LESSON 9: Is the gas(es) produced from water using a battery made of the same particles that were produced from heating the water?

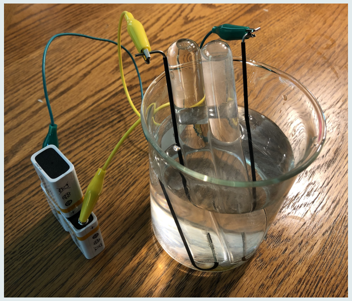
PREVIOUS LESSON

We carried out an investigation on the flammability of the gas produced by heating water. We collected data on the mass and volume of the liquid that formed from the gas. We argued that the resulting property data indicates that the gas we collected is made of the same particles that were in the water we started with.

THIS LESSON

INVESTIGATION

1 day



We carry out an investigation to test the flammability of gases produced by providing energy to water with electricity. We revise our models to reflect the particle level changes happening when we produce gases from water by heating (boiling) vs. with electricity (electrolysis).

NEXT LESSON

We will gather and summarize information from a reading on investigations that scientists did and molecular models they developed. We will individually use those models to predict and explain what gas is produced in the bath bomb reaction and what is happening to the particles in the system.

BUILDING TOWARD NGSS

MS-PS1-1, MS-PS1-2, MP-PS1-5

WHAT STUDENTS WILL DO

Revise and use a model based on observable patterns in data that show the unobservable mechanisms that occur at a particle level when energy is added to a substance with electricity to produce new substances with new properties.

WHAT STUDENTS WILL FIGURE OUT

- Two different gases with different properties are produced from adding electrical energy to water.
- The least abundant gas is oxygen gas. The most abundant gas could be propane, methane, or hydrogen.
- The particles that make up these different gases must come from the water particles already there.
- The way that particles separate and come together is different in a physical change such as boiling and condensing water vs. a chemical reaction where we turned one substance (water) into a new one(s) [hydrogen gas and oxygen gas].

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION: SHARING IDEAS ABOUT THE GAS(ES)** Share ideas about the gases produced from boiling compared to those produced by electrolysis. Suggest what properties to test and plan the data collection.	A, B	
2	15 min	**INVESTIGATING ELECTRICAL ENERGY AND WATER** Demonstrate flammability tests for the two gases produced by electrolysis. Discuss what the data mean.	C-G	Investigation of Electrical Energy and Water
3	5 min	**ADDING TO INDIVIDUAL PROGRESS TRACKERS** Add new ideas from the investigation to individual Progress Trackers.	H	*Some Common Gases* from lesson 5,
4	20 min	**DEVELOP AND USE A MODEL TO EXPLAIN SEPARATING WATER INTO HYDROGEN GAS AND OXYGEN GAS** Develop a revised class consensus model of what happens when thermal energy and electrical energy are added to water.	I	

End of day 1

Lesson 9 • Materials List

	per student	per group	per class
Investigation of Electrical Energy and Water materials			• *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* • *Adding Electrical Energy to Water* • test tube clamp • matches • a captured gas sample from test tube A • a captured gas sample from test tube B
Lesson materials	• science notebook • *Some Common Gases* from lesson 5		

Materials preparation (120 min minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare a card for the Word Wall that says: **Chemical reaction--a process that produces new substances (with new properties) from the particles that make up the old substances.**

Investigation of Electrical Energy and Water
Group size: Whole class demo
Setup

- You will prepare three parts to this setup.
  - 1) Prepare a student hydrolysis setup from lesson 7: *Adding Electrical Energy to Water*.
  - 2) Prepare a teacher hydrolysis setup from this lesson, similar to the one you used to collect the gas before class. Read *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* to see how to set up the electrolysis apparatus. Watch https://www.teachersopensciedfieldtest.org/chemical-reactions for additional guidance.
  - 3) Set aside at least two samples of already captured gases from a hydrolysis setup: a captured gas sample from test tube A, and a captured gas sample from test tube B.

