The Water Cycle
Lesson 4a: Using Molecules to Explain Evaporation and Condensation

Grade 5	**Length of lesson:** 45 minutes	**Placement of lesson in unit:** 4a of 6 two-part lessons on the water cycle
Unit central questions: How does water change in the world around us? Does Earth ever run out of water?		**Lesson focus question:** How can ideas about water molecules help us explain evaporation and condensation?
Main learning goal: Changes in the energy (motion) of molecules help explain how water changes state during evaporation and condensation.		
Science content storyline: Water molecules move differently when they're in different states (liquid, solid, and gas). We can use this idea to explain what is happening during phase changes like evaporation and condensation. In a liquid state, water molecules are loosely attracted to each other and can slip and slide past one another. As water molecules in the liquid state absorb energy, they move faster, break away from other molecules, escape the surface of the water (a phase change), and spread throughout the air as individual gas molecules called *water vapor*. This process of liquid water absorbing heat, increasing its molecular motion, and changing from a liquid to a gas is called *evaporation*. Boiling water in lesson 1a is an example of evaporation: When the water boils, the molecules gain energy, move faster, and break away from each other to form water vapor in the bubbles and at the surface of the water. When water-vapor molecules in the air lose heat energy (cool), they slow down and are attracted to each other to form liquid-water droplets. This process is called *condensation*. An example of condensation is the water that formed on the cup of ice water in lesson 2a.		
Ideal student response to the focus question: When liquid water absorbs heat, the water molecules gain energy and start moving faster. Eventually they move so fast, they can break away from each other and fly off by themselves into the air as individual gas molecules (water vapor). This is *evaporation*. When water-vapor molecules in the air cool down, they lose heat energy, slow down, and join up with other water-vapor molecules to form drops of liquid water. This is *condensation*.		

Preparation

Materials Needed	**Ahead of Time**
• Science notebooks • PhET *States of Matter* simulation (https://phet.colorado.edu/en/simulation/states-of-matter) • Chart paper, markers • *Optional:* cold soda can or bottle. (Right before the lesson, set the can or bottle out at room temperature to allow condensation to form.) **Student Handouts** • 4.1 Questions about Energy and Water Molecules (1 per student)	• Review the Water Cycle Content Background Document: sections 1.1, 1.3, and 1.5. • Review the PowerPoint slides and modify them as you wish. • Practice using the PhET *States of Matter* simulation so you can effectively demonstrate the relationships among temperature, molecular motion, and change of state. Knowing when to stop the water-vapor cooling is a little tricky. *Stopping it before the liquid water turns to ice may take some practice.* • *Optional:* Set out a cold soda can or bottle to see how long it takes for liquid-water droplets to form.

Lesson 4a General Outline

Time	Phase of Lesson	How the Science Content Storyline Develops
2 min	**Link to previous lesson:** As a quick review, the teacher has students interpret diagrams of water molecules in liquid and gaseous states.	• When water is in its liquid state, molecules are loosely connected, allowing individual molecules to slip or slide past one another. When water is in its gaseous state (water vapor), molecules aren't held together; that is, individual water molecules break away from each other (move apart) and spread throughout the air.
2 min	**Lesson focus question:** The teacher introduces the focus question, *How can ideas about water molecules help us explain evaporation and condensation?*	
5 min	**Setup for activity:** The teacher elicits student ideas about water molecules that can explain evaporation and condensation (the focus question) and charts the ideas before introducing the PhET simulation.	• We can use scientists' models to explain how water molecules move when they're heated and cooled, and when they evaporate and condense.
15 min	**Activity:** The teacher demonstrates the PhET simulation, using this model to help students understand how energy changes in water molecules are related to the state changes of evaporation and condensation. Students write down answers to questions at each stage of the simulation.	• Changes in molecular energy help explain how water changes state. Evaporation happens when water molecules in the liquid state gain energy (often when heated) and move fast enough to break away from each other as individual water-vapor molecules. Condensation occurs when water-vapor molecules lose energy (cool), causing individual water molecules to slow down and link together as liquid water.
10 min	**Follow-up to activity:** Students use ideas about energy and water molecules to explain two situations: evaporation of rain puddles and condensation on a cold soda can (or bottle).	• As water molecules in the liquid state absorb (gain) heat energy, they move faster. These fast-moving molecules can escape other water molecules at the surface (a phase change) and spread out into the air as individual gas molecules (water vapor). This process of liquid water absorbing heat energy, increasing molecular motion, and changing from a liquid to a gas is called *evaporation*. • When water-vapor molecules in the air lose heat energy (cool), they slow down and are attracted to each other, forming liquid-water droplets. This process is called *condensation*.
10 min	**Synthesize/summarize today's lesson:** Students answer the focus question and discuss their responses. They also explain evaporation and condensation phenomena in terms of changes in the motion (energy) of water molecules. Then the teacher summarizes key science ideas from the lesson.	
1 min	**Link to next lesson:** The teacher links science ideas to the next lesson.	

