LESSON CLUSTER 9

Explaining Condensation and the Water Cycle

Lesson 9.1: Boiling and Condensation

You have been studying changes of state for quite a while now. You have studied melting, freezing or solidifying, evaporation, and boiling. That means there is only one change of state left to study: condensation.

You know that if a liquid is heated enough, it turns into a gas. The molecules of the liquid move fast enough to escape from the attractive forces that hold them together and begin moving freely through space.

What do you suppose happens if we slow down the molecules of a gas by cooling the gas? The slow-moving molecules begin to stick to each other and form clumps. Clumps with lots of molecules make up drops of liquid. This process, where a gas turns back into a liquid, is called condensation.

Sometimes it is possible to use boiling and condensation to purify dirty liquids. Your teacher will show you how.

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Do Demonstration 9.1 in your Activity Book

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Let's explain what happened.

When you heat the flask, the liquid water changes to water vapor at the bottom of the flask and rises to the surface as bubbles. This, of course, is called boiling. The hot water vapor goes through the tube into the bottom of the cold test tube. When the water vapor hits the cold test tube, the molecules slow down and move closer together. When the molecules slow down enough, the attraction among them makes them stay close together. They cluster together to form a liquid.

The dye and other substances in the flasks are made of molecules that do not boil as easily as water. When the water boils and goes through the glass tubing, the dye and other substances stay behind in the flask.

The process of boiling or evaporating a liquid and then condensing it again is called distillation. It is possible to separate very complex mixtures by this process. For example, we can get pure water from salt water by distillation. To do this, we would boil off the pure water, leaving the salt and other materials behind in the flask. In a similar way, we distill gasoline and many other useful substances from petroleum. Petroleum is a very black, complex mixture containing thousands of different substances. By distillation we can separate out those substances that make up gasoline.

You don't need a test tube to see water boil and then condense. You can actually see water condense whenever you boil water, or soup, or any other liquid. The water vapor produced by boiling is invisible. But when the water vapor cools off it condenses to form the tiny droplets of water that we see and call steam. As these droplets rise a little higher, they evaporate and change into invisible water vapor once again!

Lesson 9.2: Purifying Water Without Boiling

In the last lesson your teacher demonstrated one way of purifying water. When water boils, the liquid water turns to vapor, but other substances are left behind. Then the water vapor can condense into pure water.

There are other ways of purifying water that do not involve boiling. Your teacher will show you one now.

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Do Demonstration 9.2 in your Activity Book

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Did you figure out how the demonstration worked? It worked by a three-stage process:

1. Evaporation. The water in the tumbler evaporated. Molecules were escaping from its surface. The heat from the overhead projector made the water evaporate faster by making its molecules move faster. When the water evaporated, the salt and food coloring were left behind.
2. Spreading of water vapor. The evaporation made the air inside the aquarium very humid; it contained lots of water molecules. This humid air spread throughout the container.
3. Cooling and condensation. This humid air cooled down when it came near the cool plastic wrap at the top of the aquarium. When the air cooled down, the water molecules in the air moved more slowly, and the attraction between them made them clump together to form drops of water. The tiny drops of water collected into larger drops that fell into the cup.

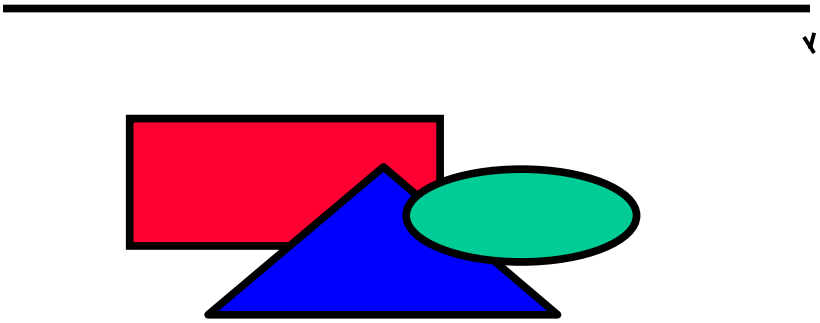
There are many ways that this demonstration and the distillation of boiling water (Demonstration 9.1) are alike. In both demonstrations, the water changed from a liquid to a gas, then condensed back into a liquid again. In both cases, the water was purified because the salt and food coloring did not change into gases.