- You will be testing the captured gas in test tubes A (hydrogen) and B (oxygen) for flammability. You will need to have a couple of tubes of each gas to practice with before you demonstrate it for the first time in front of the students. **Do not skip this part!** Additionally, you will need at least 1 tube of each gas for each class. If you want to repeat the demo, then you will need two tubes of each gas. To prepare multiple tubes to test, you may want to prepare three setups to run in parallel. The supplies for doing this are provided for you in the standard materials kit.

- **Prepare the tubes to collect the gas.** Read *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* to see how to setup the electrolysis apparatus to collect the gases. Watch https://www.teachersopensciedfieldtest.org/chemical-reactions for additional guidance.

- **Test the gas in tube A (hydrogen) for flammability.** Read *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* to see how to test the flammability of gas A (hydrogen) and gas B (oxygen). Watch https://www.teachersopensciedfieldtest.org/chemical-reactions for additional guidance.

- **Notes for during the lab:** Have a cup of water available to discard burnt matches or splints.

Safety: Follow the same safety guidelines as those for the students when you test the gases:

- Wear safety goggles.

- Teacher and student volunteers should tie back long hair.
- Don't connect the battery until you have completely set up the system.
- Don't allow the two wires, alligator clips, or pencil leads to come in contact with each other. They will become hot quickly.
- Do not allow the battery to come in contact with the water.
- Disconnect the clip from the battery as soon as you have made observations.

Storage

- Store batteries separate from each other.
- Batteries will last longer when stored in the freezer.
- Dry the alligator clip ends if they get wet, to prevent rusting. If the alligator clips become rusted or oxidized (brownish-orange colored), they tend to not conduct electricity anymore to items they come into contact with. Here is how to clean them off:
    - Submerge the ends in soda pop or carbonated water for a couple of hours.
    - Remove them and scrub the ends with a wire brush, steel wool, or toothbrush.
    - Dry the ends immediately with a cotton swab or paper towel.

Disposal

- When alkaline batteries are depleted, they can be safely discarded with normal household waste.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

We will figure out that the gases produced from electrolysis are different gases and also different from the gas produced by boiling water. We will figure out that the gases come from water. We will figure out that water is made of two different particles. We are building the conceptual understanding of mass conservation and that molecules of substances can be broken apart into atoms of different substances.

Where We Are NOT Going

In this lesson, we will not name the particles “atoms” and “molecules.” That vocabulary is developed in the next lesson. We will not develop the idea that water is made of two hydrogen particles and one oxygen particle. Rather, we will simply know that water is made of two different kinds of particles. Although we are designating that one is oxygen, at this time we are not designating that the other is definitely hydrogen. We will figure that out in the next lesson.
We are not representing the gases produced as being made of more than one particle (e.g., oxygen gas as diatomic in nature). We will represent them as being made of one particle for now, just as early scientists did with Dalton’s atomic theory. We will revise that model with one more lesson. If students introduce the idea that they have heard that water molecules are H_2O, an alternate way to develop a representation of the water particles is provided at the end of the teacher guide.

Instead of using pure distilled water, you are making a solution of magnesium sulfate and distilled water. The dissolved particles of magnesium sulfate help speed up the process of hydrolysis that produces the hydrogen and oxygen gas. We are not introducing this substance as part of the system that you used to rapidly produce the gases to students. The gases could have been produced with pure distilled water at higher voltages and/or longer periods of time without the addition of this dissolved substance, which was added to be able to conveniently and rapidly produce gas.

No attempt is made to introduce electrons or ions in this process. This idea is above grade level.

LEARNING PLAN for LESSON 9

1 · NAVIGATION: SHARING IDEAS ABOUT THE GAS(ES)

5 min

MATERIALS: science notebook

Sharing predictions. Display **slide A** and allow 3 minutes for students to discuss the questions as a class. If students didn't have a chance to discuss this question with a partner at the end of the last class, have them do that first for a couple minutes, before sharing out as a whole class. The questions are:

- Do you think that the gas we will collect from the battery and water system will be made of the same particles as the gas we collected from the boiling water?
- How could we investigate these ideas? How would we test the gas(es)?

