# What is the opposite of sweating?

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

## Overview

When you sweat, liquid water on your skin turns to vapor. This phase changes takes away energy, cooling you. And when water vapor turns to liquid water, it releases energy. When water vapor condenses on a surface, it warms it—by quite a bit!

The transport of energy by such phases changes in the atmosphere is very important to understanding weather and climate, but it can be abstract and difficult for students to grasp. In this activity, your students will actually see chocolate melting due to the release of energy as water vapor changes from a gas to a liquid.

**Necessary materials:**

- 2 hot plates
- 2 miniature chocolate bars
- 2 large metal serving spoons
- 2 double boiler pans
- Water
- 2 chef hats (optional)

*Water in the lower pan boils. The resulting water vapor condenses on the upper pan, releasing heat energy. The warming of the upper pan is almost entirely due to the energy released when the water condenses.*

## Theory

Imagine heating water in a pan on your stove. When you turn on the burner, you are adding heat energy to the water, and its temperature will rise. If you have 1 kg of water at 0°C, you will need about 420 kJ to raise it to the boiling point at 100°C.

Now, imagine that you keep the burner going. The temperature won't rise anymore; instead, the heat energy that you put in is used to convert the liquid water to water vapor—you are boiling the water away. To completely boil away 1 kg of water takes 2260 kJ—much more energy than it took to heat the water up. This **latent heat** is responsible for most of the warming and cooling that water does in the environment, as we will see.

Water will evaporate at lower temperatures than that at which it boils. Evaporation is still the change of liquid water to water vapor, so heat energy is needed. If you sit outside on a hot summer day, you sweat. Water on your skin evaporates, cooling your skin as it does. The evaporation of 1 kg of water at normal skin temperature of 30°C carries away even more energy than boiling—2400 kJ. This is A Good Thing; it means that your body can keep itself cool by evaporating modest amounts of water.

When water evaporates, it carries away thermal energy. This is something most folks know and understand. But the opposite is also true: *When water condenses, it gives up thermal energy.*

Air cools when it rises and expands, but the rate of cooling decreases for moist air, because as it cools water vapor condenses, releasing energy as it does. Condensing water vapor to liquid water means that small droplets of water form—a cloud. Making a cloud reduces the cooling of the rising air. Dry air cools by about 10°C for a rise of 1000 m; moist air (that is, air containing water vapor) cools by about 5°C for a rise of 1000 m.

Summing up: **Sweating keeps you cool, and making clouds keeps the air warm.** The consequences of evaporation for biology are dramatic, and the consequences of the condensation heating are no less dramatic for the atmosphere. Water vapor is one of the key elements that the atmosphere uses to move energy around

## Doing the Experiment

This is a teaching demonstration we like to call *Cooking with Condensation*. It's great fun and the results are quite memorable.

> **SAFETY NOTE: The hot plates, double boilers, and boiling water can get very hot. Warn students to be careful and avoid touching these items, before, during, and after the demonstration. You will want to use 2 reliable adult volunteers to demonstrate.**

- Before you begin, set up the two cooking stations identically. Turn both hot plates to high. The only variable in the experiment will be that one double boiler pan is dry and the other one has water boiling in it.
- Explain to your students that you are going to explore the question: Do things get warmer or colder when water vapor condenses? As a class, brainstorm examples of this happening such as: mirrors or windows getting misty when you take a shower, droplets forming on the outside of a cold glass of lemonade on a warm summer day, dew on grass blades in the early morning, etc.
- Tell them that you are going have a competition to test the question above. Ask each of your students to make a prediction before you begin.
- Choose two volunteers to compete in the contest: *Cooking with Condensation.* The goal is to see which cook can start melting a chocolate bar before the other. The two volunteers should put a chocolate bar into the bowl of the spoon. They should hold the spoons equidistance above the double boiler they are using. We suggest 2 to 3 inches above.
- Comment on what is happening to the spoons. The one above the boiling water is getting foggy looking. Occasionally have the two cooks hold up the spoons at an angle. The one cooking over the boiling water will start showing some chocolate melting around the edges of the bar.
- Discuss what they think is happening to melt the chocolate in the spoon. The water vapor changed to a liquid phase releasing energy as it condensed on the spoon. Return to the examples the class brainstormed at the beginning of the activity. Review what is happening with each example as the water vapor changes phase during condensation.

## Summing Up

When students observe this demo, they see the results of water molecules going from a gas to a liquid phase, releasing heat energy as they condense. The solid chocolate bar absorbs this energy and begins melting, changing phase to a liquid.

Check out the following activities to explore more about this concept: *How can clouds keep the air warmer?* and *How can freezing make something warmer?* Your students will never look at phase changes quite the same again!

## For More Information

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

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