QUESTION FROM THE CLASSROOM

By Bob Becker

Q My chemistry teacher told our class that all colored gases are poisonous. He said that gases are generally invisible, so if you can see the gas, it surely is bad for you. But what about steam? That's a gas you can see but it is just made up of water in the gaseous state, so it can't be poisonous—right?

A You are right that water in the gaseous state is not poisonous. And your chemistry teacher is also right that all colored gases are poisonous: Any gas that you can see is dangerous and should be avoided. Here's the catch: What you are calling "steam" is not really water in the gaseous state.

SHUTTERSTOCK

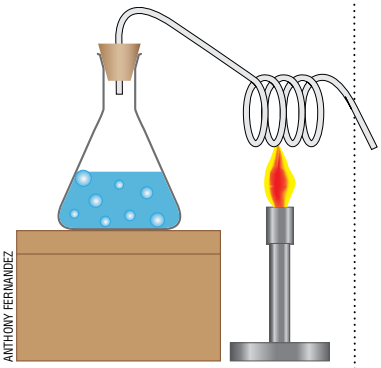
Pure gaseous water only exists next to the spout of the kettle. Elsewhere, it is mixed with liquid droplets to make the visible steam.

Let's say you put some liquid water in a kettle on the stove. Within a few minutes, the water inside reaches 100 °C, and it begins boiling. You then start to see what you think is gaseous water billowing out of the spout. Actually, pure gaseous water is present only in the gap between the spout of the kettle and the beginning of the billowy cloud. (Some gaseous water is also present in between the visible steam particles, but at much lower pressures and mixed with air.) This gap is shown in the picture below.

This gas only lasts a few milliseconds, because as soon as this hot invisible gas hits the cool air in the room, it quickly condenses into little tiny droplets of liquid water, which is what you are seeing. The droplets, in the form of mist, are suspended momentarily in the air, but they do not represent gaseous water.

Many chemistry textbooks contain the same misconception. So, I do the following demonstration, as illustrated below. I boil some water in a large Erlenmeyer flask on a hot plate. The flask is fitted with a one-holed rubber stopper that has a 50- to 60-centimeter long copper tube protruding from it. This tubing is bent to the side and wrapped into a coil.

Once the water starts boiling, and what looks like steam starts pouring out of the end of the tube, I light a burner and place it beneath the copper coil. This takes the 100 °C gas passing through the copper tube and heats it up to well above 200 °C. At that temperature, it takes much longer for the gas to cool to temperatures at which it would condense to droplets of liquid water.



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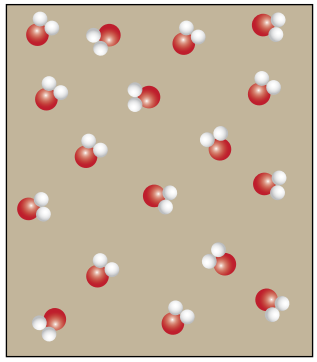
Erlenmeyer flask on a hot plate.

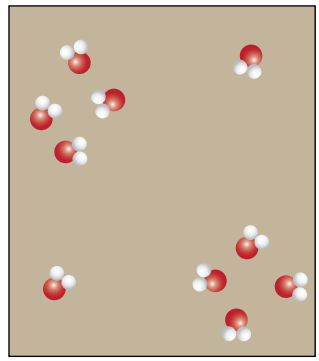
After about 15 seconds of heating, the billowy cloud simply disappears and all they see is—nothing. In fact, it looks as though there is nothing at all coming out of the end of the tube. I point out to them that they can see the water still boiling vigorously in the flask, and all that gaseous water has to be coming out of the tube, because there is nowhere else for it to go.

I hold a digital thermometer in the invisible stream of gas, and the thermometer quickly rises to 200 °C—its upper limit. I also hold a piece of white paper in the hot stream, and after a few seconds, it starts to scorch. Although the paper does not quite catch on fire, a wooden match held in the hot stream quickly ignites.

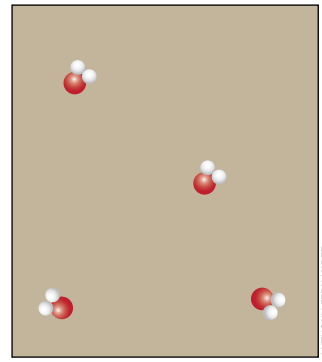
This experiment is perhaps most impressive, and I always enjoy pointing out to my students that they just witnessed a fire started by water!



Liquid Water



Steam



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Gaseous Water