After students have had time to respond, say, *Several of you suggested capturing the gas and testing it for its properties. We have had some experience with that! We have tested flammability and density. Let's test the flammability of the gas. Now, gas was produced at both pencil leads, and you may have noticed that more gas was produced on one lead than was produced on the other. Just to be safe, let's collect them separately and see if they have the same properties or different properties. We will need an observation chart to record our data.*

Plan how you will collect and record data. Display **slide B**. Work with the class to construct an observation chart for two tests for flammability. Take no more than 2 minutes to plan and copy this observation chart. There should be some way to distinguish between the gases from each lead. They are labeled A and B below, but students may choose a different method. Draw the chart on the board and have students copy it into their notebooks. The class data table should look something like this:

Observations of Flammability

	Gas A (most gas)	**Gas B (least gas)**
Observations from the flammability test		

2 · INVESTIGATING ELECTRICAL ENERGY AND WATER

15 min

MATERIALS: Investigation of Electrical Energy and Water, science notebook

Showing a new apparatus. Have one of the *Adding Electrical Energy to Water* from lesson 7 available and also the image on **slide C**. Your setup, *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced*, is a different version of the ones that students used. Have them compare the parts between the two setups. If available, use a document camera so all can see the parts of the new setup. Tell students that your metal leads conduct electrical energy a bit better than pencil leads. Also point out that your apparatus has a way to trap the gas from each lead.

After students see that the new setup is like their setup, say, *What did you notice from your first observations and what do you notice now?* Students should be able to readily see that one gas is being produced much faster than the other. Mark the one that is produced faster as A and the one that is produced slower as B. The students labeled these in their observation table as most gas and least gas. They should recognize that if the gas is being produced faster, then there will be more of that gas. Some students may notice that the gas in tube A is produced twice as fast or there is twice as much gas in A than in B.

Explain that you have collected gas from the apparatus. Say, *I ran this setup for several hours and collected two tubes of gas. I labeled them A and B after I corked the tubes.* Show them the two tubes that you have prepared. Reassure students that you have tested these tubes already and know that this is safe. Emphasize that students need to put on their safety goggles for the entire demonstration. Ask for a volunteer to help you with the task of testing for flammability.

SAFETY PRECAUTIONS

Follow these instructions to ensure safety for you and your students as you do the demonstration described below.

- It is very important that you practice this test before you do it with students. When practicing and while doing the demonstration, be sure to tie back long hair and remove any dangling jewelry.
- If you have baggy sleeves, either push them up or secure them with an elastic tie.
- Be sure that the test tube of gas is pointing away from students and away from you. You can mount the test tube on a test tube clamp if you wish.
- Any student that assists you in the demonstration should follow the same recommendations.
- Make sure that there is a cup of water nearby to discard the burnt matches or wooden splints.

Test gas A for flammability. You and the volunteer should wear safety goggles, tie back long hair, and ensure that there are no baggy sleeves or dangling jewelry. Tell the volunteer that he/she will strike a match and light a wooden splint on fire. Then they will hand it to you. You will hold the test tube (with cork in place) with a test tube holder and point it away from you and the volunteer and also point it downward. Tell the class to be quiet and make observations with their eyes and ears. As the volunteer lights the splint (or match), remove the cork with the tube facing downward. Move the splint toward the opening of the tube. Make sure it has a burning flame on it. There should be a small explosion that sounds like a bark when the splint reaches the opening or enter the tube.

Allow students time to record their observations and discuss. If you have more tubes, repeat the test.

Show **slide D**. Lead a quick discussion about this test to get students to compare this gas with the gas from boiling water and to make predictions about the gas in tube B. An example dialog is shown below.

