

Why are clouds white?

A laboratory experiment from
the
Little Shop of Physics at
Colorado State University



Overview

Clouds are made from air (which is transparent) and droplets of water (also transparent.) So clouds are made of things which are clear. Why can't we see through them? Why are clouds white, and not clear?

We let students ponder this question by having them consider a related question: Can you make a colorful cloud with colored water?

Theory

Isaac Newton performed a classic series of experiments over 300 years ago to demonstrate that the white light from the sun is composed of all the colors of the rainbow. Light is a wave (an electromagnetic wave) and these colors are each characterized by their **wavelengths**. The wavelengths of light are quite small. Red light has a wavelength of 0.0000007 meters, just 0.7

microns. One micron is 1 millionth of a meter, so that's pretty small—and that's the longest wavelength your eyes can see. Blue light has a wavelength of about 0.4 microns.



How can clouds be white when they are made of millions of tiny cloud droplets—which are clear?

Necessary materials:

Activity 1

- Clear container of water
- One ultrasonic mister (provided)
- Paper towels
- Food coloring

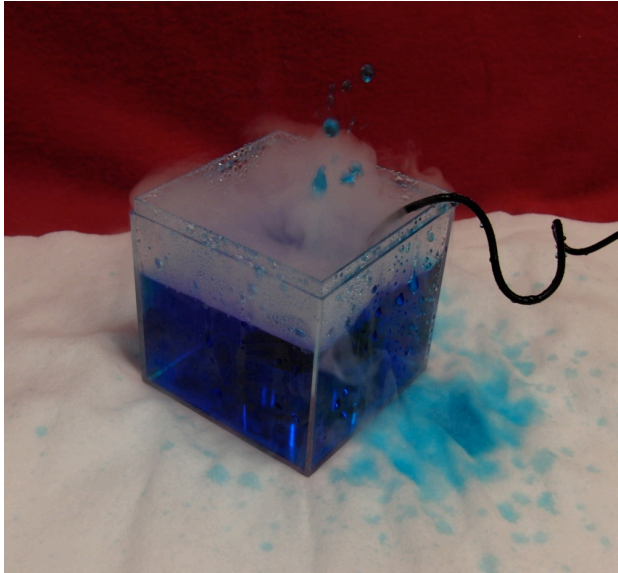
The ultrasonic mister is the crucial piece for this experiment. It's necessary to break the water up into droplets to create the "cloud" above the water. You can find ultrasonic misters at <http://www.mainlandmart.com/foggers.html>.

If your cloud isn't appearing, make sure there is the right amount of water above the little metal speaker. Too little water means it won't work; too much means that the cloud that forms will be

Clouds are composed of millions of tiny water droplets (**cloud droplets**) or ice crystals. The average size of cloud droplets is about 10 microns. This is pretty tiny, but these cloud droplets are much bigger than the wavelengths of visible light. Since a cloud droplet is much bigger than any wavelength of light, all the different colors of light behave the same when they hit a droplet—they **scatter**. Scattering means that light is redirected in random directions. All of the colors are scattered equally, so the light is diffuse and made up of all colors...and the net result—clouds appear white!

Doing the Experiment - Activity 1

This is a demonstration activity to do with the whole class, centered around a discussion.



The larger water droplets splatter the blue color on the paper towel, but the cloud remains white!

Pose the question to your students: Why are clouds white? Gather their ideas and then explain that you have an activity that will help them ponder the answer to this question.

Put down a white paper towel on your table and then put a clear container with water in it.

Submerge the ultrasonic mister in the water and plug it in. As students observe the white cloud forming, explain: *A cloud is made up of small droplets of water in air. Air is clear and so is water.* Then ask: *So why does the cloud appear white?*

Now, ask the class: Could we make a cloud that is another color using food coloring?

Collect predictions and then have a student add food coloring to the container.

In a very short time, students should see a white cloud appearing over the colorful water. If droplets of water escape from the container however, they may leave little food coloring spots behind!

Have a discussion with your class about what they think is happening and why.

Doing the Experiment - Activity 2

This is a quick activity that students can easily try for themselves.

Have students put on the safety goggles.

Have them place a clear ice cube on the black felt square. Fold the material over the ice cube so it is covered.

Carefully crush the felt covered ice cube with the hammer and then open up the material. The smashed ice pieces should look white!

Review that this is another case of scattering and that the ice looks white because all the wavelengths of light are scattered equally.

Necessary materials:

Activity 2

- Clear ice cubes
- Black felt squares
- Safety goggles
- Hammers

If you use clear ice cubes, the results will be more dramatic for your students. We boil water, let it cool, and then freeze it in ice cube trays to get the clearest cubes.

Doing the Experiment - Activity 3

This is a great activity to pose a mystery to your students. It is also a great demonstration that helps explain why some clouds look gray or dark.

1. Assemble your mystery blocks before class begins. Take two rectangles of the paraffin wax and sandwich a piece of aluminum foil between them. The aluminum foil should be slightly smaller than the rectangles of wax. Melt the wax together by using the trigger lighter..
2. When your class arrives, tell them that you have a mystery for them to solve. Using a bright desk lamp, overhead light, or sunlight, hold the wax block horizontally so the top layer is very white, but the bottom layer is gray. Now dazzle your students by flipping the block over, so now the gray block has turned white and the white block has turned gray!
3. Ask them what they think could be happening. (The paraffin scatters light just like the cloud droplets. When light enters the wax block, the different wavelengths are scattered equally in random directions and the block appears white. But the aluminum foil blocks most of the light from reaching the lower block. The lower block still scatters all colors of light equally, and so it doesn't have a color, but because it scatters less light than the top block it appears gray. The gray and the white are really the same color—that is, no color at all—but they differ in intensity.)
4. Ask your students: Why do clouds sometimes appear white and sometimes gray? (All clouds are the same color, no color at all. When we see light scattered off the front of a cloud, it sends a lot of light our way; the cloud appears white. But if the sun is behind a thick cloud, not much light makes it to the bottom, so the cloud appears gray.)

Necessary materials:

- Paraffin Wax rectangles
- Aluminum foil
- Heat source such as a long lighter for candles or barbeque grills
- Heat source such as a long lighter for candles or barbeque grills

The wax we use is used for canning and candle making. You can find it at a grocery or hardware store.



Your students will be stunned when you flip this wax block over!

Summing Up

Clouds appear white because of scattering. The droplets in clouds are big compared to the wavelength of light, so all wavelengths scatter the same. It's a different story for the scattering of light from molecules of air in the atmosphere. These are much tinier than the wavelength of light, so blue light scatters much more than red. So the sky is blue and sunsets are red.

But clouds are white; they have no color at all, even if the water making them up has color. Clouds can appear white or gray. In fact, the same cloud can appear white to one person and gray to another. This has to do with where you are with respect to the cloud. People flying in an airplane may pass over a cloud that looks quite bright as it scatters the abundant sunlight from above, but an observer on the ground may see the same cloud as gray, because little sunlight penetrates to the lowest level.

For more information:

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: <http://cmmmap.colostate.edu>

Little Shop of Physics: <http://littleshop.physics.colostate.edu>