Dragon's Breath

Did you ever breathe out a big breath of steam, just like a dragon? It's great fun to exhale a cloud in front of your face and pretend that you can scorch the countryside with one blast of your mighty breath. But you can't perform this trick all the time. Why can you see these breath clouds sometimes, but not all the time?

That short-lived dragon's breath is a little cloud. What are the ingredients you need to make a cloud? You need water vapor in the air, temperature at or below dew point, and a surface on which the water vapor can condense. Let's look at the variables one at a time.

Water Vapor in the Air

There is always water vapor in the air. Sometimes there is very little water vapor, and sometimes there is a lot. Water vapor in the air is called **humidity.**

Temperature plays an important role in humidity. The rule is, the warmer the air, the more water vapor it can hold. At 35°C, a kilogram (kg) of air can hold 35 grams (g) of water vapor. That same kilogram of air at 0°C can hold only 3.5 g of water vapor.

When air is holding as much water vapor as it can, it is said to be **saturated.** When air is saturated, no more water vapor can enter the air.

The amount of water needed to saturate a mass of air is not the same at all temperatures. Let's think about a kilogram of air that is holding 3.5 g of water vapor. The 3.5 g of water vapor will saturate the kilogram of air at 0°C. That same 3.5 g of water vapor, however, represents only 10% of the 35 g needed to saturate the kilogram of air at 35°C. The amount of water vapor in the air compared to the amount of water vapor *needed to saturate the air at a given temperature* is **relative humidity.** Relative humidity is reported as a percentage.

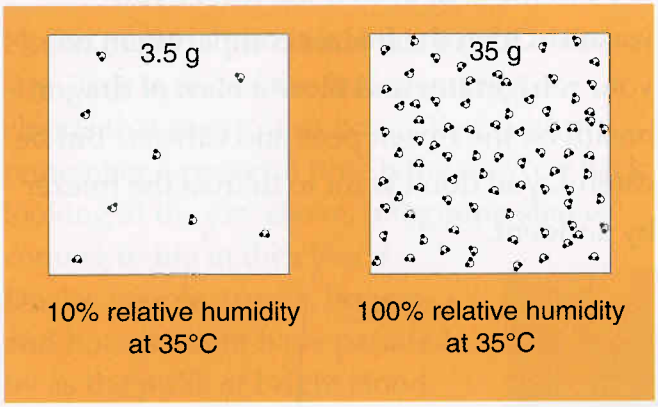
The relative humidity of the kilogram of air holding 3.5 g of water vapor at 0°C is 100%. When the same kilogram of air with the same 3.5 g of water vapor is heated to 35°C, the relative humidity is only 10%.

Water/air saturation points (g/kg)

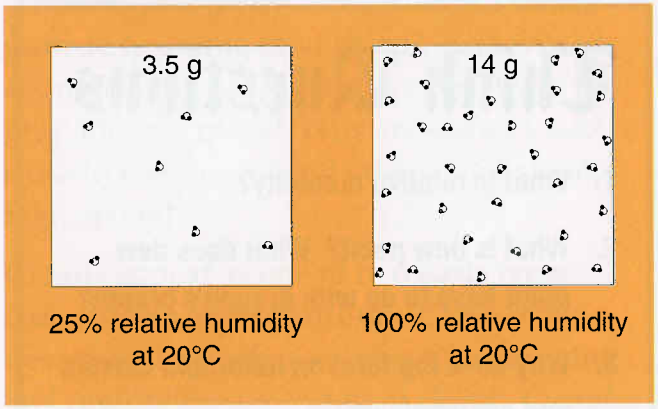
Air temp. (°C)	Grams water per kilogram of air
–40	0.1
–30	0.3
–20	0.8
–10	2.0
0	3.5
5	5.0
10	7.0
15	10.0
20	14.0
25	20.0
30	26.5
35	35.0
40	47.0

Dew Point

Picture the kilogram of warm 35°C air holding 3.5 g of water vapor. That's 10% relative humidity. This is a cartoon of 3.5 g of water vapor in the air compared to the 35 g of water vapor needed to saturate the air at 35°C.