Suggested prompts	Sample student responses	Follow-up questions
Wow! That was pretty exciting. How does that result compare to the data we collected on the gas produced from boiling water?	*It was way different!* *The gas from boiling water put out the flame and this one exploded!*	*What does that tell you about the gas that was in test tube A?*
You say that the gas in tube A has different properties. Does that mean it is a different gas?	*Yes!*	*How do you know that?*
Do you think the gas in tube B will have the same properties?	*Yes--I think it is the same gas.* *No--I think it is a different gas.*	*Why do you think that?*

Test gas B for flammability. Show **slide E**. Ask for a new volunteer and follow the same safety guidelines. Reassure students that you have already tested this and you know it does something different. You will do something different to the burning splint for the gas in tube B.

Test gas B the same way that you tested gas A except blow out the burning splint and insert it into the tube while the splint is still glowing. It should relight. You may be able to do this several times. Recork the test tube in-between each test.

Allow students time to record their observations and discuss. Lead a quick discussion about this test to get students to compare this gas with the gas from boiling water and the gas from tube A. An example dialog is shown below.

Suggested prompts	Sample student responses	Follow-up questions
What does this tell you about this gas compared to the gas in tube A?	*It seems to be flammable but it behaved differently.*	*Do you think that means it is a different gas?*
How could we figure out if these two flammability tests tell us if the gases are different or if they are the same?	*I remember that the property of flammability had different descriptions on the big data sheet we looked at earlier.*	*So, do you think we can find some answers on the data sheet, Some Common Gases?*

Tell students to look at *Some Common Gases* from lesson 5 and use the flammability data to help them figure out what gases might be captured in the tube. Tell students to record their ideas in their notebooks.

Connecting to mass data. Show **slide F**. Say, *When scientists were first doing these types of investigations, one thing that they measured that we did not is the mass. They collected such measurements in a closed system. They found that the mass before adding electrical energy was the same as the mass after the gas was produced.* Continue with a short discussion using the dialog below as a guide.

Suggested prompt	Sample student response
Can you recall what we figured out earlier when we did mass measurements in a closed system?	*We figured out that the gas from the bath bomb must have come from the substances in the bath bomb because the mass stayed the same in the closed system.*
What does that tell us about what is happening to the matter in our system when we added electrical energy to water?	*Just like we did with the gas from the bath bomb--the gas must have come from something we started with.*
How do you know that from the data?	*Well, if the gas was new matter, the mass would have increased because matter has mass. Since the mass stayed the same, the matter that makes the gas must have come from the matter we started with--it is just different.*
How would you describe the differences?	*The matter that makes up the gas has new and very different properties than the matter we started with.*

Turn and talk about what we have figured out. Show **slide G**. Say, *It seems like we have figured out something really important about water and what it is made of. Turn to your elbow partner and discuss the discoveries you made from this investigation.*

3 · ADDING TO INDIVIDUAL PROGRESS TRACKERS

5 min

MATERIALS: *Some Common Gases* from lesson 5, science notebook

Adding ideas to individual Progress Trackers. Show **slide H**. Have students turn to their Progress Trackers and draw a line under the last entry. They should continue the two-column format and record the lesson question. Ask, *Who can remind us of the question we are trying to answer in this lesson?* Students should respond with, “After running an electric current through water, is the gas produced made of the same particles that were produced from heating the water?”

Have students copy this question into the first column of their progress tracker. Remind students to reference *Some Common Gases* as they develop an answer to that question. Give students 4 minutes to write down science ideas that they figured out related to answering that question.

4 · DEVELOP AND USE A MODEL TO EXPLAIN SEPARATING WATER INTO HYDROGEN GAS AND OXYGEN GAS

20 min

MATERIALS: science notebook

Gather students into a Scientists Circle. Show **slide I**. Move to a Scientists Circle and ask students to bring their science notebooks. Have them turn to their last entry in their progress trackers.

Use a dialog similar to the one below to establish the line of evidence for the model you will build.

