CLOUD IN A BOTTLE

AT A GLANCE

Students will participate in a classroom activity that simulates cloud formation and introduces the science of weather.

OBJECTIVES

Students will:

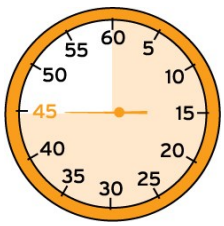
- Explain the water cycle's role in the formation of clouds
- Explain how changes in temperature and pressure can affect cloud formation

KEY VOCABULARY
atmosphere, condensation, convection, cloud, evaporation, humidity, phase change, pressure, state of matter, temperature, water vapor

SUGGESTED GRADE LEVELS: 3—5

NGSS:
PS1.A
ESS2.A
ESS2.C

PACE YOURSELF
ONE 45 MINUTE PERIOD



museum of science+industry chicago

ADVANCE PREPARATION (Optional)

1. Have students track the weather in their community for a week.
2. Have students keep a cloud journal: draw one cloud they observe every day and describe the overall cloud cover.
3. Desktop states of matter: have students keep time as ice melts in a cup. Then, track and measure evaporation over the course of a day.

MATERIALS

Activity

Teacher Demo:
2 Liter Plastic Bottle with Cap (washed)

3 tbs of warmed (not boiling) water

Matches

Individual Student or Group Exploration:
12oz. Plastic Water Bottle per group/student

goggles

Rubbing alcohol

Bottles made of thin plastic with a defined 'waist' work best

WHAT YOU NEED TO KNOW

Cloud formation is a visually stunning reminder of the complex energy systems at work in our **atmosphere**—the air that surrounds the earth containing gases, water vapor and more. Understanding cloud formation first requires us to remember that air is primarily composed of nitrogen, and oxygen, but also of **water vapor** among other variables. The main energy input in this atmospheric system is the Sun. Incoming solar radiation heats the Earth's surface, and the surface warms the atmosphere from below.

