

# Do cities affect the weather?

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

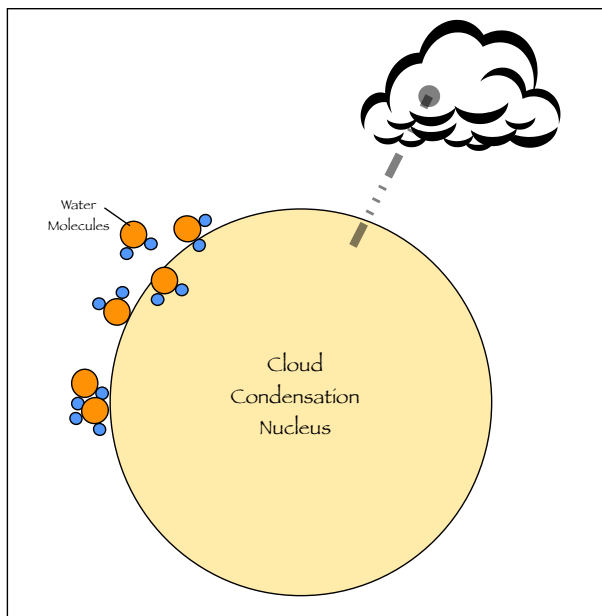


## Overview

Clouds reveal the patterns of weather to the keen observer. They are weather stations in the sky, giving us indications of what the weather may bring. They are poetical and a pleasure to watch, taking on shapes and sizes that ignite the imagination. What, however, is within these inspiring shapes, and how do they form?

## Theory

The cloud inside our bottle, as well as clouds in the atmosphere, form when four conditions are present: water vapor, cooled air, supersaturation, and condensation. Water is the only substance in the atmosphere that naturally occurs as a gas, solid, or liquid. The water that makes up clouds is all around us in the gaseous form of water, water vapor.



*Molecules of water vapor are helped to form a droplet of liquid water by a condensation nucleus.*

## Necessary materials:

- Two 2-liter bottles
- Tire valves to fit in the caps
- Air freshener (Glade Powder Fresh works well.)
- Bike pump with pressure gauge
- Sucker sticks to release air pressure.

The most important element is the tire valve, purchased at an auto parts store. These will fit inside the bottle cap, and allow you to pressurize the bottles. A pump with a gauge is also important, because it will let you pump up the bottles to a known pressure.

In humid areas, water vapor can account for 4% of the volume of the atmosphere. In dryer areas, less than 1% of the atmosphere is water vapor.

Water vapor can condense to form liquid water if the air is cooled, because cooler air can hold less water vapor. Air cools as it rises due to **adiabatic cooling**. (Adiabatic, pronounced “a-dE-&-’ba-tik” means that there is no transfer of heat between an air parcel and its surroundings.) When a parcel of air rises, it expands; the expansion requires energy, which comes from the thermal energy of the air, so the air cools. As we noted, cold air holds less water, so when the air rises, as it cools, the water vapor will “want” to condense out of the air—it will want to form droplets. The air can become **supersaturated**, with a relative humidity greater than 100%, but the droplets don’t form yet... they need help. Liquid water has surface tension. This means that making a droplet requires energy to create this surface tension. The water molecules can get around

this energy barrier by condensing on a surface. In the summer, when a cold glass of ice water meets warm, moist air, water droplets form on the outside of the glass.

In the atmosphere, **condensation nuclei** provide the surfaces on which water vapor can condense. Dust particles will allow water vapor to form a droplet as in the above diagram; alternatively, soluble materials such as salt will dissolve in the condensing water vapor, facilitating droplet formation in a slightly different manner. Without cloud condensation nuclei, the relative humidity must be several hundred percent in order for water vapor molecules to condense freely. Condensation nuclei in the atmosphere range from dust, to volcanic ash, to pollution. With these nuclei, the water vapor in the air can condense to create a cloud made of billions of tiny droplets of liquid water.

## Doing the Experiment

### **SAFETY NOTES :**

- **The bottles will easily hold more pressure than the pump can provide as long as they are intact. If a bottle has any defect, replace it.**
  - **When you pump the bottles up, they won't explode, but the caps can fly off at high speed if they are released. You should fasten the caps in place to eliminate this possibility. Folks open soda bottles all the time with no ill effects. But these bottle caps have valves in them so a bit of caution is warranted.**
1. Add a small amount of water to both bottles.
  2. Spray (just one squirt!) the air freshener into one bottle. Swirl the water around the bottle so all the air freshener has a chance to mix in.
  3. Pump up the bottles to a fixed pressure; 30 psi/2 bars is plenty. The air in the bottles will warm as you do this. Students can easily feel where the energy comes from for this increase in thermal energy!
  4. Let the bottles cool to room temperature.
  5. Let the air out of the valves of both bottles at the same time using the sucker sticks, and observe. Compare the bottle with the condensation nuclei to the bottle without. What differences do you see? Do you think there were some condensation nuclei present in the bottle we did not spray with air freshener? What else could you use for condensation nuclei?

### **Summing Up:**

So, how could cities change the weather? The dust and pollution by cars and industry in cities increase the number of condensation nuclei in the atmosphere. In 2003, NASA provided evidence from satellites, models, and observations that this can affect the local weather. Clouds are more likely to form downwind from cities, but, in some cases, this means that rain is less likely because the droplet size is smaller. These tiny droplets do not condensate into rain droplets instead they remain suspended in the air.

### **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>