Suggested prompts	Sample student responses	Follow-up questions
Were you able to answer the lesson question?	*Yes!* *Well, I wasn't able to answer all of it. We figured out the properties of the gases but we haven't thought about the particles.*	*What did you figure out about the properties?*
We know that the gases produced from adding electrical energy to water have different properties. What else do we know about the gases?	*We know that they must come from the water.* *We know that the two gases are different because they have different properties.*	*How do you know that?*
Do you know what the two gases are?	*I think they are hydrogen and oxygen!* *The one that exploded could have been methane.*	*Why do you think that?*
We collected more of one gas than we did of the other--do you know which is which?	*The most gas was hydrogen and the least gas was oxygen.* *We know that because of the flammability test.*	*How could we represent that in our model?*
If you got two different gases from water, what does that tell you about the particles that make up water and that make up the gases?	*The water particles must split apart into two different particles.* *And, those particles are the gases!* *That the water is made of two different kinds of particles stuck together.*	*We represented water earlier in our model. What new model can we develop to represent all that we have figured out?*

Lead a discussion on big ideas and build a consensus toward a revised model. Use the dialog below to help you build a consensus with the class and revise the new model to include what they have learned.

Say, *If you make any claims, be sure to back it up with evidence and reasoning.* Refer to the Anchor Chart in the room. Suggest that the class give feedback as they have done before, by snapping their fingers when they hear evidence used to support a claim and lightly tapping their feet when they hear a scientific principle used in reasoning.

Suggested prompts	Sample student responses	Follow-up questions
What are some of the big science ideas that came from this investigation? You can use what you added to your Progress Tracker to give you ideas. You can add to your ideas as you hear your class share something you may not have included.	*When we added electrical energy, the water changed.*	*How did water change?* *Did it change back?*
	Two gases were made and they didn't turn back into water.	
What did you figure out when we added electrical energy to water?	*Two gases were produced!*	*How do you know two gases were produced? Do you know which gases were produced?*
	There was twice as much of one gas produced than there was of the other gas.	*What do you think that means for the way we represent the particles for water and the gases?*
	The most gas was hydrogen or methane--we don't know which, though.	*How can we make sure our model shows this important idea?*
	The mass did not change.	*How do we show that in our model?*
	We know the gases had to come from the water.	
Think back to the last lesson. What was the big idea that came from adding thermal energy to water?	*The gas that came from boiling water changed to a liquid when it cooled.*	*What did that information tell you?*
	And adding thermal energy didn't do anything to the water except change it to a gas.	
	Then it cooled and became water again.	*How do you know it changed back to water?*
How do you think we should represent this?	*The particles we draw for water should be the same as what we drew for adding energy with electricity.*	*How should we represent adding thermal energy?*
	We can make the particles farther apart when it is a gas and closer together when they are liquid.	

KEY IDEAS	**Purpose of this discussion:** To come to an agreement about what is produced when adding electrical energy to water and to agree on how to represent this process and boiling water for our consensus model. **Listen for** • One gas was produced from boiling water and it was just water in the gas state. • The clear liquid produced from boiling water came from the gas that cooled. • The properties of the clear liquid were the same as water, so water never changed into something new--it just changed state. • Two gases were produced when adding electrical energy to water. • The two gases had different properties, so they are not the same gas. • There was twice as much of one gas than the other gas. • The mass doesn't change when adding electrical energy to water to produce gases. • The gases produced must come from the water. • One gas could be hydrogen, methane, or propane and the other is oxygen. • There was twice as much hydrogen, methane, or propane produced as oxygen. • Our model needs to change!