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2 min	**Link to Previous Lesson** **Synopsis:** As a quick review, the teacher has students interpret diagrams of water molecules in liquid and gaseous states. **Main science idea(s):** • When water is in its liquid state, molecules are loosely connected, allowing individual molecules to slip or slide past one another. When water is in its gaseous state (water vapor), molecules aren't held together; that is, individual water molecules break away from each other (move apart) and spread throughout the air.	Link science ideas to other science ideas.	**Show slide 1.** In the previous lesson, we learned about water molecules and how they move in different states of matter. Let's see if you can identify water molecules in different states of matter! **NOTE TO TEACHER:** *Ask students the following questions as you display the PowerPoint images of water molecules in the water-vapor state and the liquid state.* **Show slides 2 and 3.** 1. What does this diagram show? 2. What state of matter do you think these water molecules are in? How do you know?	**For slide 2:** • *Question 1:* It shows water molecules with two Hs and one O. • *Question 2:* It's water vapor (gas) because the molecules are far apart. **For slide 3:** • *Question 1:* It shows the water molecules touching. • *Question 2:* It's the liquid state because the molecules are touching, but they	

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				aren't organized like water in the solid state. They slip and slide past each other in different directions.	How would you describe the movement of water molecules in the liquid state?
2 min	**Lesson Focus Question** **Synopsis:** The teacher introduces the focus question, *How can ideas about water molecules help us explain evaporation and condensation?*	Set the purpose with a focus question or goal statement.	**Show slide 4.** Our focus question for today is *How can ideas about water molecules help us explain evaporation and condensation?* Write this question in your science notebooks and draw a box around it. **NOTE TO TEACHER:** *Also post this question where everyone can see and refer to it throughout the lesson.*		
5 min	**Setup for Activity** **Synopsis:** The teacher elicits student ideas about water molecules that can explain evaporation and condensation (the focus question) and charts the ideas before introducing the PhET simulation. **Main science idea(s):** • We can use scientists'	Make explicit links between science ideas and activities **before** the activity.	Yesterday we watched a simulation, or scientific model, of water molecules to learn about how they move in liquid, solid, and gaseous states. Today we'll use the same simulation to help us develop an explanation of what happens to water molecules during evaporation and condensation. **Show slide 5.**		

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	models to explain how water molecules move when they're heated and cooled, and when they evaporate and condense.	Ask questions to elicit student ideas and predictions.	But first, what do you think happens to water molecules during evaporation and condensation? What ideas do you have about how water molecules move that can help us explain these processes? **Turn and Talk:** Discuss these questions with a partner and be ready to share your ideas with the class. **Whole-class discussion:** Let's start with your ideas about evaporation. What do you think happens to water molecules during this process? **NOTE TO TEACHER:** *Chart students' ideas so they can look at this list later to see which ideas the scientific model does and does not support.* *Make it clear to students that these are their **current** ideas, and they may not all be scientifically accurate or correct. One of the characteristics of scientists is that they're open to changing their ideas if new evidence or better ideas come along.*	Maybe like when we boiled water, the strong heat breaks the water molecules apart into oxygen gas and hydrogen gas, and that's how they evaporate. *[Misconception]* Liquid-water molecules get so hot that they move apart, escape the surface of the liquid, and become water-vapor (gas) molecules.	Do others agree or disagree? Why and how might that happen? Why do you think heating makes water molecules escape the surface of the liquid?

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			Now let's hear your ideas about condensation. What do you think happens to water molecules during this process?	Maybe water molecules stick to cold things like magnets, and that's why we see condensation on cold soda cans. *[Misconception]* Maybe molecules of water get bigger *[expand]* when they get cold, and that's why we can see them on the glass. *[Misconception]* When water-vapor molecules get cold, maybe they huddle together like we do on the playground when it's cold.	What might cold things/cooling have to do with it? What evidence do we have from yesterday's simulation that supports or challenges this idea? What evidence do we have from yesterday's simulation that either supports or challenges this idea?

