 3: Observe the movement of the water molecules. Remind students that the pink molecules represent water molecules as water vapor and the blue molecules represent water molecules as liquid water.
- Step 4: Press ANALYZE, then replay the run to make further observations.

Select a water molecule that has formed part of a raindrop. Observe the path of the molecule as you use the slider to scroll back and forth in time. Pay close attention to what happens as the molecules condense to form raindrops.

Find a place where a lot of liquid water is forming in the atmosphere. Use the Atmosphere Window to zoom in on the molecules and see what happens when water vapor turns to liquid water.

3. Give students time to use the Sim and complete the notebook page. Circulate and offer assistance as needed. Allow time for students to complete the investigation and discuss and answer the questions in their notebooks.
4. **Discuss interactions of molecules during condensation.** Have students set aside their devices. Use the questions in the notebook to guide discussion.

- What are the water molecules like before they condense?  
  [They are spread apart as water vapor.]

- What happens at the nanoscale when water condenses and forms a raindrop?  
  [Water molecules in the air come together into clusters to form raindrops.]

- When water vapor condenses into liquid water, the behavior and arrangement of the molecules change, but all of the molecules are still there.

Remind students that in the Sim, the color of water vapor and liquid water molecules are different. In reality, the molecules that make up water vapor and liquid water are the same molecules; they are just spread further apart in water vapor.

5. **Introduce and post the new key concept.** Read aloud the key concept.

   *Water molecules are far apart in water vapor and close together in liquid water.*

6. **Discuss when water molecules fall as rain.**

- When does liquid water in the atmosphere fall as rain?  
  Accept all responses.

7. **Show when molecules fall as rain.** Project the Sim and choose any landscape. Let the Sim run with Water Molecules ON. Go to ANALYZE and move the time slider left, back to where water vapor begins to condense.

- When the water vapor condenses into liquid water, it does not fall as rain right away.

  Slowly move the time slider right, forward in time, and point out that more and more water vapor condenses.

- What do you notice about when raindrops form?  
  [Raindrops form after a lot of water vapor condenses into liquid water.]

**Teacher Support**

**Instructional Suggestion**

_Producing More Experience: Clouds in the Sim_  
To provide another opportunity for students to see that clouds are liquid water and not water vapor, consider projecting the Sim and pointing out when clouds form. Choose any landscape and make sure the Water Molecules toggle is ON. Run the Sim until after it rains. Go to ANALYZE to replay the run and point out that when the water molecules cluster...
together to form liquid water, a cloud forms. Move the slider left, back to when there is only water vapor, and point out there are no clouds. When there is only water vapor, you can also turn Water Molecules OFF to show that there is nothing on the screen, emphasizing that water vapor is invisible.

Instructional Suggestion

Going Further: Mathematical Thinking

To further support students in understanding the scale of water molecules and why water vapor is invisible, prompt students to make sense of the size of a water molecule: \(0.00000000028\) meters. Show students how long \(2.8\) meters is by using a meter stick to draw a line on the board that is \(2.8\) meters long. Ask students how many times \(2.8\) needs to be divided by 10 to get to \(0.00000000028\) meters [ten times]. Explain that dividing by 10 ten times means that a water molecule is \(10^{10}\) smaller than \(2.8\) meters. Provide students with examples of objects they can see and their sizes (width of human hair = \(0.0001\) meters; grain of sand = \(0.0004\) meters; dust particle = \(0.00002\) meters) to help them make sense of the size of things they can and cannot see. Have students compare these sizes to the size of a water molecule. The purpose of this activity is to provide a real-world connection to the power of 10.

Possible Responses

Investigation Notebook

Investigating Condensation (page 22)

Describe the water molecules in water vapor before they condense into liquid water.
Water molecules in the air are spread apart.

What happens at the nanoscale when water vapor condenses into liquid water?
Water molecules in the air come together into clusters.

Does all of the liquid water in the atmosphere fall as rain? Why or why not?
Not all of the liquid water falls as rain. Liquid water falls as rain when there is enough of it in the atmosphere.

