Talk Science

Professional Development

Transcript for Grade 5 Scientist Case:
The Water to Vapor Investigations

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1. The Water to Vapor Investigations Through the Eyes of a Scientist

We met Professor Roger Tobin in his office at Tufts University, where he is chairman of the Physics Department. We asked him to do some of the very same investigations your students do in the Water to Vapor section of the 5th grade Inquiry Project curriculum. Your students use a 2-bottle system to help them answer the question, "What happens to water when it evaporates?" They see water disappear from the lower bottle and reappear in the upper bottle. Their observations provide evidence that allows them to infer that water that they cannot see exists in the air as water vapor.

This case focuses on the core science concept material. The material in question is water. Evaporation and condensation change the form of water from liquid to a gas called water vapor and back, but they do not change the material. It's still the same stuff --- water. Evaporation and condensation change the form of matter but do not change the material.

In these videos, notice what Roger observes about the 2-bottle system, and what inferences he makes from those observations. He talks about water vapor, condensation, and evaporation in both everyday phenomena and on a microscopic, particle scale. These ideas are very challenging for students. The better you understand how a scientist thinks about them, the better you'll be able to facilitate productive classroom discussion and support student learning.

Note: The particle model that Roger uses to explain his observations is introduced in Section 3: Water to Ice.

2. What Does a Scientist Observe When He Looks at the Two-Bottle System?

Notice what Roger observes about the Two-bottle system, and how he thinks about the patterns of water droplets forming.

Roger: What we have here is we have two bottles and they're coupled together by this seal that allows gas, or water if it could, to flow between the two bottles, but it doesn't allow the gas or water to go in or out. Any water vapor here, any air here, can easily move from one bottle to the other. So if we were, for example, to see water in this upper bottle, we would know that it couldn't have been the liquid flowing uphill. It would have had to have come by some process through the, through the gas -- through the air -- to get there.

Sara: Yesterday I put some salty water into this lower bottle and I turned the light on and I've left it on overnight. I'm wondering, as a scientist, what you see when you look at this two-bottle system.

Roger: Well I see first of all -- let me move that so I can see it a little better -- so the first thing I'm struck by is all these droplets here on the inside of this lower bottle and really interesting patterns of them. I mean first of all there's this whole area at the top that doesn't really show any droplets. There's sort of a foggy area up there but there's not really the droplets.

Sara: Can you explain why the water droplets form on the side of the bottle?

Roger: Well, I can explain some of it but there are some things about it that I don't completely understand. I understand, I think, why we don't get droplets on the top because that's the hottest part, that's the part that's closest to the lamp. And so that surface of the bottle is hotter than the rest of it and so it makes sense to me that that part you wouldn't get condensation, just like you don't get condensation on a glass that's at room temperature, you have to have it a little bit below -- cooler -- in order to get the condensation. So it makes sense to me that you would get condensation on the sides and the bottom where it's cooler than it is on the top.

Sara: And what about the upper bottle?

Roger: Well, so in the upper bottle this is very interesting because there's all this, there's all this liquid water here. And we know that the liquid can't have flowed uphill from the puddle. We know that that liquid can't have come in from the outside -- it's just been sitting in the room -- so we're kind of forced to conclude that this liquid must have somehow come from the liquid in the lower bottle. And yet how could it have gotten there? It would seem that somehow it's moved through the air, because we know the air is free to move between the two bottles.

So this is a nice piece of evidence for the -- it's indirect evidence – for the existence of this stuff we call water vapor because there must have been some form of water in the gas here that moved from the lower bottle into the upper bottle, and then when it hit the walls of the upper bottle (which are not cold but they're cooler than the bottle that was being heated) so when it hit those relatively cool surfaces, it condensed into these droplets and then some of them flowed down and actually left this fairly sizeable little puddle down on the bottom of the bottle. It's quite remarkable.

Notes

Notes

Summary

Water droplets form on the surfaces that are cooler, but not on the hotter surface near the lamp.

Roger uses evidence he gathers by careful observation to infer that evaporated water exists as gas called water vapor.

3. How Does a Scientist Think About Water Vapor?

Notice how Roger explains what water vapor is and explains why we cannot see it.

Sara: Tell me more about water vapor.

Roger: So, water vapor. One way to think about it is it's just a name -- it's a name for this form of water when we can't see it. When it's in the air somehow and is invisible to us. As scientists we now think of materials -- all materials-- as being made up of molecules. Made up of very, very tiny particles much, much, much too small to see that come together and can come apart to form the things, the materials, that we deal with.

And in water, the molecules that comprise the water are tightly packed and attached to each other sort of like people holding hands, and so they form this visible material that we call water. In water vapor the molecules are dispersed. They're just not connected to one another anymore, sort of like a crowd of people spreading out to a point where they can no longer touch one another and spreading out in the city or something.

So at that point since we can't see the individual molecules – they're just sort of interspersed amongst the other molecules that comprise the air-- they become invisible to us but they're nevertheless, we now know, still present.

Sara: So are they still little drops of liquid?

Roger: They're no longer liquid because liquid is the molecules holding hands. They're just the individual particles.

Sara: Some people think that steam from a kettle or mist is water vapor. How would you explain to them that it's not water vapor?