In one way, though, the two demonstrations were different. In Demonstration 9.1, the water was changed from a liquid to a gas by boiling. In Demonstration 9.2, the water changed to a gas by evaporation. Boiling is not the only way to produce water vapor that can later condense. Evaporation works more slowly but just as well. By using evaporation it is possible to distill liquids without boiling them.

Lesson 9.3: A Solar Still

In Lessons 9.1 and 9.2 you saw examples of stills. Stills are devices that purify liquids by boiling or evaporating them, then condensing the gases back into liquids. Stills can be very useful. Suppose, for example, you were trapped on an island with no pure water to drink. You will die if you drink a large amount of ocean water; it has too much salt in it. What could you do?

The crew of the Mimi found themselves with a problem like this. They were shipwrecked, and they could find no fresh water. They solved their problem by constructing solar stills.



Let's try explaining how the solar still works. It is a three-stage process:

1. Evaporation. The water down at the bottom, which is dirty or salty, is heated by the sun. Its water molecules move faster and more of them escape from the surface. The water evaporates, leaving salt and dirt behind.
2. Spreading of water vapor. The water molecules mix with the other gases in the air and move all through the container. The air becomes very humid.
3. Cooling and condensation. The plastic at the top is cooler than the air inside the still. The molecules slow down when they come close to it. The attraction between the water molecules pulls them together, and they form drops. Pure water—without any salt--condenses on the plastic.

This three-stage process -- evaporation, spreading, condensation--occurs whenever there is water inside a closed room or container. Try answering some questions about other situations where it occurs.

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Do Question Set 9.3 in your Activity Book

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Lesson 9.4: Condensing in the Open Air

It is easy to see where the water vapor that condenses in a solar still comes from. It evaporated from the water at the bottom of the still. What if there is no liquid water in a room, though? Can water vapor still condense?

The answer, of course, is yes. There is always water vapor in the air. This water vapor comes from oceans, lakes, rivers, and from you. If the air is cooled, the water molecules slow down, and the attraction between them causes them to cling together. The water vapor condenses.

The water molecules that slow down and stick together on a cold glass probably evaporated at many different times and places. Some molecules escaped from the ocean, others from lakes or rivers. Some molecules escaped from the leaves of trees or other plants. Some came from your breath. The motion of those water molecules mixed them with the other molecules of the air and brought them into the room. Water condenses on a cold glass because the glass cools the humid air around it and causes water vapor in the air to condense.

A little bit of water condenses on cold drinks but there is lots of water vapor in the air. Enough to make billions of gallons of water. Most of the water in the air condenses to form various kinds of precipitation: rain, snow, fog, sleet, hail, or dew.

All precipitation occurs when humid air cools off, the water vapor in the air condenses. Rain, for example, starts when humid air rises high up, where the air is cold. The water molecules in this cooling air slow down and clump together to form ……raindrops!

Every day the sun shines on the oceans and billions of gallons of water evaporate. Those water molecules travel all over the world, then condense and come down as rain (and other forms of precipitation). The salty oceans produce salt-free rain; the whole world is like a giant solar still!

Rain water collects into lakes and rivers, the rivers run into the oceans, and the whole process can start over again. This is how all the precipitation on Earth originates. The same water goes through the process over and over again, evaporating, spreading, condensing, and evaporating again. The whole process is called the water cycle.

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Do Question Set 9.4 in your Activity Book

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Lesson 9.5: Condensation and Precipitation

We said in the last lesson that all forms of precipitation (rain, fog, dew, snow, sleet, hail) are caused by condensing water vapor. In this lesson we will discuss in more detail how different kinds of precipitation are formed. As you read, remember that all kinds of precipitation form in the same basic steps; the differences are only in the details. The steps you already know about:

1. Evaporation: Water evaporates from oceans, lakes and rivers, plants and animals.
2. Spreading: Water vapor is carried around by winds.
3. Cooling and condensation: The air cools off, and the water molecules clump together to form drops (or, if it is cold enough, crystals of ice).

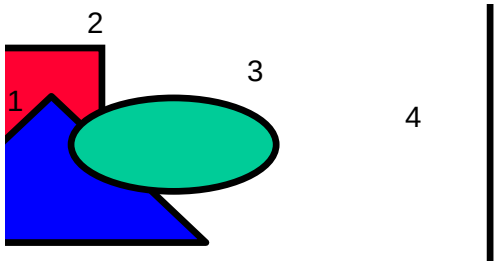
When we see those drops or ice crystals high up in the air above us, we call them clouds. When they come close to the Earth, we call them precipitation: rain, fog, snow, sleet, or whatever. Now let's talk about how some specific types of precipitation are formed.