The Earth System Simulation

What students should do and notice:
Students should pick any landscape from the options on the landing page, and run the Sim with Wind off and the Water Molecules toggle on. In Analyze, they should press on a molecule and watch as they use the slider to scroll back and forth in time. They should notice that these molecules evaporate from a body of water, move up in the atmosphere, and condense to form clusters of liquid water. Students should also press on a molecule where liquid water is forming in the atmosphere and notice that rain liquid water forms when molecules from water vapor cluster together.
Name: _______________________________________ Date: ________________

**Reading About Phases of Water**

2. Answer the two questions below.
3. Draw what is happening at the nanoscale in the diagram on the next page.

Describe water molecules when they are in water vapor.

___________________________________________________________________
___________________________________________________________________

Describe water molecules when they are in liquid water.

___________________________________________________________________
___________________________________________________________________
Reading About Phases of Water (continued)

In the nanoscale zoom-in on this diagram:

- Draw and label the molecules of liquid water in the cup.
- Draw and label the molecules of water vapor outside the cup.
- Draw and label the molecules of water that condensed on the cup.
Investigating Condensation

Use the Sim to investigate condensation, then answer the questions below.

1. Choose any landscape.
2. In RUN, check that Wind is OFF and the Water Molecules toggle is ON.
3. Observe the movement of the water molecules.
4. Press ANALYZE, then replay to make further observations.
   - Select a water molecule that has formed part of a raindrop. Observe the path of the molecule as you use the slider to scroll back and forth in time. Pay close attention to what happens as the molecules condense to form raindrops.
   - Find a place where a lot of liquid water is forming in the atmosphere. Use the Atmosphere Window to zoom in on the molecules and see what happens when water vapor turns to liquid water.

Describe the water molecules in water vapor before they condense into liquid water.
___________________________________________________________________
___________________________________________________________________

What happens at the nanoscale when water vapor condenses into liquid water?
___________________________________________________________________
___________________________________________________________________

Does all of the liquid water in the atmosphere fall as rain? Why or why not?
___________________________________________________________________
___________________________________________________________________
Students read about how phases of water differ at the nanoscale and then draw what happens to water molecules when water condenses.

Instructional Guide

1. Review ideas about condensation.

¿Qué aprendimos cuando observamos un vaso de agua con hielo en una bolsa de plástico en De dónde vienen las gotas de agua: Investigación 2? [Las gotas de agua vienen del vapor de agua en el aire].

¿Por qué el vapor de agua se condensó en los vasos en nuestras investigaciones? [Porque estaban fríos].

Por nuestras investigaciones, sabemos que las gotas de agua se forman en el vaso cuando el vapor de agua en el aire se enfrió y se condensa de gas a líquido.

2. Refer to the Investigation Question and introduce today’s focus.

Hoy continuaremos investigando cómo se forman las gotas de lluvia haciendo zoom a la imagen para ver qué le sucede al vapor de agua cuando se condensa en forma líquida. Primero leeremos una sección de la Enciclopedia del agua.

3. Distribute books. Distribute one copy of Water Encyclopedia to each pair of students.

4. Project and introduce notebook pages 20–21. Have students turn to pages 20–21, Reading About Phases of Water, in the Investigation Notebook. Review the instructions with them.

   • Step 1: Read the “Phases of Water” section of Water Encyclopedia (pages 28–29).
   • Step 2: Answer the two questions below.
5. **Circulate while students read, write, and draw.** Encourage students to talk with their partners as they complete the notebook page.

6. **Discuss ideas.** Go through the questions and ask for volunteers to share their ideas. Explain that students will further investigate these ideas in the next activity.

7. **Introduce and post the molecule vocabulary card.** Have students turn to page 25 in *Water Encyclopedia*. Read the first paragraph aloud.

   - Como leyeron en el texto, una molécula es un grupo de átomos unidos de una manera particular.

   Post the molecule vocabulary card to the classroom wall.

8. **Introduce the word nanoscale.** Point out the image of water molecules on page 25 of *Water Encyclopedia*.

   - La gota de agua es algo que pueden ver u observar, pero las moléculas individuales están en la nanoscale. ¿Qué ideas tienen sobre qué es la nanoscale?

   Accept all responses.

   - De ahora en adelante, pensaremos en lo que está sucediendo en la escala observable, la cual podemos ver, y lo que está sucediendo con las moléculas en la nanoscale, la cual es demasiado pequeña para observarla directamente.

**Teacher Support**

**Instructional Suggestion**

**Providing More Experience: Today’s Daily Written Reflection**

*If you wanted to convince someone that the air is something and not nothing, what could you do?* This prompt (on page 19 in the Investigation Notebook) allows students to reflect on the concepts they learned in the previous lesson.