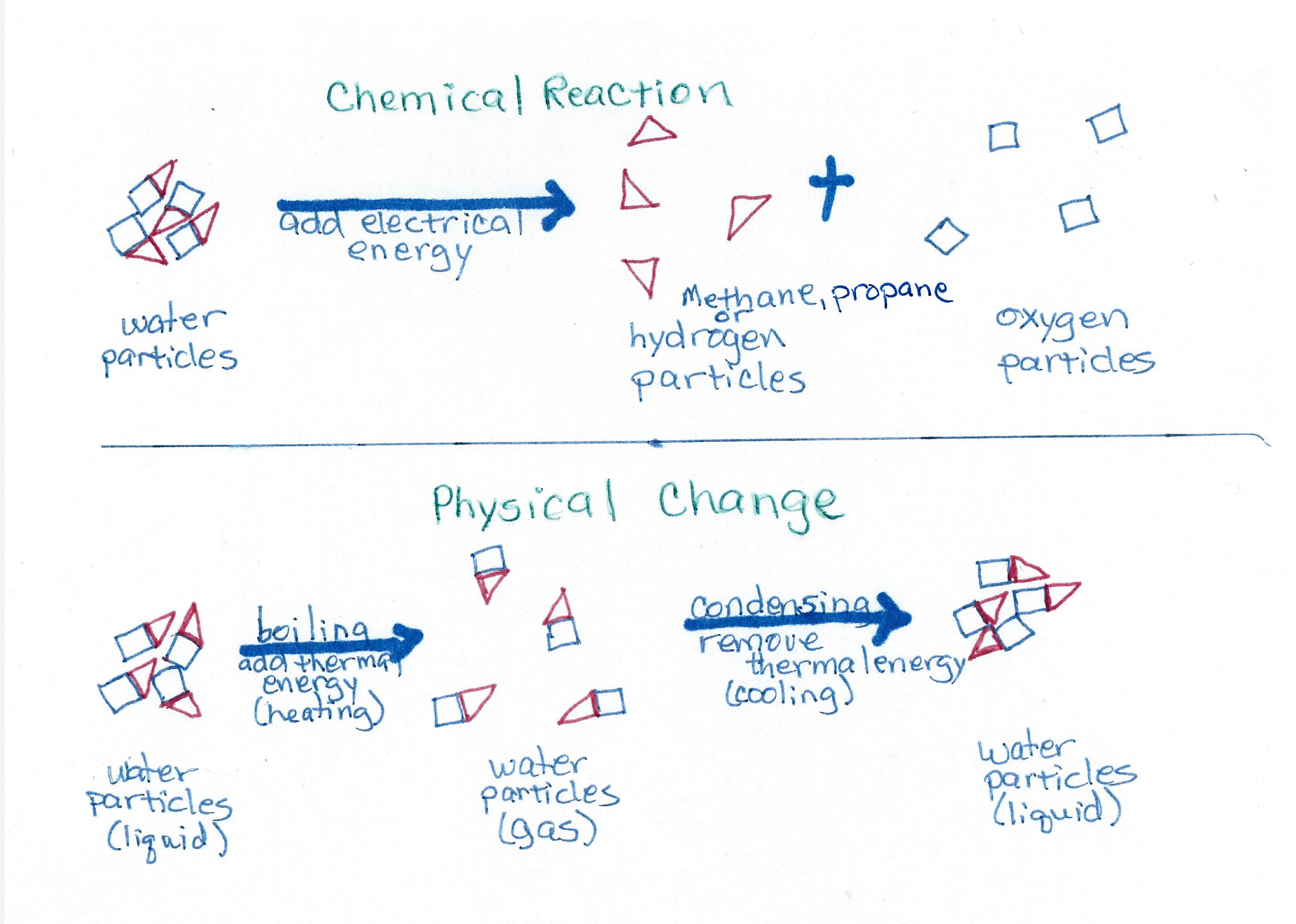
Develop a new consensus model. As the discussion progresses, work with the class to build a new consensus model that is similar to the one below. Key revisions include:

- adjusting the water particles to include two different types, colors, or shapes that make up each particle of water,
- creating a representation of the types of changes that result from adding thermal energy vs. adding electrical energy, and
- noting that water particles remain intact as they break apart from other water particles when water is boiled but that water particles themselves break apart into the two different types of pieces/particles that make them up when electricity is added.

