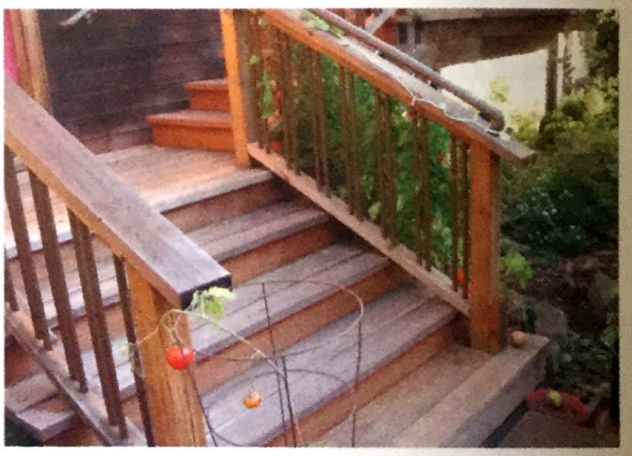
INVESTIGATION 3

ES3b. Students know when liquid water evaporates, it turns into water vapor in the air and can reappear as a liquid when cooled or as a solid if cooled below the freezing point of water.

Drying Up

You know when something is wet. It is covered with water, or it has soaked up a lot of water. When it rains, everything outside gets wet. When you go swimming, you and your swimsuit get wet. Clothes are wet when they come out of the washer, and a dog is wet after a bath.



But things don't stay wet forever. Things get dry, often by themselves. An hour or two after the rain stops, porches, sidewalks, and plants are dry. After a break from swimming to eat lunch, you and your swimsuit are dry. After a few hours on the clothesline, clothes are dry. A dog is dry and fluffy after a short time. Where does the water go?

The water **evaporates.** When water evaporates, it changes from water in its **liquid** form to water in its **gas** form. The gas form of water is called **water vapor.** The water vapor leaves the wet object and goes into the **air.** As the water evaporates, the wet object gets dry.

What happens when you put a wet object in a sealed container? It stays wet. If you put your wet swimsuit in a plastic bag, it's still wet when you take it out of the bag. Why? A little bit of the water in your suit evaporates, but it can't escape into the air. The water vapor has no place to go, so your suit is still wet when you get home.

Have you ever seen water vapor in the air? No, water vapor is invisible. When water changes into vapor, it changes into individual **water molecules.** Water molecules are too small to be seen. The water molecules move into the air among the nitrogen and oxygen molecules. Water vapor becomes part of the air. When water becomes part of the air, it is no longer liquid water.

Review Questions

1. **What is water vapor?**
2. **Where is water vapor?**
3. **What does water vapor look like?**
4. **What happens when a wet object gets dry?**

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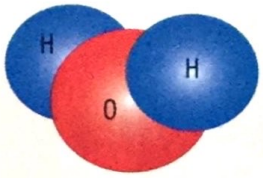
Evaporation

Evaporation is the change from liquid to gas. In the case of water, liquid water changes into water vapor. The water vapor then moves into the air. But what actually happens when evaporation takes place? To find out, we have to think about water as molecules.

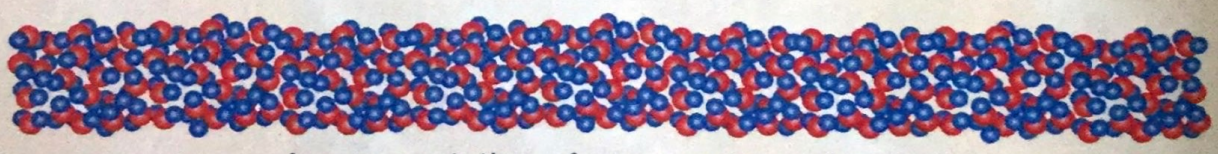
A water molecule is made of three **atoms,** two hydrogen atoms and one oxygen atom. Scientists have figured out that one water molecule looks like this.