**Rationale**

**Pedagogical Goals: Diagramming Molecules During Condensation**

The purpose of having students complete a diagram after reading about water in different phases is to provide them with an opportunity to relate what they’ve read to the hands-on activities they have done. Students may struggle with
how to draw condensed water in this diagram because it requires them to synthesize what they know about condensation with what they’ve read about water in different phases. At this point in the lesson, some students may not understand or articulate that molecules of water come together when water vapor condenses into drops of water on a cup. Even so, the activity allows students to generate initial ideas which they can then test in the Sim, where they will be able to observe molecules during the process of condensation.

Rationale

Pedagogical Goals: Particles vs. Molecules

In The Earth System unit we use the term *molecule* rather than using the more general term particle. The word *molecule* is introduced in this lesson so that students can use scientific language to describe what happens during condensation and evaporation at the nanoscale. In discussing these ideas with students, we have found that it is more straightforward to use the word *molecule*. However, it is not important that students understand the precise definition of the word at this point in the unit. For now, the important thing for students to understand is that water is made up of tiny particles called water molecules. If you would like to provide more support for students to make sense of the precise definition of *molecule*, you might spend more time discussing the representation of water molecules on page 25 of Water Encyclopedia. You can point out how the red and white circles that make up each water molecule represent atoms, which are even smaller than molecules.

By using the term *molecule*, the unit enables students to begin developing a more precise understanding of matter at the nanoscale—differentiating between different kinds of molecules lays the groundwork for understanding chemical reactions at the nanoscale, which will become important in Chapter 5. In Chapter 5, students have a chance to explore chemical reactions at both the observable scale and the nanoscale, and gain the understanding that different substances are made of different molecules, which is key to making sense of chemical reactions. However, students are not expected to develop understanding of the specific arrangement of atoms within the molecules of each substance, the chemical formulas of molecules, the chemical bonds that hold atoms together, nor the difference between molecules and ionic compounds.

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Background

Student Thinking: Scale, Proportion, and Quantity in This Unit

The Earth System unit focuses students on understanding how water moves between parts of the Earth system at both the observable scale and the nanoscale. Understanding what happens to water when it evaporates into water vapor or when it condenses from water vapor is easier when you can actually visualize water changing phase. Likewise, understanding how water vapor moves around the atmosphere and causes different amounts of rain in different places is much easier when you can visualize this movement. Reading about water at different scales in Water Encyclopedia and working with The Earth System Simulation helps students visualize water moving around Earth in different phases. Take opportunities in this lesson and across the unit to help students begin to understand the nanoscale.
Background

Crosscutting Concept: Scale, Proportion, and Quantity Across Chapter 2

In Chapter 2, students investigate the question Why does more rain form over West Ferris than East Ferris? This requires them to be able to describe how raindrops form and where the water in raindrops comes from. An essential aspect of explaining how raindrops form is developing an understanding of water vapor and how water vapor condenses into liquid water. A nanoscale understanding of water and what happens to water molecules as water changes phases is required to elevate a mysterious description of condensation or evaporation, in which water seems to appear or disappear, to a mechanistic explanation involving the movement of molecules. Chapter 2 begins with opportunities to explore condensation at the observable scale, then allows students to develop more sophisticated explanations of how raindrops form by investigating what happens at the nanoscale. Students investigate evaporation at both scales as well.

Instructional Suggestion

Providing More Experience: Acting Out Different Phases of Water

The idea of particulate matter is a very challenging concept for students to grasp. You may want to give them more experience with how molecules are arranged in the different phases of water that they learn about in this lesson (liquid and gas). You could have students act out the different phases of water through hand motions or by moving around the classroom. For a quick extension, you could show students how to model water vapor by making fists to represent water molecules and then moving your fists around erratically, like molecules of gas moving through the air. You could then model liquid water by bringing your fists together, and moving them as a pair more slowly. For a longer extension, you could have students stand in an open space in your classroom and have them meander around each other briskly, keeping some distance between themselves, to represent water vapor. To represent liquid water, you could have them huddle close together in a clump and move around each other, staying in a tight configuration.

Possible Responses

Investigation Notebook

Reading About Phases of Water (pages 20–21)

Describe water molecules when they are in water vapor.
Water molecules in water vapor are spread apart and moving fast.