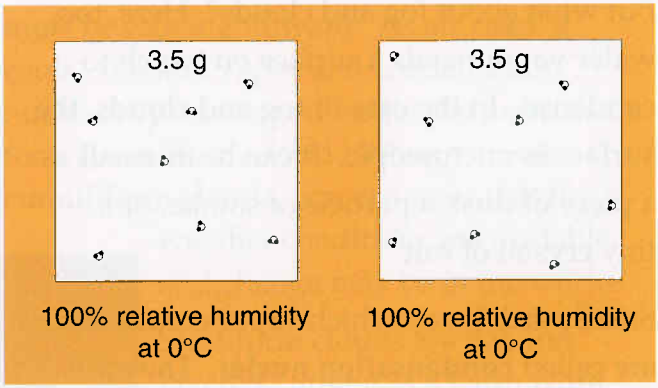


As the kilogram of air cools off to 20°C, there are still 3.5 g of water vapor in the kilogram of air, but at 20°C a kilogram of air is saturated when it is holding 14 g of water vapor.



At 10°C, a kilogram of air is saturated when it is holding 7 g of water vapor. When our kilogram of air with its 3.5 g of water vapor cools to 10°C, the relative humidity is now up to 50%.

If the mass of water vapor in a kilogram of air doesn't change, its relative humidity goes up and up as it cools. When it gets to 0°C, an interesting thing happens. Without changing the mass of the water vapor in the air, the air becomes saturated. The kilogram of air can hold only 3.5 g of water vapor at 0°C, and that's the amount in our air.



What happens when the air gets even colder? The table shows that a kilogram of air at –10°C can hold only 2 g of water vapor. Our kilogram has 3.5 g of water vapor. What happens to the extra 1.5 g of vapor? It condenses into ice crystals.

The temperature at which a volume of air is saturated with water vapor is known as **dew point.** When the temperature drops even a tiny bit below the dew point, water condenses as ice crystals, dew, fog, or clouds.

Condensation Surface

Water vapor needs a surface on which to condense. When the air reaches dew point, water will condense on grass, leaves, and windows as dew. Dew is a thin layer of tiny drops of water. Dew forms on large surfaces.

But what about fog and clouds? Here, too, water vapor needs a surface on which to condense. In the case of fog and clouds, the surface is microscopic. It can be as small as a piece of dust, a particle of smoke, or a tiny crystal of salt.

Small particles on which vapor condenses are called **condensation nuclei.** The air is full of tiny things that can act as the nucleus around which condensation starts. Once a droplet is started, more water vapor can condense on the surface of the water droplet.

Back to Dragon's Breath

Air in your lungs is warm—close to 35°C—and humid. In fact, the humidity of an exhaled breath is at or very near 100% relative humidity. Most of the time the water vapor in the exhaled humid air enters the atmosphere and just adds to the humidity of the air. When the warm air from your body is exhaled on a cold day, it cools rapidly. Cold air holds less water vapor. Your breath air quickly drops to dew point and becomes saturated with water vapor. The water vapor from your breath instantly condenses on invisible dust particles present in the air, and you let out a blast of cold dragon breath!

The colder the air temperature, the easier it is to saturate the air with the water vapor from your breath. So where could you go today to breathe out a cloud? Your face would have to be in the cold even if the rest of you wasn't. Open the freezer compartment on your refrigerator and blow a blast of dragon breath on the frozen peas and carrots. But be careful, you don't want to defrost the freezer by accident.

Think Questions

1. **What is relative humidity?**
2. **What is dew point? What does dew point have to do with dragon's breath?**
3. **Why does fog form on bathroom mirrors and car windows?**
4. **On what kind of day would it be possible to create frozen dragon's breath?**