A representation of one water molecule

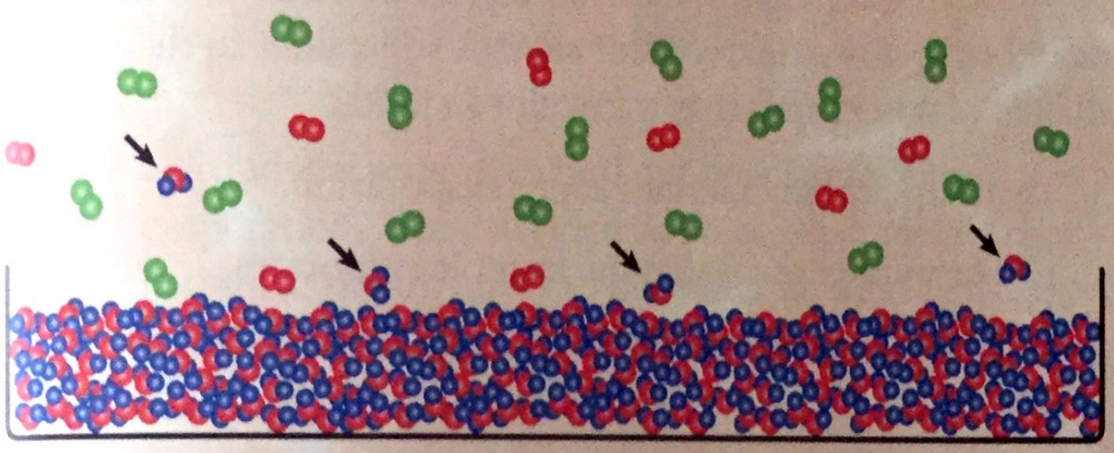
When water is in its liquid state, the molecules are all attracted to one another and in contact with each other. But they are not attached together tightly. As a result, the molecules move around and over one another. The molecules are in constant motion. That is why liquid water flows.

If you could see the molecules in a tiny spot of liquid water, they would look something like this.



A representation of many water molecules

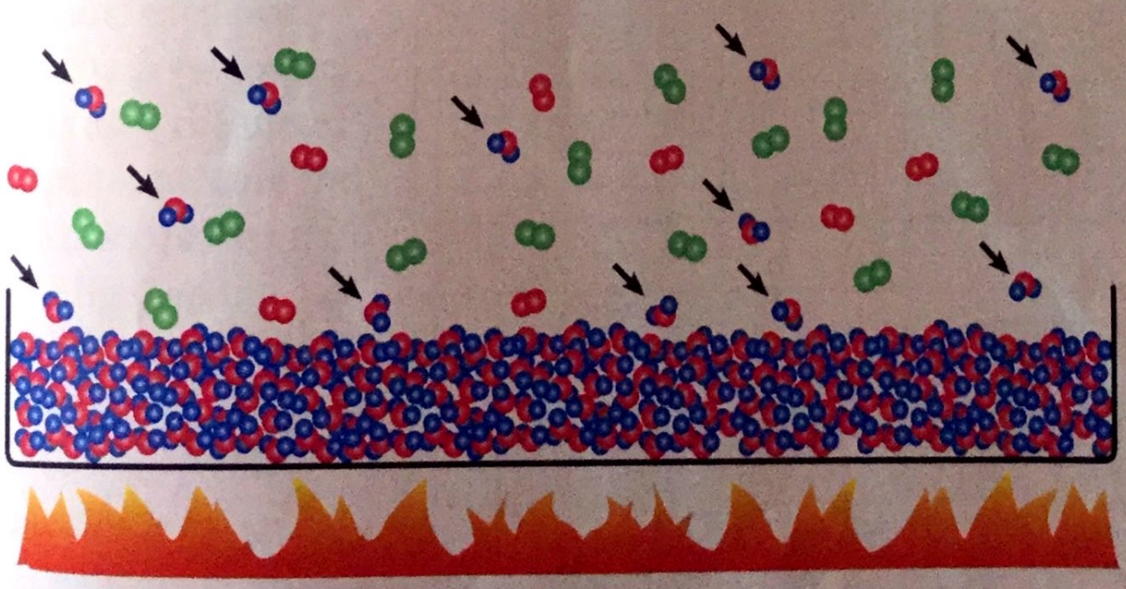
Remember, the molecules are in constant motion. They are bumping into each other all the time. Sometimes a water molecule at the surface gets bumped so hard that it is knocked free from the mass of liquid. The free molecule moves into the air as a water-vapor molecule.



Water molecules go into the air, which is mostly nitrogen and oxygen molecules.

Adding Heat

The rate at which water molecules escape from the liquid depends on how hard the water molecules hit each other. One way to increase the force with which molecules hit each other is to heat them up. When water is heated, the molecules move faster. When fast-moving molecules hit each other, they hit each other harder. As a result, more molecules break free from the surface of hot water than from cold water.



Water evaporates faster when water is heated.

There is a limit to the amount of water vapor that can enter the air. When the air has taken in as much water vapor as it can, the air is **saturated** with water vapor. Cold air can hold only a small amount of water vapor. It doesn't take much evaporated water to saturate cold air.