Describe water molecules when they are in liquid water.
Water molecules in liquid water are close together and can move around each other.

In this diagram:

- Draw and label the molecules of liquid water in the cup.
- Draw and label the molecules of the water vapor outside the cup.
• Draw and label the molecules of water that condensed on the cup.

Representations of molecules may vary. However, drawings should show that molecules are closer together in liquid water and farther apart in water vapor.
Exploring The Earth System Simulation

Students are introduced to *The Earth System* Simulation and become familiar with its features.

**Instructional Guide**

1. **Introduce *The Earth System* Simulation.**

   Hoy vamos a usar un simulador digital, o Simulación, para aprender más acerca de cómo se forman las gotas de lluvia, tanto en la escala observable como en la nanoescala. Tendrán tiempo para explorar la Simulación en parejas, y luego usarán la Simulación para observar cómo se forman las gotas de lluvia.

2. **Students think about water molecules during condensation.** Have students briefly discuss condensation on the nanoscale with their partners.

   ¿Qué piensan que les sucede a las moléculas de agua cuando el vapor de agua se condensa en gotas de lluvia en la atmósfera?

**Reglas para usar aplicaciones**

- Solo una persona “maneja” a la vez.
- Todos pueden hacer sugerencias sobre cómo usar la aplicación.
- Hablen sobre lo que observan.
- Roten en el rol de “conductor”.

4. Project *The Earth System Simulation*. Project the Student Apps Page and select *The Earth System* and then the Simulation. Choose any landscape.

5. Organize students into pairs and distribute digital devices. Distribute one digital device to each pair of students and have them go to *The Earth System* Simulation. Let students know they will have a few minutes to explore the Sim.

6. Give pairs several minutes of free exploration time. Circulate as students explore the Sim, encouraging them to discuss what they are observing with their partners. Listen for student questions or alternate conceptions as they relate to the basic components of the Sim. Halfway through the free exploration time, provide a signal for students to switch “drivers.”

7. Discuss observations. Have students to share their observations with the class.

¿Qué observaron mientras exploraban la Simulación?

8. Discuss features of the Sim. Students are very quick to learn on their own and will be more engaged if they can discover and share some of the Sim’s features. Demonstrate, or allow students to demonstrate, what they discovered about how the Sim works. Point out the following features if students don’t bring them up in the discussion:

- **Landscape**: In the landscape screen, students can choose one of twelve landscapes.
- **Wind**: Students can turn wind off or designate its direction.
- **Water Molecules toggle**: Students can toggle water molecules on to show what is happening to water molecules. When water molecules are visible, a key appears that labels liquid water and water vapor molecules.
9. Discuss how the Sim allows students to observe at the nanoscale. On your projection of the Sim, point out the Water Molecules toggle and turn it ON. Explain that this allows students to see what is happening to water molecules at the nanoscale, which is too small to observe otherwise. Point out that blue molecules represent liquid water and pink molecules represent water vapor, as shown in the key in the lower right corner of the landscape.

10. Introduce the idea of the Sim as a model.

La Simulación es un modelo. Un modelo es algo que los científicos crean para responder preguntas sobre el mundo real.

11. Discuss the globe as a model. Hold up the inflatable globe and explain that it is a model too. Have students identify ways that a globe is an accurate or inaccurate model of Earth.

How is the globe an accurate model of Earth? How is it inaccurate? [Accurate: shaped like a ball, has oceans and land in the right shapes. Inaccurate: smaller than real Earth, filled with air, has words written on it.]

12. Discuss diagrams as models. Refer to the diagrams students made of water molecules on or around a cup on page 18, Where the Water Drops Come From: Investigation 2, in the Investigation Notebook.

Sus dibujos de moléculas y las imágenes de moléculas en la Enciclopedia del agua también son modelos. Las moléculas en realidad no se ven así y no son tan grandes, pero estos modelos hacen que sea más fácil para nosotros darle sentido al agua a la nanoescala.

13. Discuss inaccuracies in the Sim. Emphasize that models can be accurate in some ways and inaccurate in other ways.

Dependiendo de para qué los estén usando los científicos y los ingenieros, los modelos muestran algunos aspectos del mundo real con precisión, pero no son precisos de otras maneras.