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			Look at all the interesting ideas you came up with! The neat thing about scientific models is that we can use them to test our ideas. So now we're going to use the simulation to see whether our ideas are correct. As you watch each model, notice what's happening and record your observations when you answer the questions on the handout I'll be giving you in a moment.		
15 min	**Activity** **Synopsis:** The teacher demonstrates the PhET simulation, using this model to help students understand how energy changes in water molecules are related to the state changes of evaporation and condensation. Students write down answers to questions at each stage of the simulation. **Main science idea(s):** • Changes in molecular energy help explain how water changes state. Evaporation happens when water molecules in the liquid state gain energy (often when heated) and move fast enough to break away	Select content representations and models matched to the learning goal and engage students in their use.	**Show slide 6.** **NOTE TO TEACHER:** *Distribute Questions about Energy and Water Molecules (handout 4.1) for students to insert in their science notebooks.* **NOTE TO TEACHER:** *Make sure to run the PhET simulation ahead of time so you can effectively demonstrate heating and cooling and the change from water vapor to liquid water during condensation. (Be careful as you work with the simulation. As the water-vapor molecules lose heat energy, they can quickly turn from the liquid state to ice, so you'll want to practice stopping the simulation before that happens.)* First, let's run the simulation to see what happens when we heat liquid water. **NOTE TO TEACHER:** *Heat the liquid water just enough to show*		

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	from each other as individual water-vapor molecules. Condensation occurs when water-vapor molecules lose energy (cool), causing individual water molecules to slow down and link together as liquid water.	Make explicit links between science ideas and activities **during** the activity. Engage students in analyzing and interpreting data and observations.	*changes in molecular speed.* ***Be careful not to heat it too much!*** So what happens to water molecules when we heat them? What did you observe? Now answer question 1 on your handouts and record your observations. **NOTE TO TEACHER:** *Continue heating the liquid water until all the molecules have changed state to water vapor.* This simulation showed only the process of evaporation. So what happens to water molecules during evaporation?	They move faster. The liquid-water molecules move really fast and break apart. *[Fuzzy language; possible misconception]* The molecules pop out of the liquid water into the air, and they spread out all over the place.	Say more about what you mean by "break apart." *[Make sure the student doesn't mean that the Hs and the O in a water molecule split apart.]* What state are the

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					water molecules in when they spread out all over the place?
				Gas.	
					Why do the gas molecules "pop out" of the liquid water?
				Because they get heated up.	
					What does heating do to the molecules?
				It adds energy.	
			Now answer question 2 on your handouts and record your observations.		
			Next, let's look at what happens when we cool water vapor.		
			NOTE TO TEACHER: *Cool just enough water vapor to show changes in the speed of molecules.* ***Be careful not to cool the water vapor too quickly!***		
			So what happens to water molecules when we cool them? What did you observe?		
				They move slower.	
					What does cooling have to do with the water molecules moving slower?
				The molecules lose heat energy.	
			Now answer question 3 on your handouts and record your observations.		

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			NOTE TO TEACHER: *Continue cooling the water vapor until all the molecules have changed state to liquid water.* This simulation showed only the process of condensation. So what happens to water molecules during condensation? Now answer question 4 on your handouts and record your observations. **NOTE TO TEACHER:** *Decide whether to have students work on question 5 of the handout in small groups or pairs.* ***If time is running short, you can skip this question (and slide 7).*** **Show slide 7.** Now let's look at our initial ideas on the chart. Which ideas does the scientists' model support? Which ideas does it **not** support? **Small groups or pairs:** Discuss your initial ideas about evaporation and	The water-vapor molecules move slower and slower and stick to each other. They're in the liquid state.	What state are the molecules in when they stick to each other?

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			condensation and whether the scientists' model supports or does **not** support them. Then record your answers to question 5 on the handout. Be ready to share the results with the class. **Students work in small groups or pairs.** **Whole-class discussion:** Which of your ideas does the scientists' model support? Which ideas does the model **not** support? **NOTE TO TEACHER:** *Challenge students to justify their responses with descriptions of what is/is not shown in the scientists' model. Ask students to provide evidence from the simulation to support their answers.*	*Ideas that the scientists' model **does not support**:* • Maybe the strong heat breaks water molecules apart into oxygen gas and hydrogen gas, and that's how they evaporate. *[Misconception]* • Maybe water molecules stick to cold things like magnets, and that's why we see condensation on cold soda cans. *[Misconception]* • Maybe molecules of water get bigger when they get cold, and that's why we can see them on glass. *[Misconception]*	*Challenge question:* What evidence do you have from the simulation to support that argument?