Warm air is different. Warm air can take in a lot of water vapor before it is saturated. But there is still a limit to the amount of water vapor that warm air can hold.

There are two general rules about evaporation.

1. The warmer the water, the faster it evaporates.
2. The warmer the air, the more water vapor it can hold.

Review Questions

1. **What causes evaporation?**
2. **Why does warm water evaporate faster than cold water?**
3. **How is water vapor different from liquid water?**
4. **How does temperature affect the amount of water vapor in the air?**

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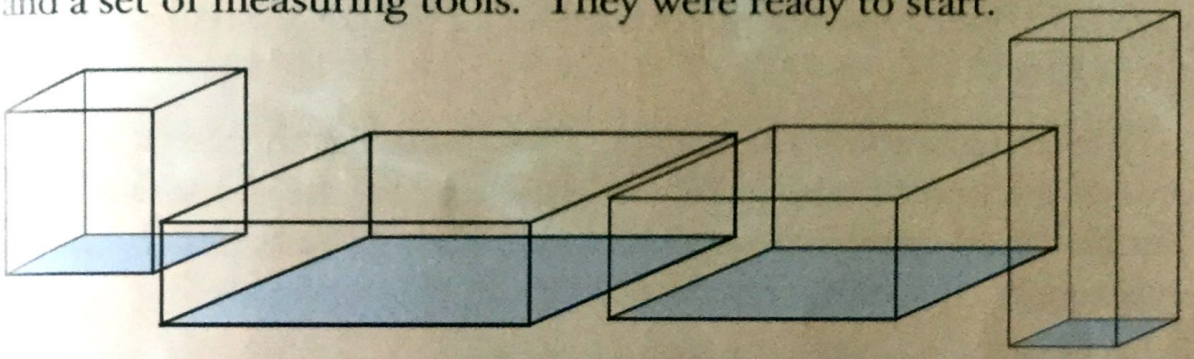
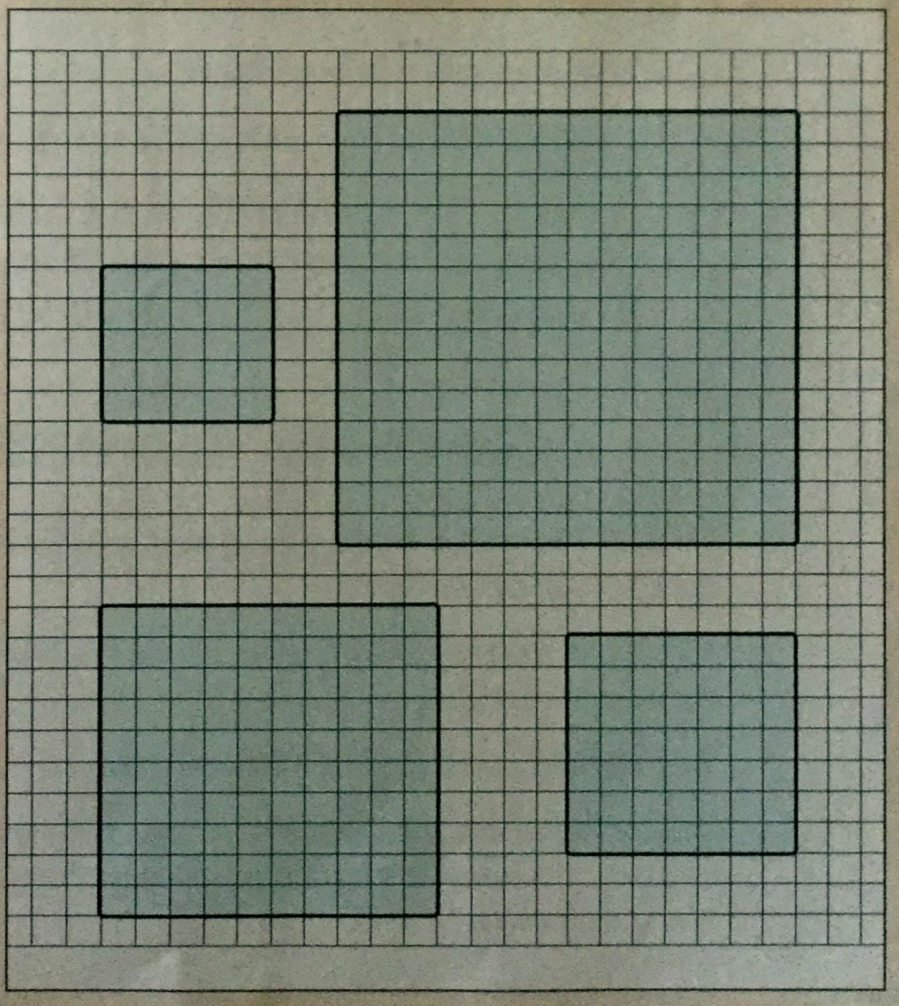
Surface-Area Experiment