Point out accurate aspects, such as water flowing down the mountain or into the ground, where it is stored as groundwater. Have pairs discuss inaccurate aspects, then have students share what they have noticed with the class. Highlight the following:

- Liquid water and water vapor are depicted with two different colors: blue and pink, respectively. The color distinction in the model enables students to distinguish between liquid water and water vapor. In reality, this is not what the molecules really look like. The molecules in water vapor and liquid water are the same. The difference between liquid and vapor is the arrangement and behavior of the water molecules. Molecules in water vapor are spread apart; molecules in liquid water are close together.
• Some areas in the atmosphere in the Sim do not show any water vapor molecules. In reality, water vapor is present in all parts of Earth's atmosphere, even indoors.

Teacher Support

Background

Technology Note: About The Earth System Simulation

The Earth System Simulation allows students to study condensation and evaporation at both the observable scale and the nanoscale. The Sim is a dynamic model that shows how molecules evaporate from the surface of bodies of water as water vapor, come together to form liquid water in the atmosphere, and fall as rain. The Sim also enables students to explore how features of the environment (e.g., the wind, mountains) can affect the movement of water vapor and, subsequently, differential patterns in rainfall. Open exploration in the Sim enables students to get an initial sense of the behavior of molecules at the nanoscale during condensation and evaporation. This will prepare students to gather information in the Sim about why one place might get more rain than another.

Background

Science Note: About Rainfall in the Sim

In the Sim, if wind is turned off, water molecules will only move vertically and will not blow over the land. This means that the Sim will not show rain forming over land unless wind is turned on. This is generally consistent with the natural phenomenon: the wind causes water in the atmosphere to move to other parts of the atmosphere, including areas over land. However, this visual (of rain forming only over water) may be confusing for students, as it is misaligned with their experiences with rain (which occurs on land). If students question why the rainfall occurs only over bodies of water, you might point out that factors like the wind allow rain to happen on land. However, note that the unit is intentionally designed so that students do not use the wind feature in the Sim until Chapter 4 when they investigate what factors cause water vapor to move to different parts of the atmosphere.

Instructional Suggestion

Technology Note: Sharing Devices with a 1:2 Ratio

Throughout this unit, pairs share digital devices. We recommend that instead of working individually, students work with partners so they can engage and talk to each other while investigating molecules in the Sim. Try to establish clear expectations for the use, handling, and storage of digital devices in order to decrease transition time between activities and minimize any potential conflict that could come from sharing a limited number of devices.

Background

Science Practices: About Models

Scientists develop and use models to help them conceptualize, investigate, and communicate ideas about how the natural world works. Scientists create models to portray structures and processes that are thought to exist in the real world but are not readily observable. A model can be a physical setup that is smaller or larger than what it represents; a diagram that depicts things that are not visible; or a computer simulation that represents salient features of a phenomenon, system, or process. Models are used to describe tentative ideas to be tested, substitute for situations that are hard to investigate directly, clarify ideas for oneself, or communicate ideas to others. In all cases, scientific models approximate whatever is being modeled in an intentional way, simplifying some aspects in order to clearly focus on others.
Rationale

Pedagogical Goals: Discussing Inaccuracies in the Sim
Discussing the inaccuracies of the Sim ensures that students do not come away with false ideas and provides an opportunity for students to learn about the scientific practice of modeling. Approximations and simplifications are inherent in models, and it is important to acknowledge them to understand the limitations of what conclusions can be made from the models. Discussing inaccuracies of the Sim calls out how it is a useful tool, but not an exact replica of the real world.

Background

Science Note: Inaccuracies in the Sim
The Earth System Simulation is intended to provide students with a model for investigating the phenomena of evaporation, condensation, and interactions of Earth’s spheres. However, some simplifications of content are necessary to support students with this key content. Note the following important simplifications:

- Liquid water and water vapor are depicted with two different colors: blue and pink, respectively. The color distinction in the model enables students to distinguish between liquid water and water vapor. In reality, this is not what the molecules really look like. The molecules in water vapor and liquid water are the same. The difference between liquid and vapor is the arrangement and behavior of the water molecules. Molecules in water vapor are spread apart; molecules in liquid water are closer together.

- Some areas in the atmosphere in the Sim do not show any water vapor molecules. In reality, water vapor is present in all parts of Earth’s atmosphere, even indoors.