Clouds and rain. You should have some idea how rain is formed from the previous lesson. The first step is evaporation. As air moves over bodies of water or plants and animals, some of the molecules of water are moving fast enough to escape and move freely in the air. As more and more molecules move from the liquid to the air, the air becomes humid. That means that the air has a lot of water vapor in it.

Next comes spreading. Sometimes this humid air travels high above the Earth.

Then comes cooling and condensation. As this warm, moist air moves higher in the atmosphere, it becomes colder and colder. The water molecules slow down, move less freely, attract each other, clump together, and form visible water droplets. If there are lots of water droplets we can see them from the ground; we call them clouds. If the air continues to get colder, these droplets of water get larger and larger until they fall to the Earth as rain.

1. Evaporation: water evaporates from lakes, plants, etc.
2. Spreading: warm humid air rises.
3. Condensation: Air cools off and water vapor condenses into drops: CLOUDS.
4. Precipitation: Drops fall from clouds to the ground: RAIN

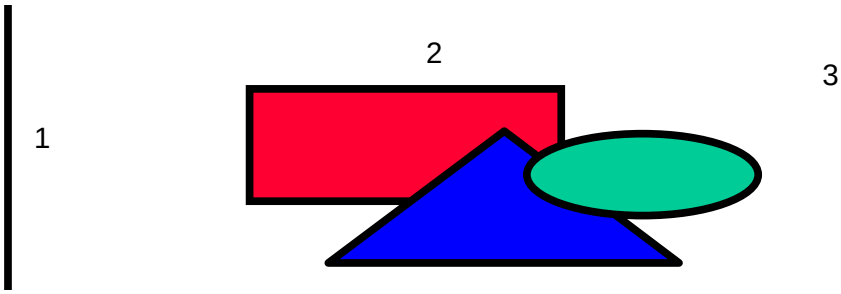


Sequence of events leading to forms of precipitation: CLOUDS and RAIN

Fog. Have you ever wondered what the inside of a cloud looks like? You actually know what it is like inside clouds because you have been inside clouds that are close to the ground. Only you didn't call them clouds. When clouds form at ground level we call them fog.

Fog forms in about the same way as clouds do high up in the sky. First the water evaporates, then the water vapor is carried around by the wind, then the air cools off and drops of water form. Fog often forms at night, when the air is cooler. If you have ever been in a thick fog, you know that the tiny droplets of water collect on your hands, face, and clothing, making you moist.

1. Evaporation: Water evaporates and air becomes warm and humid in sunshine.
2. Spreading: warm humid air spreads around.
3. Condensation: Air cools off at night and water vapor condenses into droplets: FOG



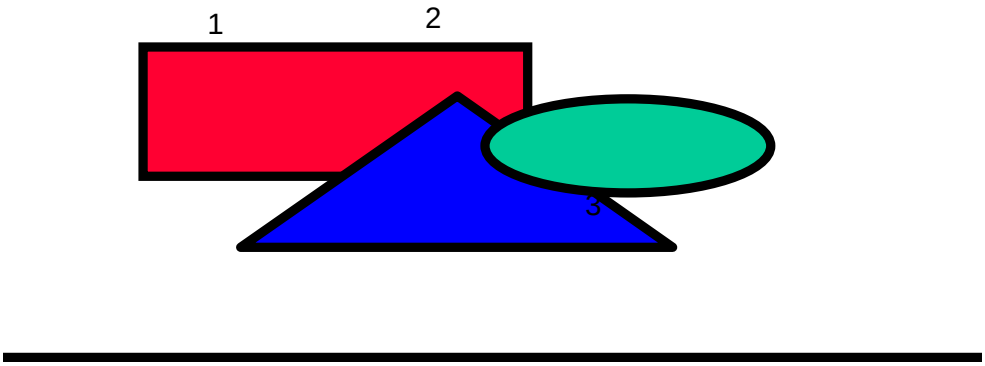
Sequence of events leading to forms of precipitation: FOG

Dew. Have you ever walked through grass in the early morning hours when the grass was wet or had water droplets on it? This is called dew. How do you think dew is formed? First comes evaporation. During the day, when the sun is shining, the ground and the plants in the ground become warm. Water evaporates from the lakes, rivers, and streams, as well as the plants and the air

and becomes humid. This humid air spreads all around. What do you think will happen after the sun goes down and the ground and plants become cool?