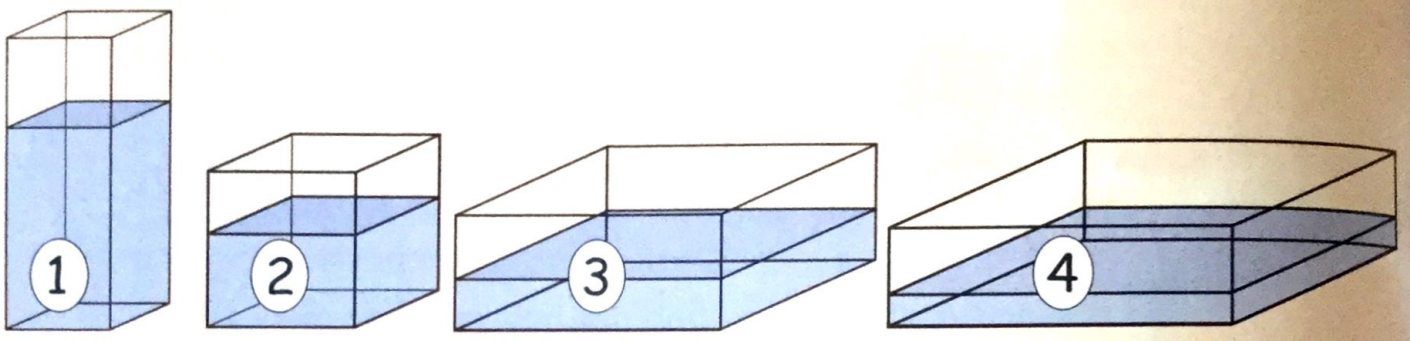
Julie and Art wanted to find out how **surface area** affects evaporation. They decided to do an experiment. They had some plastic boxes to put water in, some graph paper, and a set of measuring tools. They were ready to start.



Julie had an idea for measuring the surface area of each box. She traced around each box on the graph paper. She used the meter tape to measure the distance between the lines on the graph paper. The lines were 1 centimeter (cm) apart.



The two students numbered the boxes. The box with the smallest surface area was number 1. Then they measured 50 milliliters (ml) of water into each box. They placed the four boxes on the counter by a window.



One week later Julie and Art measured the amount of water in each box. Box 1 had 46 ml. Box 2 had 42 ml. Box 3 had 34 ml. Box 4 had 18 ml.

Art thought about the results. It seemed like the surface area of the water in the boxes had an effect on the evaporation. But he wasn't sure. Julie suggested organizing the results of the experiment. The students decided to do the following.

- Make a T-table to display their data.
- Make a graph of their data.
- Describe what they learned from the experiment.

Can you help Julie and Art? Use the information they gathered to write a report about the effect of surface area on evaporation. Be sure to include the three kinds of information listed above.

Review Questions

1. **What was the independent variable in Julie and Art's experiment?**
2. **What was the dependent variable in their experiment?**
3. **What variables did they control?**
4. **What additional information would be useful to better understand how surface area affects evaporation?**

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Condensation

When water evaporates, where does it go? It goes into the air. Water is always evaporating. Clothes are drying on clotheslines. Wet streets are drying after a rain. Water is evaporating from lakes and oceans all the time. Every day more than 1,000 cubic kilometers (km^3) of water evaporates worldwide. And all that water vapor goes into the air! That's nearly 240 cubic miles of water. That amount of water would cover the entire state of California 3 meters (10 feet) deep.