- The size of the molecules in the Sim is much larger than their actual size. This inaccuracy is intentional to allow students to see how molecules behave; however, it could lead a student have a skewed understanding of the scale of molecules or the quantity of molecules that come together during condensation.

- The rocks in the landscapes have very large cracks that water can flow through. In reality, the rocks that groundwater flows through often look solid, without large, visible cracks. Water can flow through tiny cracks and small spaces within rocks that may be too small to see at the observable scale.

- In the Sim, it takes a few minutes for water vapor to evaporate, move through the atmosphere, and condense. In reality, this process is much slower (i.e., hours rather than minutes). The Sim speeds this process up so that we can observe the entire cycle.

- When water vapor condenses into liquid water in the Sim, just three molecules come together; in reality, many, many water molecules come together during condensation.

Possible Responses

| The Earth System Simulation |
What students should do and notice:
Students should have a chance to explore the different features of the Sim with their partners and discuss what they notice. By exploring and discussing what they notice in the Sim, students become familiar with the features of the Sim.
Investigating Condensation in the Sim

Students use the Sim to investigate what happens to water molecules when raindrops form.

**Instructional Guide**

1. **Set a purpose for the Sim investigation.** Explain that students will now use the Sim to observe molecules at the nanoscale to better understand how raindrops form.

2. **Introduce notebook page 22.** Have students turn to page 22, Investigating Condensation, in the Investigation Notebook. Review the instructions.

   - **Step 1:** Choose any landscape.
   - **Step 2:** In RUN, check that the Wind is OFF and the Water Molecules toggle is ON.
   - **Step 3:** Observe the movement of the water molecules. Remind students that the pink molecules represent water molecules as water vapor and the blue molecules represent water molecules as liquid water.
   - **Step 4:** Press ANALYZE, then replay the run to make further observations.

   Select a water molecule that has formed part of a raindrop. Observe the path of the molecule as you use the slider to scroll back and forth in time. Pay close attention to what happens as the molecules condense to form raindrops.

   Find a place where a lot of liquid water is forming in the atmosphere. Use the Atmosphere Window to zoom in on the molecules and see what happens when water vapor turns to liquid water.

3. **Give students time to use the Sim and complete the notebook page.** Circulate and offer assistance as needed. Allow time for students to complete the investigation and discuss and answer the questions in their notebooks.
4. Discuss interactions of molecules during condensation. Have students set aside their devices. Use the questions in the notebook to guide discussion.

¿Cómo están las moléculas de agua antes de condensarse?
[Están separadas como vapor de agua].

¿Qué ocurre a la nanoescala cuando el agua se condensa y forma una gota de lluvia?
[Las moléculas de agua en el aire se juntan en grupos para formar gotas de lluvia].

Cuando el vapor de agua se condensa en agua líquida, el comportamiento y la disposición de las moléculas cambia, pero todas las moléculas continúan allí.

Remind students that in the Sim, the color of water vapor and liquid water molecules are different. In reality, the molecules that make up water vapor and liquid water are the same molecules; they are just spread further apart in water vapor.

5. Introduce and post the new key concept. Read aloud the key concept.

Las moléculas de agua están muy separadas en el vapor de agua y muy juntas en el agua líquida.

6. Discuss when water molecules fall as rain.

¿Cuándo cae como lluvia el agua líquida en la atmósfera?

Accept all responses.

7. Show when molecules fall as rain. Project the Sim and choose any landscape. Let the Sim run with Water Molecules ON. Go to ANALYZE and move the time slider left, back to where water vapor begins to condense.

¿Cuando el vapor de agua se condensa en agua líquida, no cae como lluvia inmediatamente.

Slowly move the time slider right, forward in time, and point out that more and more water vapor condenses.

¿Qué notan acerca de cuándo se forman las gotas de lluvia?
[Las gotas de lluvia se forman después de que mucho vapor de agua se condensa en agua líquida].

Teacher Support

Instructional Suggestion

Providing More Experience: Clouds in the Sim

To provide another opportunity for students to see that clouds are liquid water and not water vapor, consider projecting the Sim and pointing out when clouds form. Choose any landscape and make sure the Water Molecules toggle is ON. Run the Sim until after it rains. Go to ANALYZE to replay the run and point out that when the water molecules cluster
together to form liquid water, a cloud forms. Move the slider left, back to when there is only water vapor, and point out there are no clouds. When there is only water vapor, you can also turn Water Molecules OFF to show that there is nothing on the screen, emphasizing that water vapor is invisible.