Adding new vocabulary. When you finish the model, say *We have evidence that sometimes adding energy to water produces new substances with new properties and we have evidence that sometimes adding energy simply makes water change state. These two interactions are very different and we have names for them. When we produce new substances with new properties, a chemical reaction has occurred. If we do not have new substances with new properties, then it is simply a physical change. Let's add* ***chemical reaction*** *to our Word Wall.* Add a card: **Chemical reaction--a reaction that produces new substances with new properties** to the Word Wall. Also add the label, Chemical Reaction, to the new consensus model for the electrical energy model only. You can add physical change to the thermal energy model too.

ADDITIONAL GUIDANCE	These new models are an important scaffold to students' understanding of molecular and atomic representations and conservation of mass in a chemical reaction. The students have not named this type of reaction until today and they now have unobservable mechanisms to account for a phenomena. They have not formally identified conservation of mass due to conservation of atoms in all matter transformations (physical changes and chemical ones) as a scientific principle. Rather, they are building their initial understandings of these two fundamental science principles. While it will make sense to show the same number of smallest pieces on the right side and left side of the diagrams you are drawing, don't rush this scaffold by labeling anything as mass conservation. Don't label anything as atoms or molecules. This is still premature. The next couple of lessons will help students build their own understanding of these concepts.

Examples of new consensus models. You and your students should develop new models similar to those shown here. It is possible that you may need an additional 5-10 minutes to complete this, beyond the one day allocated for this lesson. If so, resume this task at the start of the next day and complete the model before launching into the next lesson:

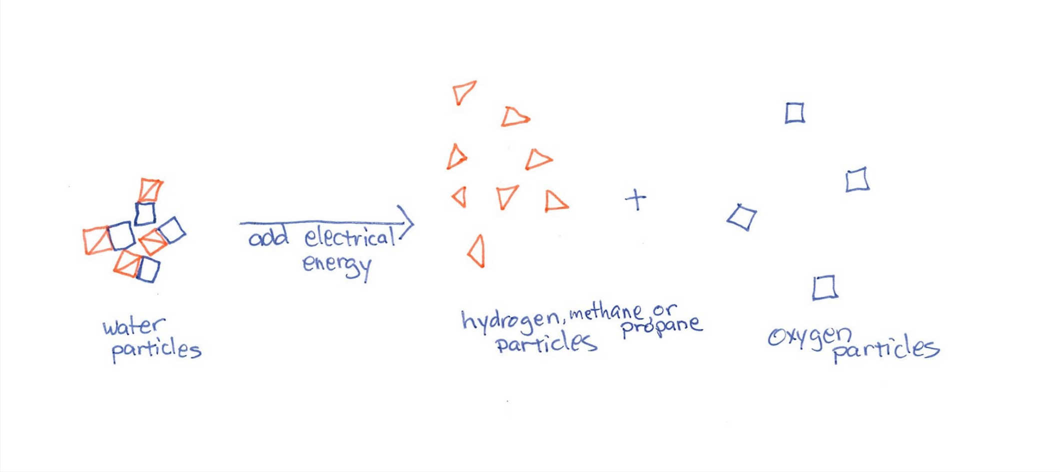

Chemical Reaction
water particles
add electrical energy
+
Methane, propane or hydrogen particles
oxygen particles
Physical Change
water particles (liquid)
boiling
add thermal energy (heating)
water particles (gas)
condensing
remove thermal energy (cooling)
water particles (liquid)