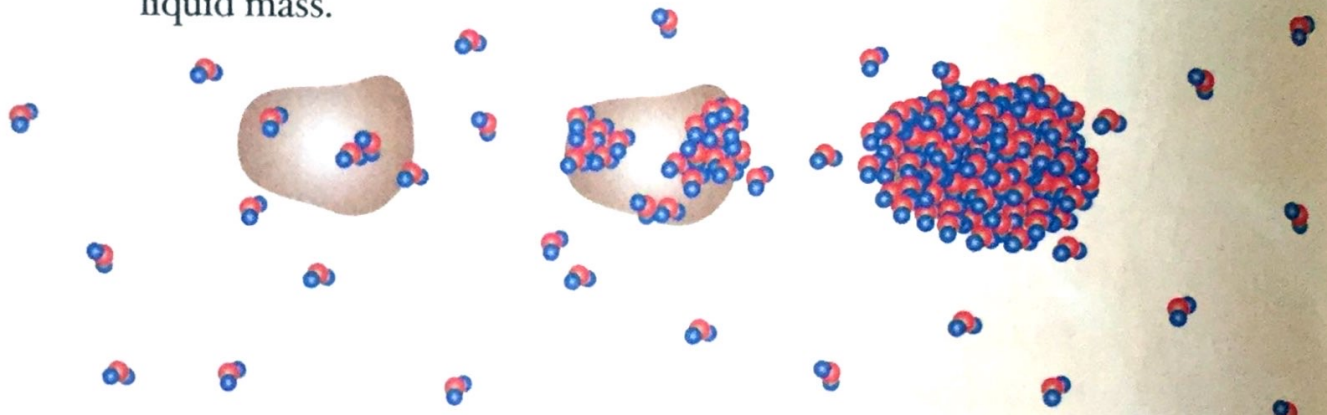
What happens to all that water in the air? As long as the air stays warm, the water stays in the air as water vapor. Warmth (heat) is energy. As long as the molecules of water vapor have a lot of energy in the form of heat, they continue to exist as gas.

But if the air cools, things change. As the air cools, all the molecules lose energy and slow down. This is when molecules of water vapor start to come together. Slowing down and coming together is called **condensation.** Condensation is the change from gas to liquid.

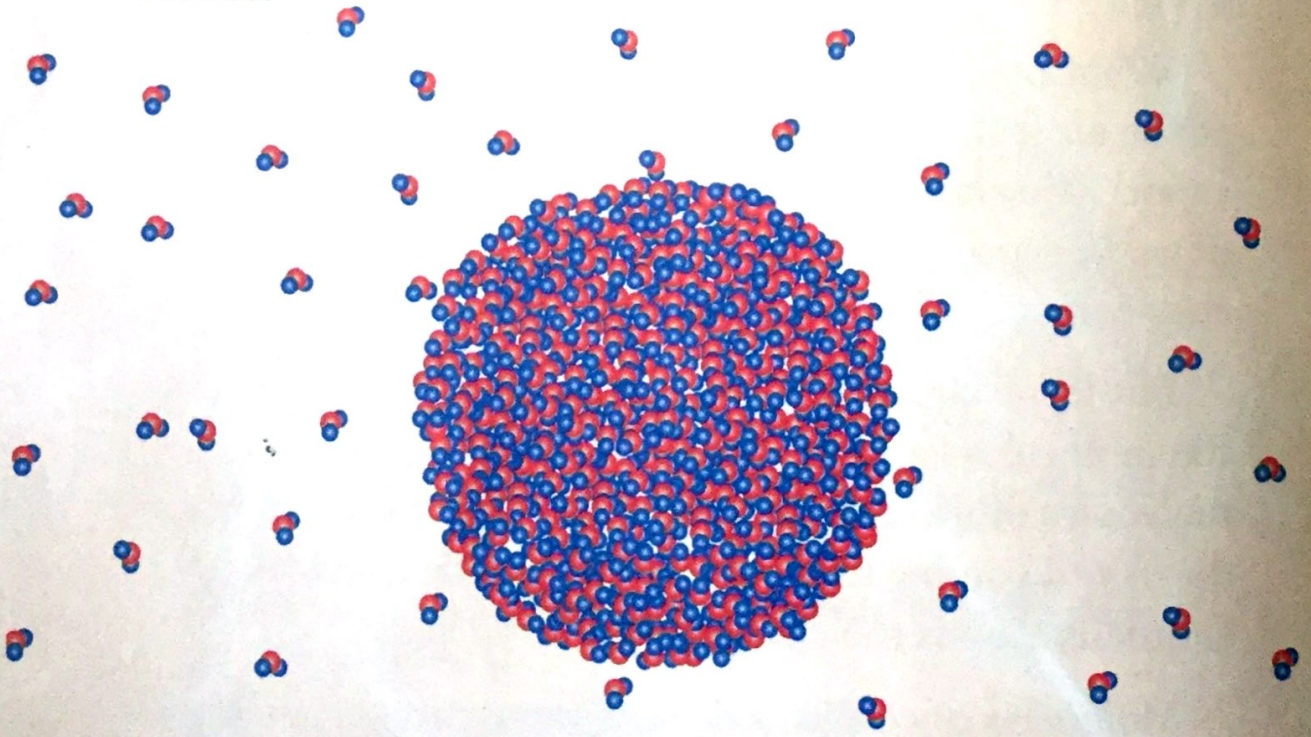
Molecules of condensed water vapor form tiny masses of liquid water. When invisible water vapor in the atmosphere condenses, the water becomes visible again. **Clouds** and **fog** are made of these tiniest masses of liquid water.