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				• Water molecules in the liquid state change into water-vapor molecules. *[Water molecules are still water (H_2O) molecules. What changes is their energy level and speed.)* *Ideas that scientists' model **does** support:* • Liquid-water molecules get so hot that they break away from other molecules, escape the surface of the liquid, and become water-vapor (gas) molecules. • When water-vapor molecules get cold, maybe they huddle together like we do on the playground when it's cold.	
10 min	**Follow-Up to Activity** **Synopsis:** Students use ideas about energy and water molecules to explain two situations: evaporation of rain puddles and condensation on a cold soda can (or bottle).	Make explicit links between science ideas and activities **after** the activity. Engage students in using and apply new science ideas in a variety of ways	So let's see if the ideas about water molecules and how they move during evaporation and condensation can help us explain a couple of everyday situations. **Show slide 8.** Look at this slide showing a puddle of		

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	Main science idea(s): • As water molecules in the liquid state absorb (gain) energy, they move faster. These fast-moving molecules can escape other water molecules at the surface (a phase change) and spread out into the air as individual gas molecules (water vapor). This process of liquid water absorbing heat energy, increasing molecular motion, and changing from a liquid to a gas is called *evaporation*. • When water-vapor molecules in the air lose heat energy (cool), they slow down and are attracted to each other, forming liquid-water droplets. This process is called *condensation*.	and contexts.	rainwater. **Turn and Talk:** Talk with a partner about the two questions on the slide: 1. What change of state is going to occur? 2. Why will this change of state happen? Use the words *energy* and *water molecules* in your answer. **Whole-class discussion:** So when a puddle forms after it rains, and the Sun is out, what change of state will take place?	Evaporation. Liquid will change to gas (water vapor). It will happen because of heat energy from the Sun. The heat from the Sun will give more energy	Does anyone disagree? *[Hopefully not!]* Evaporation is a process that will occur. What change of state is involved in evaporation? Why will this change of state happen? Can you add something about molecules to your explanation?

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				to the water molecules in the puddle. When the molecules have more energy, they start moving faster and break out of the puddle.	Say more about what happens when the water molecules get more heat energy from the Sun.
			Show slide 9. **Option:** *Show students a cold soda can or bottle with water droplets on it.* Now let's consider a cold soda can sitting outside on a table on a hot day. What change of state will occur?	Condensation. Water changes state from water vapor (gas) to liquid water. We'll see water droplets on the outside of the can.	Condensation is the process that will occur. But what change of state is involved? How will you know if this change of state has occurred? What will you observe? Why will this change of state happen?

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				Water-vapor molecules in the air near the cold can cool down and change into liquid-water droplets on the can. The water-vapor molecules near the cold can are cooling, which means they're losing heat energy, and this make them slow down.	Can you add something about energy?
10 min	**Synthesize/Summarize Today's Lesson** **Synopsis:** Students write answer the focus question and discuss their responses. They also explain evaporation and condensation phenomena in terms of changes in the motion (energy) of water molecules. Then the teacher summarizes key science ideas from the lesson. **Main science idea(s):** • As water molecules in the liquid state absorb (gain) energy, they move faster. These fast-moving molecules can escape other water	Highlight key science ideas and focus question throughout. Engage students in using and applying new ideas in a variety of ways and contexts.	**Show slide 10.** Today's focus question is *How can ideas about water molecules help us explain evaporation and condensation?* Now let's use the important ideas we've learned about energy, water molecules, evaporation, and condensation to answer this question. **NOTE TO TEACHER:** *Decide whether you want students to do this activity individually or in pairs.* I'd like half of you to answer the question about evaporation on the slide, and half to answer the question about condensation. Your task is to write a summary sentence or sentences to answer your assigned question. You'll be working on this task individually [*or*		

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	molecules at the surface (a phase change) and spread out into the air as individual gas molecules (water vapor). This process of liquid water absorbing heat energy, increasing molecular motion, and changing from a liquid to a gas is called *evaporation*. • When water-vapor molecules in the air lose heat energy (cool), they slow down and are attracted to each other, forming liquid-water droplets. This process is called *condensation*.	Highlight key science ideas and focus question throughout.	*in pairs*]. **NOTE TO TEACHER:** *Assign the first question to half of the students, and the second to the other half.* 1. What happens to water molecules during evaporation? 2. What happens to water molecules during condensation? **Students work on summary statements.** **Whole-class discussion**: Have students share and refine their summary statements. Make sure they capture the key science ideas in column 2. **Show slide 11.** So evaporation happens when water molecules in the liquid state gain heat energy, move faster, and escape into the air as water vapor or gas. And condensation occurs when water-vapor molecules lose heat energy (cool), slow down, and join together to form liquid-water droplets.		
1 min	**Link to Next Lesson** **Synopsis:** The teacher links science ideas to the next lesson.	Link science ideas to other science ideas.	**Show slide 12.** These ideas about water molecules and energy help us explain the processes of evaporation and condensation. Tomorrow we'll watch a demonstration		

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			of water changes in a system and think more about what happens when water molecules change state.		