**Instructional Suggestion**

**(Going Further: Mathematical Thinking)**

To further support students in understanding the scale of water molecules and why water vapor is invisible, prompt students to make sense of the size of a water molecule: 0.00000000028 meters. Show students how long 2.8 meters is by using a meter stick to draw a line on the board that is 2.8 meters long. Ask students how many times 2.8 needs to be divided by 10 to get to 0.00000000028 meters [ten times]. Explain that dividing by 10 ten times means that a water molecule is $10^{-10}$ smaller than 2.8 meters. Provide students with examples of objects they can see and their sizes (width of human hair = 0.0001 meters; grain of sand = 0.0004 meters; dust particle = 0.00002 meters) to help them make sense of the size of things they can and cannot see. Have students compare these sizes to the size of a water molecule. The purpose of this activity is to provide a real-world connection to the power of 10.

**Possible Responses**

**Investigation Notebook**

**Investigating Condensation** (page 22)

Describe the water molecules in water vapor before they condense into liquid water.

Water molecules in the air are spread apart.

What happens at the nanoscale when water vapor condenses into liquid water?

Water molecules in the air come together into clusters.

Does all of the liquid water in the atmosphere fall as rain? Why or why not?

Not all of the liquid water falls as rain. Liquid water falls as rain when there is enough of it in the atmosphere.

**The Earth System Simulation**

**What students should do and notice:**

Students should pick any landscape from the options on the landing page, and run the Sim with Wind off and the Water Molecules toggle on. In Analyze, they should press on a molecule and watch as they use the slider to scroll back and forth in time. They should notice that these molecules evaporate from a body of water, move up in the atmosphere, and condense to form clusters of liquid water. Students should also press on a molecule where liquid water is forming in the atmosphere and notice that rain liquid water forms when molecules from water vapor cluster together.
Leer sobre las fases del agua

1. Lee la sección titulada “Fases del agua” en la Enciclopedia del agua (páginas 28 a 29).
2. Responde las dos preguntas debajo.
3. Dibuja lo que está ocurriendo a la nanoescala en el diagrama en la página siguiente.

Describe las moléculas de agua cuando están en vapor de agua.

___________________________________________________________________
___________________________________________________________________

Describe las moléculas de agua cuando están en agua líquida.

___________________________________________________________________
___________________________________________________________________
Leer sobre las fases del agua (continuación)

En la vista ampliada de la nanoescala en este diagrama:

- Dibuja e identifica las moléculas de agua líquida en el vaso.
- Dibuja e identifica las moléculas de vapor de agua afuera del vaso.
- Dibuja e identifica las moléculas del agua que se condensó sobre el vaso.

Vista a la nanoescala
Investigar la condensación

Usa la simulación para investigar la condensación, y luego responde las preguntas debajo.

1. Elige cualquier paisaje.
2. En la opción RUN (accionar), chequea que Wind (el viento) esté OFF (apagado) y que el interruptor de Water Molecules (moléculas de agua) esté ON (encendido).
3. Observa el movimiento de las moléculas de agua.
4. Oprime ANALYZE (analizar) y luego vuelve a repetir la simulación para hacer observaciones adicionales.
   - Selecciona una molécula de agua que haya formado parte de una gota de lluvia. Observa la trayectoria de la molécula a medida que usas la barra de ajuste para desplazarte hacia atrás y hacia delante en el tiempo. Pon mucha atención a lo que ocurre a medida que las moléculas se condensan para formar gotas de lluvia.
   - Busca un lugar en donde se esté formando mucha agua líquida en la atmósfera. Usa la ventana Atmosphere (atmósfera) para ver de cerca las moléculas y ver lo que ocurre cuando el vapor de agua se convierte en agua líquida.

Describe las moléculas de agua en el vapor de agua antes de que se condensan en agua líquida.

___________________________________________________________________
___________________________________________________________________

¿Qué ocurre a la nanoescala cuando el vapor de agua se condensa en agua líquida?

___________________________________________________________________
___________________________________________________________________

¿Toda el agua líquida en la atmósfera cae como lluvia? ¿Por qué sí o por qué no?

___________________________________________________________________
___________________________________________________________________