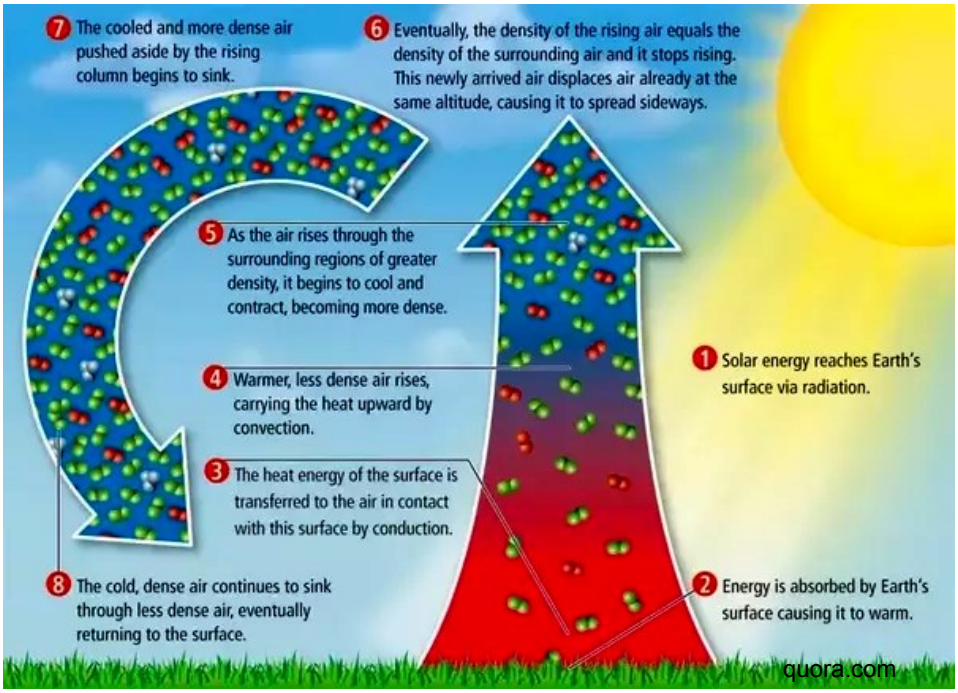


Figure 3 — Convection in the Atmosphere

Similarly, the Earth's surface also heats liquid water until it **evaporates** and becomes water vapor in the air. As this air continues to heat, its molecules become more energetic, forming a layer of rapidly moving, low-density air. This warm and energetic layer of air is overlain by colder, denser air—creating an physically unstable situation. The result is a phenomenon known as **convection**, a cycle where colder air sinks and warmer air rises due to differences in their densities. The convection of air in the lower atmosphere creates low **pressure** centers (places where air rises), and high pressure centers (places where air is sinking towards the ground). The rising and falling air causes surrounding air to move toward or away from these pressure centers. On the large scale, we feel this as wind.

How does convective air flow form clouds? That warm, low-density air rising away from Earth's surface is carrying water vapor up with it. As it travels away from Earth's surface, lower atmospheric pressure and distance from its heat source causes that air to cool. Eventually, the air **temperature** is cold enough that water can no longer stay in the air as vapor, so it **condenses** to form tiny water droplets. Collections of these tiny water droplets are what we know as **clouds.**

Figure 4 — A cloud is made up of small water droplets.

Key Vocab

Weather Words	Definitions
• Atmosphere	The layer of gases surrounding the earth or another planet.
• Convection	The movement caused within a fluid (which can be liquid or gas) by the tendency of hotter and less dense material to rise and colder, denser material to sink, which results in transfer of heat.
• Condensation	Change in the physical state of matter from gaseous phase into liquid phase. It is the reverse of evaporation
• Cloud	A visible mass of liquid droplets or frozen crystals made primarily of water and suspended in the atmosphere above the surface of the Earth.
• Evaporation	Change in the physical state of matter from liquid phase into gaseous phase that happens at the surface of a liquid. It is the reverse of condensation.
• Humidity	The amount of water vapor in the air. On an average August morning in Chicago, the humidity is measured at 85%.
• Phase Change	A physical change of matter from one state (solid, liquid or gas) to another.
• Pressure	The force exerted by one substance on another per unit area. An example would be the force of air on the walls of a balloon as you blow it up.
• Temperature	A scale of how hot or cold a substance is relating to the measure of energy of the molecules in the substance. Chicago is coldest in January and February (avg. 20 °F) and warmest in July (avg. 80°F).
• State of Matter	A distinct form that matter can exist in. The four most common states of matter are: solid, liquid, gas, and plasma.
• Water Vapor	The gaseous phase of water.

CLOUD IN A BOTTLE

WARM UP

Ask students to think back to the weather reports they watched and/or the cloud journals they made. When did they see clouds?

What do they think clouds are made of?

How do they think clouds form?

Use this 'Cloud in a Bottle' activity to ignite curiosity and get students observing.

ACTIVITY

Walk students through the discussion of the atmospheric cycle that forms wind and clouds. Trying to address preexisting ideas and/or misconceptions:

Convection Cycle

- The Sun heats Earth's surface.
- Earth heats the lower atmosphere and liquid water.
- Evaporation occurs—liquid water becomes water vapor in air.
- Warm air is low density. It rises, carrying water vapor.
- The air above it is colder and denser, so the two need to switch positions (warm air is like oil and the cold air is like vinegar. The oil should be on top because it is less dense).
- The cold air begins to fall.
- When it reaches the Earth's surface it begins to heat up, and starts the cycle again.

Wind

- Convection creates areas of high and low pressure (falling and rising air respectively).
- This movement causes surrounding air to move as well (similar to creating a wake in water).
- On the large scale, all these molecules of moving air are what we feel as wind.

Cloud Formation

- During convection, warm air and water vapor rise.
- As it moves away from Earth's surface it begins to cool.
- Once it is cold enough, the water vapor in it condenses—turns back into a tiny drops of liquid.
- Collected together, the droplets of water are what we call a cloud.

ACTIVITY

Suggestion: Try both the large and small scale versions of cloud in a bottle for yourself first to test how much pressure you need to apply to get a result.