You probably know the next step. It is cooling and condensation. As the air next to the ground becomes cool, the water molecules in the air move slower, hit each other less often, attract each other more, and move closer together, forming clusters of trillions of molecules of water that we call droplets. Drops of water clinging to plants and other materials on the surface of the Earth are call dew.

1. Evaporation: Water evaporates and air becomes warm and humid in sunshine.
2. Spreading: Warm humid air spreads around.
3. Condensation: Grass cools off at night and water vapor condenses on it: DEW



Sequence of events leading to forms of precipitation: DEW

Snow, sleet, frost and hail. Sometimes water vapor condense in places where it is really cold, so cold that liquid water freezes into ice. When the happens, instead of water droplets you get – crystals of ice! Many of the clouds that you see are actually made of ice crystals rather than drops of water. When those pieces of ice come down to the ground, we call them other forms of precipitation: snow, sleet, frost or hail. Whether it comes in the form of ice or liquid water, though, all precipitation is formed by the same basic steps. First water evaporates, then the water vapor spreads around with the wind, the it cools off and condenses (and sometimes freezes, too).

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Do Questions Set 9.5 in your Activity Book

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Lesson 9.6 You Drank the Water that George Washington Used to Wash His Boots

The rain that falls to Earth today is not new water, but water that has been on Earth for centuries. You know that molecules are very, very small. In fact, a gallon of water has about 120,000,000,000,000,000,000,000,000 molecules in it. The chances are, therefore, that some of the water you drank today had at least one molecule of water that George Washington used to wash his boots with in 1776.

Imagine that in 1776, George Washington stood under a cherry tree and washed his boots. Some of this water was soaked into the ground, was taken up by the roots of the cherry tree, and evaporated from the leaves of the cherry tree. The wind carried these molecules far across the Atlantic Ocean and they rained down on the ocean in a thunderstorm.

In the ocean, they were constantly moving like all the other molecules of water in the ocean, and they were constantly being hit by all the other molecules. Eventually, some of the molecules from George Washington's boots moved fast enough to escape again into the air, where they moved freely.

The air currents moved them northward and eastward until they were again part of a big, beautiful cloud that was cooled by air coming from the north. They lost some of their speed and became part of rain droplets that fell over the lush vineyards of France. The roots of the grapevines took the molecules in, and again they evaporated from the leaves and became part of the free-moving air. This continued until the molecules moved through three or four more water cycles all the way to the Pacific Ocean. They were carried across the United States from the West to the East Coast. In the Central plains, a cold Canadian mass of air pushed the molecules high in the air where they slowed down, became part of a cloud, and eventually fell as rain.

They made their way deep in the soil and continued down until they reached the ground water. Many cities pump their water from this ground water. It became part of the drinking water and this morning you drank some of the very same molecules George Washington used to wash his boots in 1776.

The purpose of this story was to show you that the amount of water that is on the Earth remains about the same, and is only recycled over and over again

through evaporation, spreading, and condensation. This repeated evaporation, spreading, and condensation is called the water cycle.

Most of the water molecules on Earth are very, very old; they have been around since the Earth began. During that time they have been through many, many water cycles, evaporating, spreading, and condensing, and evaporating, spreading, and condensing again. They have been carried all over the Earth by wind and rivers and ocean currents. Through all the changes and movements, though, the molecules themselves have stayed the same. The water molecules and the water cycle go on and on.

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Do Review Question Set 9.6 Now

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THE LAST PAGE

Yes, this is the last page of the unit. Your long study of molecules is over. We hope you have learned a lot about molecules and about how they can help you explain many different things. Can you think back to how molecules can explain the way things dissolve? What about thermal expansion? Compression of gases? Changes of state?

Even if you have learned a lot about molecules, there is still much more to learn. We can use ideas about molecules to explain what happens inside our bodies when we breathe, for examples, or how we grow or what happens when things burn or decay. We cannot explain those things in this unit, but we hope that this unit will prepare you to learn and understand much more in the future. There is always more to learn; we hope you find it interesting!