Roger: Well, water vapor, as I said, is the individual molecules and they're way, way too small for you to see them. And water vapor is around us all the time and yet we don't see it. In order for you to see things, they have to reach a certain size, they have to get to a kind of a critical size that is very, very much larger than the size of an individual molecule. So the fact that you can see the steam or the fact that you can see the plumes of steam coming out of a power plant or something or a cloud for that matter, the fact that you can see it is already telling you that it's not simply water vapor; it must be water in some form that is big enough to become visible.

Notes

Summary

Roger uses a particle model to explain the difference and similarity between water in the liquid and gas (vapor) phase.

In the gas (vapor) phase, water particles are too small and spread apart to see.

4. How Does a Scientist Think About Condensation?

Notice how Roger explains his observations of condensation.

Roger: So what I see here is this bottle filled with ice water. I can feel it it's cold, and I notice that there are droplets of water all over it below the level where the ice is. I don't see any water droplets on the outside in this warmer part of the plastic up here where the ice doesn't touch it. But down here I see lots of water droplets. I can taste it, it tastes like water -- that is it doesn't really taste at all. So you ask yourself, well where did this come from, where could this stuff have come from? Now you could think that somehow it comes through the plastic (but) -- you could do experiments where you put other materials inside, or you could in fact put nothing inside. You could have a bottle that you emptied and put in the refrigerator or the freezer so it just had cold air inside. Or it doesn't have to be a bottle, right? You could just take a spoon and put it in the freezer and if you put it out on a day like this, it will condense, you'll get water on it. Well it cannot come out of the spoon, spoons don't have water in them.

Sara: Why do the water drops form on the outside of the bottle?

Roger: Clearly it has something to do with the temperature. I mean I have a warm piece of plastic here and it's not collecting water droplets.

Sara: And you have a bottle of water here --

Roger: I have a bottle of water here and it's clearly not collecting water droplets on the outside. So I could conclude, without knowing anything about the mechanism, that somehow it has to do with temperature. That when you have a sufficiently cold surface and you have water vapor around, that this happens -- that the water in comes -- that water vapor in contact with a cold surface returns to the form of being liquid.

If we go to a particle model, and we start thinking about temperature, the way scientists think about temperature is as telling you something about how much energy the individual particles have, how fast they're moving, how hard they're vibrating, if they're holding hands. The hotter things are, the more they move, the more they vibrate, the more they jiggle, the faster they move. And so you can imagine that if you have these molecules holding hands in a liquid and they start jiggling harder and harder and faster and faster as they get warmer, sometimes one of them is going to jiggle hard enough that it breaks its connection to the others and it can go flying off. And that's how we think about evaporation occurring.

On the other hand if you have a cold surface and the molecules come down then they hit the surface they lose some energy they slow down because they're getting colder when they touch the cold surface. And then if another molecule happens to come along and also is cold, they're more likely to be able to grab onto each other and hold hands. And then another one comes along and they can hold hands. And so they can clump together and they'll stay like that because they don't have enough energy, they're not jiggling hard enough to be able to break apart and go off back into the vapor.

Summary

In evaporation, an occasional molecule in the liquid gets enough energy from random thermal motion to break its bonds to its neighbors and escape.

Condensation is the opposite of evaporation — when a molecule in the vapor hits a cool surface, it can lose enough energy to reconnect with the neighboring molecules.

5. How Does a Scientist Think about Evaporation?

Watch How Roger observes water evaporating and explores possible explanations of where the water goes.

Sara: I'm going to spray water on this cup and I'd like to be able to see water evaporate from a scientist's perspective. Could you look at a little drop of water evaporating and tell me what you see?

Roger: Okay, so when I just look at it with my eye, all I see is sort of a mist, a fog. But looking through a magnifying glass I can see these little droplets, all different sizes. And as I watch closely, I can see them -- the smaller ones especially -- getting a little bit smaller as I watch. So what I see is little drops of water just getting smaller and they just appear to be shrinking.

So if I didn't know anything more about water and what it's made of and how these phenomena work, the kinds of questions I would ask would be, is it just shrinking but it's still the same amount of water or is the amount of water in the droplet actually changing? And you would need to do

Notes

some experiments to tell. One thing you might do for example is weigh the cup very carefully while this is happening and if the droplets are simply shrinking but not losing material then you would expect the weight would stay the same, whereas if they're actually losing material then the weight would decrease. Now I doubt that we can do that here. I happen to know, because people have done experiments like this, that the answer is that the droplets are shrinking because they're actually losing material. There's not as much water; the water is going away. And I guess we sort of all know that from watching puddles dry up and eventually we know that if we watch long enough the droplets will simply go away.

So then again the question one would ask would be, is the water just gone, has it somehow just simply vanished from the universe or has it somehow been transformed into some other form where we're not able to see it, where it's no longer part of the droplet? And just this observation doesn't answer that; it could be either one.
We know now as scientists that -- that the water cannot simply disappear, the matter can't go away, that in fact it's going into a form in the air we call water vapor where it's not visible to us but it nevertheless exists.

Summary

Roger explores several different possible explanations for where the water has gone.

You can't see the water that used to be in the drops, but those water particles still exist as water vapor in the air.

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