Condensation usually happens on a cold surface. In class you observed condensation on the cold surface of a plastic cup filled with ice water. But there are no cups of ice water in the sky. What kind of surface does water vapor condense on?

Most condensation in the air starts with dust particles. Water molecules attach to a dust particle. When a tiny mass of water has formed on a dust particle, other water molecules will join the liquid mass.

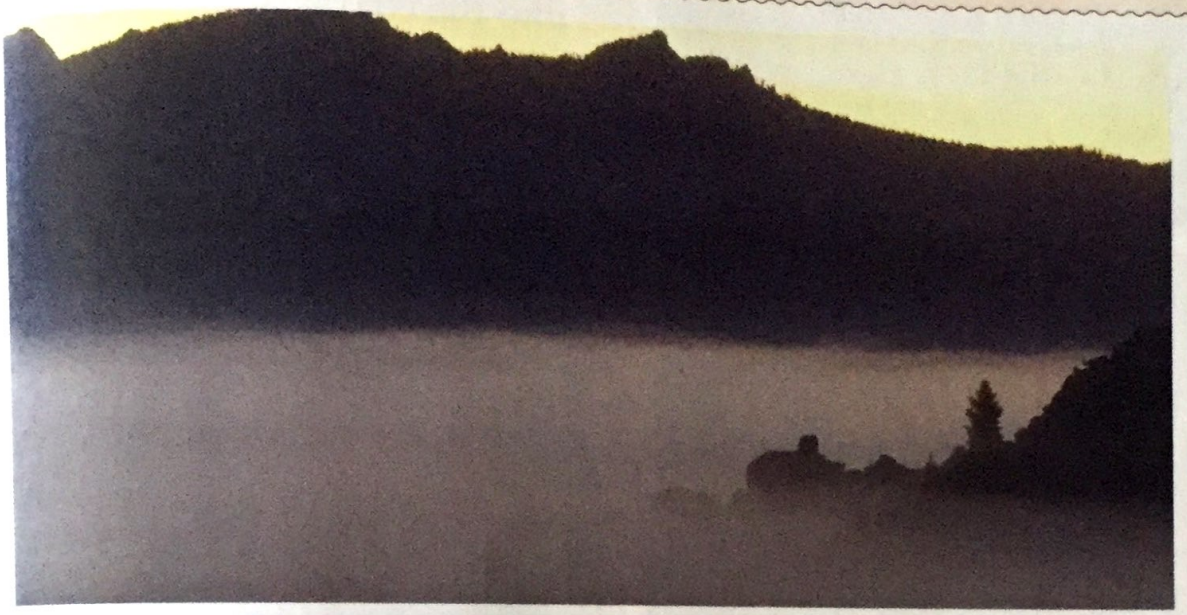


The mass grows and grows until a tiny droplet of water has formed.



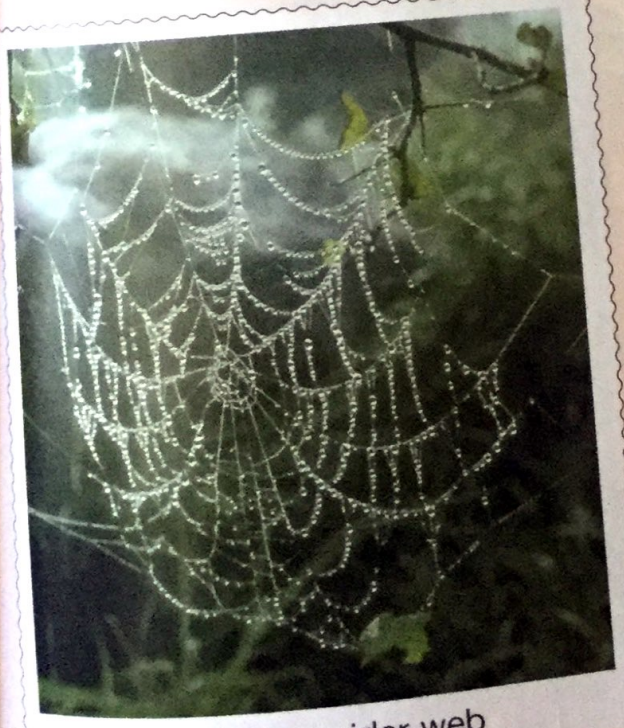
When you look up in the sky and see clouds, you are seeing droplets of liquid water. Each droplet is made up of billions of water molecules, but a single droplet is still too small to see. But you can see them when trillions and trillions of them are close together in clouds.