1. Light a match. Hold the empty bottle over it, even inserting the match into the bottle's neck, and blow out the match so that the smoke enters the bottle. Quickly cover the top with your thumb. The smoke from the match will provide the 'dust' which the water vapor in your bottle can condense around to form our cloud. The 'dust' (in our case carbon molecules) is not necessary in cloud formation, but it helps the process by giving the water vapor molecules something to collect around. In our atmosphere, the tiny particles that water vapor may condense around tiny particles known as aerosols made of dust and/or other materials.

2. Holding the bottle at a 45 degree angle to limit the amount of smoke lost, add 3 tbsp of warm water to the 2L bottle. There should be enough to form a shallow pool at the bottom; adjust as needed. (You can do this with a narrow spoon, and eyedropper, a turkey baster, or a pipette.)

3. Replace the cap and swish the water around to coat the insides of the bottle. This adds water/water vapor to the atmosphere inside the bottle, increasing humidity.

4. Squeeze the bottle hard. There should be no cloud. This simulates the high pressure air close to the ground, although the vapor and dust are present, the high pressure (and resulting higher temperature) do not allow the vapor to condense.

5. Release the bottle quickly — a cloud should form! As air travels away from the bottom, pressure decreases and temperature cools, and the vapor condenses around the dust particles to form a cloud .

Students should wear goggles *while completing the activity below*:

The smaller student bottles can create clouds without the use of the match. Simply have students add 1 tbsp of rubbing alcohol to their bottles and tighten the cap. Swish the alcohol around and then begin to squeeze and twist the bottle at the waist — increasing temperature and pressure as in the demo.

Pressure can be released simply by untwisting the cap.

Warning: untwisting the cap while squeezing the bottle can result in the cap shooting off with some speed (some students may already know this). However, you could use this knowledge and redirect the energy by conducting this part of the activity outside or in a gym/multi purpose room where the distance of the caps' trajectory can act as a measure of the pressure within the bottle.

Have students take a scientific approach to this activity by utilizing the data collection sheet (last page) to record hypothesis, observations and additional notes such as if the repeated twisting begins to wear on the bottle - how might that affect their results?

The bottles can be used in this manner more than once, though they may have to be re-inflated between trials.

We also suggest, if possible, to have the data recording sheet laminated or placed into a plastic sheet protector so that it can be reused with dry erase markers.

DIFFERENTIATED INSTRUCTION

1. Younger students and students with disabilities may need assistance in twisting the smaller water bottle. This can be done in the moment or prepped by giving the bottles a quick twist, while un-capped, prior to the activity.
2. Older or more advanced students could be given the smaller water bottles as a challenge: how can they replicate the necessary temperature and pressure changes to create a cloud without the matches?
3. This could also be run as a more directed activity, with each student group prepping their bottles as a class and making individualized recordings of the results.
4. Work with students to modify the variables in your initial demo: how does the effect vary with more or less water, matches or applied pressure? Have students make a prediction.

EXTENSIONS

ART

Have students design 2-D or 3-D clouds. Consider using recycled materials (another cycle!) to keep things earth friendly. Or show students images/videos and ask them to draw what they see in the cloud: is it a castle-cloud? Maybe a dog-cloud?

LANGUAGE ARTS

Note: this activity can be used at the beginning or the end of the lesson.

Look for books that feature clouds. In literature clouds are often more than just the weather, sometimes they signal good times ahead or maybe that the narrator's mood has turned stormy or hungry (*Cloudy With A Chance Of Meatballs*, anyone?). Have students write a story that takes note of the clouds: how does it affect the story they tell?

SCIENCE

Have students diagram and label the different types of clouds. Consider checking back on the cloud journals (or making new ones): can they identify the clouds they see? How do the clouds they see correlate with the weather that day?

DIGITAL RESOURCES

- How Stuff Works cloud page
  https://science.howstuffworks.com/nature/climate-weather/atmospheric/cloud.htm

RELATED EXHIBITS

Science Storms.

DATA COLLECTION SHEET				
Trial Number	Number / Degree of Twists	Hypothesis	Observation	Additional Notes