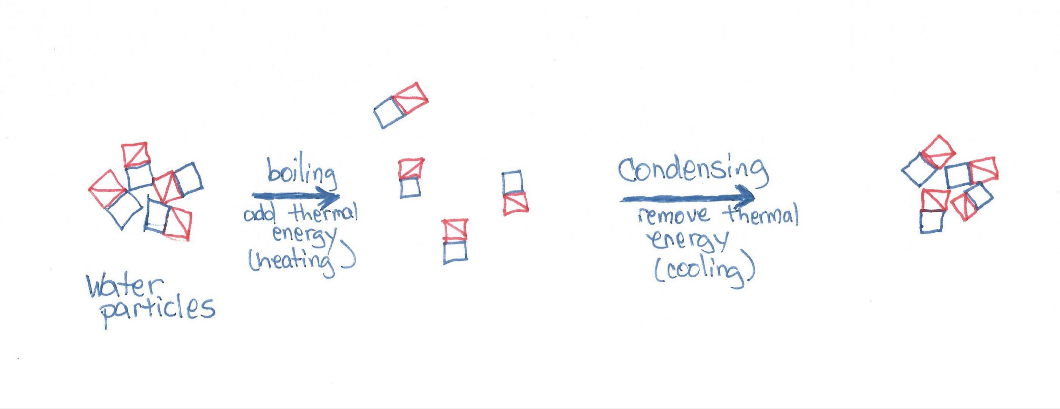
ADDITIONAL GUIDANCE

If students bring up the idea that water is H_2O and want to put two particles of hydrogen in the water molecule, check to see if the class can come to consensus on this change. They will learn this in the next lesson but if your students agree that the model should show two hydrogens in water, then represent their ideas in the model. If students go in this direction, they may also want to put twice as many hydrogen particles in the hydrogen gas that is produced to account for conservation of mass and the additional hydrogen that is produced from the electrolysis. Again, if your students come to a consensus that the model should be represented this way, then add these details to the model. Students may recognize that they may need more information or evidence to know for sure. That information will come in the next lesson.

Possible representation of an alternate model: Additional revisions can be included in the model if your students go in this direction and agree to add them. If they don't, these key ideas will come up in future lessons in this unit. These changes would include the revisions pictured from the first models with these additions:

- Water had two identical particles (hydrogen) connected to a different particle (oxygen).
- There are twice as many hydrogen gas particles as oxygen gas particles that are produced during electrolysis.





Check for understanding. Ask students to summarize differences in the way that particles separate and come together in a physical change such as boiling and condensing water vs. a chemical reaction where we turned one substance (water) into a new one(s) (hydrogen gas and oxygen gas). Ask why one process produces new substances and the other does not. Alternate guidance for using these questions in an exit ticket as an individual assessment opportunity is described below.

ASSESSMENT OPPORTUNITY	You could administer an exit ticket at the end of this lesson or an entrance ticket before the start of the next lesson to quickly take stock of the ideas developed in this new model. Here are two potential questions to use: "Both models we developed show particles of matter separated from other particles. Both models show the same type of particles we started with. What is different about particles in a chemical reaction as compared to particles undergoing a physical change, such as boiling water? Why does one produce new substances and the other does not?" Look for these ideas in student responses: • Particles that make up the initial substance (water) are made of smaller joined-together particle clusters that are different types of particles. • The particles of water break apart or separate into their smaller pieces in a chemical reaction. • The particles of water stay intact, although they break away and separate from neighboring particles of water, when they go from a liquid to a gas state and back. • Producing a new substance involves breaking the original particle cluster you start with into the smaller pieces that make it up. Boiling water does not break up the particle cluster of water.

Connect to the bath bomb phenomenon. Ask students to think back to the bath bomb gas. Say, *Let's use these models to try to explain the bath bomb gas bubbles. Do you think what happened to water can also happen to other substances? What new ideas do these models give us about what might have been happening when we combined three substances together (baking soda, citric acid, and water) and got a new substance--carbon dioxide--to appear.* Accept all student responses. Students are likely to suggest that maybe particles of those substance are also breaking apart into the smaller particles that made them up to start with in that process.

Connect to the next lesson. Write the broader question on the board that we are considering, which we will need investigate next time, "Can the particles (molecules) of other substances be broken down into smaller pieces to make new substances with new properties?"