Where else have you seen condensation besides up in the sky in the form of clouds? Sometimes water vapor condenses close to the ground. This is called fog. Being in fog is really being in a cloud that is at ground level.

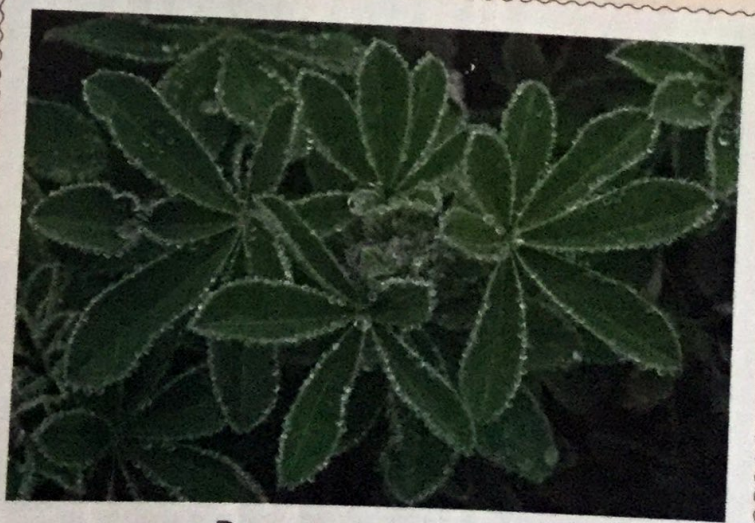


Fog close to the ground

As you know, water vapor doesn't always condense in air. If you go out early in the morning following a warm day, you might see condensation called **dew.** In the pictures below, dew formed on a spider web and along the edges of the leaves on a plant.



Dew on a spider web

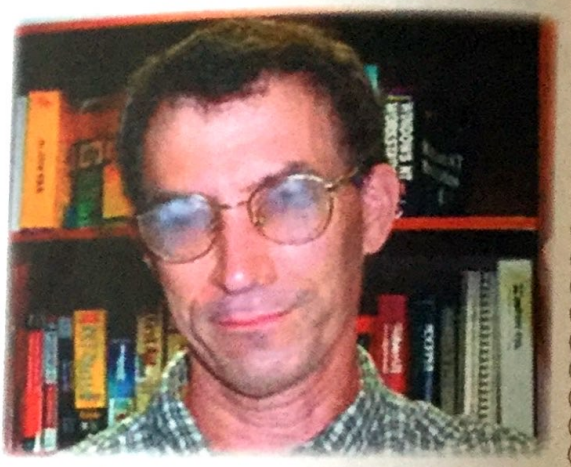


Dew on plant leaves

Condensation on a window

Water vapor condenses indoors, too. On a cold morning you might see condensation on your kitchen window. Or if you go outside into the cold wearing your glasses, they could get fogged with condensation when you go back inside.

What happens to the bathroom mirror after you take a shower? The air in the bathroom is warm and saturated with water vapor. When the air makes contact with the cool mirror, the water vapor condenses on the smooth surface. That's why the mirror is foggy and wet.

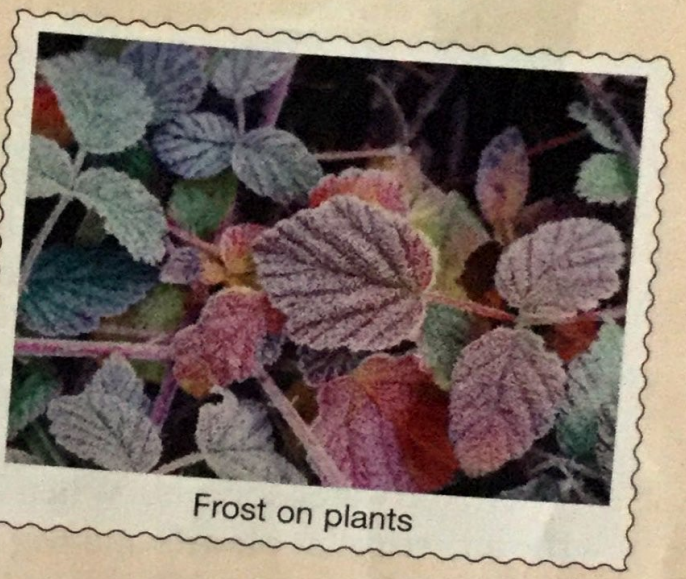


Condensation on glasses

Condensation on the mirror

When the temperature drops below the **freezing point** of water (0°C or 32°F), water vapor will condense and freeze. Frozen condensation is called **frost.** Frost is tiny crystals of ice. Frost might form on a car window on a cold night. You can also see frost on plants early on a winter morning. But you have to get up before the Sun if you want to see the beautiful frost patterns.

Frost on a window



Frost on plants

Review Questions

1. **What is condensation?**
2. **What role does temperature play in condensation?**
3. **What is frost?**
4. **Why does condensation form on a glass of iced tea?**

Summary: Water Vapor

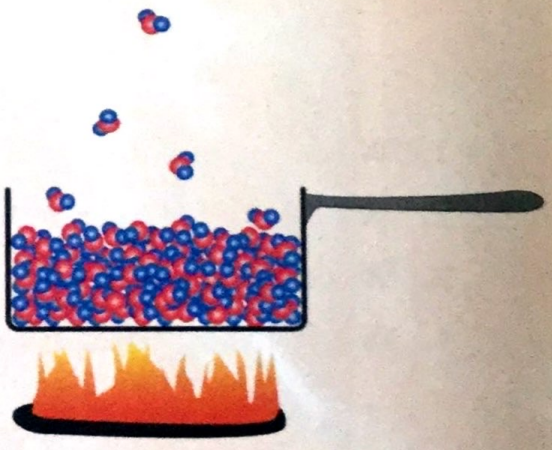
Water is a unique substance. It exists on Earth in all three common states of matter, solid, liquid, and gas. The solid state is called ice. The liquid state is called liquid water, or just water. The gas state is called **water vapor.**

Water changes between the gas and liquid states easily. When liquid water changes to water vapor, we say the water dried up. When we describe the change from liquid to gas scientifically, we say the water **evaporated.**

When liquid water appears out of thin air, we have several common names for it. The name we use depends on when and where the water appears. When it appears as tiny droplets in the air, we call it **clouds** and **fog.** When it appears on windows, plants, and cars, we call it **dew.** The scientific name for water that appears out of the air is **condensation.**

What causes water to evaporate and condense? Energy in the form of heat.

When you put a pan of water on the stove, heat energy transfers to the **water molecules.** The water molecules move faster and bang into one another harder. Molecules at the surface of the water get knocked free. The free molecules enter the air as water vapor. The larger the **surface area** of water exposed to air, the faster the water evaporates.



The mixture of gases we call air is all free molecules. Most of the air molecules are nitrogen and oxygen. Water molecules are a small but important part of the air. Water vapor will never be a

large part of the air because there is a limit to the amount of water the air can hold. When air is holding all the water vapor it can, the air is **saturated.**

Warm air can hold more water vapor than cold air. This is a very important idea. Think about a mass of warm air that is saturated with water vapor. What will happen if the mass of warm, saturated air cools down? Cool air can't hold as much water as warm air. What will happen to the water in the air?

When water vapor cools, molecules move slower. Slower water molecules start to stick together. Water molecules in contact with one another condense to form liquid water.

Condensation usually starts on a surface of some kind. It could be a window or a plant. Or it could be a tiny bit of dust floating around in the air. Once a few molecules of water have condensed on a surface, other molecules will condense on the tiny spot of liquid water. The spot of water will grow until it is big enough to see. Visible condensation is known as clouds, fog, and dew.

Fog and low clouds over South San Francisco, California

When the temperature is below freezing (0°C or 32°F), you might see **frost** in the early morning. Frost is frozen condensation. It can form on windows, cars, and outdoor plants. Frost is made of tiny crystals of ice. The patterns created by the crystals in frost can be very beautiful. But to see them you have to get up early. As soon as sunshine falls on the frost, it will melt. If you get up late, all you will see is dew.

Summary Questions

Now is a good time to review what you have recorded in your science notebook. Think about the evaporation and condensation investigations you conducted.

1. **What happens when liquid water evaporates?**
2. **What happens when water vapor condenses?**
3. **What is frost and how does it form?**

California Science Standard

ES3b. Students know when liquid water evaporates, it turns into water vapor in the air and can reappear as a liquid when cooled or as a solid if cooled below the freezing point of water.

Vocabulary

water vapor
evaporate
cloud
fog
dew
condensation
water molecule
surface area
saturate
frost