[MUSIC PLAYING]

JESSICA HARROP: Hi, I'm Jessica and today I'm going to talk to you about a chemical demonstration I like to call colorful indicators. Indicators show us what we normally wouldn't be able to see, from the canary in the coal mine to a paint that changes color with temperature to the acid base indicators we'll be seeing today. And chemist Dr. Bassam Shakhashiri here he is-- is going to be showing us the demo. He's the president of the American Chemical Society and performing this demo right here at MIT.

[WHOOSH]

BASSAM SHAKHASHIRI: Now what I'm going to do is an experiment using another form of carbon dioxide. It's called dry ice. Dry ice is solid carbon dioxide. And you'll notice I'm putting what on?

AUDIENCE: Gloves.

BASSAM SHAKHASHIRI: Putting gloves. And I'm going to open this bucket and pick up three chunks of carbon dioxide solid. This is solid carbon dioxide. Its temperature is minus 78 degrees Celsius. It's very cold. Dry ice changes from being a solid to a gas by a process we call sublimation. Sublimation is happening right now, but we can't see it. How come we can't see it? Because carbon dioxide as gas is what?

AUDIENCE: Invisible.

BASSAM SHAKHASHIRI: It's invisible. It has no color. So sublimation is happening right now. We can't see it. And I'm going to put those three back in here and ask you to focus your attention on what you see between my two hands here. What do you see between my two hands?

In order to sharpen your powers of observation and develop the skills of reporting these observations, I ask you to pretend to be the play by play radio announcer, describing to someone who was not with us what's going on. Not the TV announcer, that person has got it made because the picture tells almost everything. So, there are how many cylinders?

AUDIENCE: Six.

BASSAM SHAKHASHIRI: And what do you see inside the cylinders?

AUDIENCE: Colored liquid.

BASSAM SHAKHASHIRI: Colored liquids. OK, I'm listening to you on the radio. And what I hear you say is that there are six cylinders. And they have in them colored liquids. Come on. Your brain learned a lot more information than those two statements, right? Right?

So they're about this big, you said. I can see you on the radio saying it's about this big, right? You've got to do better than this, OK? Are they 100 milliliters in size? Are they 10 milliliters in size? Are they somewhere in between? Yes.

We put a bracket on it when we estimate in science. We put a bracket on it. All right. And they have, yes, colored liquids. How do you know they're liquids? They could be gels. How do we find out?

We shake them up a little bit. Because we know from experience, it's a keyword, we learn things-- a brain learns things, so we use them, right? So they're liquids. So I'm going to take chunks of dry ice and put them in the cylinders in a very special way. And when I get done, you tell me what the special way is.

AUDIENCE: It's blowing out.

BASSAM SHAKHASHIRI: What's blowing out? You see any bubbles? What kind of bubbles are those?

AUDIENCE: Blue. Green. Green.

BASSAM SHAKHASHIRI: What? You want to know what's in there? You already know what's in there. Dry ice, I put the dry ice in there. What did I put the dry ice into? Into two cylinders that have colored liquids in them, right?

And I put the dry ice in every other cylinder. I didn't put it in every cylinder, right? Every other cylinder, leaving one for comparison purposes. So these are dyes that change color when the pH of the liquid changes.

[WHOOSH]

JESSICA HARROP: All right. So let's break down. What's happening in these cylinders. There's six of them. And each set is a different color because they're different acid base indicators inside them.

So this set starts out blue. This one starts out pink. And the final one is purple. And every cylinder contains a few drops of sodium hydroxide, which is a base. NaOH, sodium hydroxide, and it's a base.

So let's start with the basics. What is an acid and a base? One definition is that acids are compounds that donate a hydrogen ion or H plus to another compound. And the compound that accepts that hydrogen ion is a base. So acids are hydrogen ion donors. And bases are hydrogen ion acceptors.

Here's some examples. Sodium hydroxide is a base. It's used to make soap. And acetic acid, which looks like this, it makes vinegar sour.

All right, so let's look back at our cylinders here. This first set of cylinders contains the indicator bromothymol blue. Let's take a look at the spectrum. All right, so let's take a look at bromothymol blue, the indicator in the first set of cylinders.

As you can see here, there's a scale of numbers. This is a pH scale. The higher the number, the more basic the solution. The lower the number, the more acidic. So our solution started off basic. It was blue. It had sodium hydroxide in it. And this is what the chemical structure of the molecule looks like when it's blue. The chemical bonds in the molecule are absorbing colors of the visible spectrum that are not blue. So blue is reflected back to our eyes.

Now, if our compound picks up a hydrogen ion which it would if you added an acid to it, the molecule changes color. Now it absorbs blue and reflects yellow. Since the colors depend on the structure of the molecule, a chemist could reprogram the molecule to switch its color at other pHs, other numbers on this scale.

That's useful depending on the kind of reactions she may want to study. Now, nature experiments with color all the time. Animals use color to avoid predators, attract mates, scare off enemies, etc.

[WHOOSH]

All right, so now let's take a look at what's happening in the second set of cylinders that started off pink.

[WHOOSH]

The indicator in there is phenolphthalein. The same thing is happening with our bromothymol blue, but this time when the solution is basic, it's pink. And when it's acidic, it's colorless.

[WHOOSH]

But why does adding dry ice change the solution from basic to acidic? Well, dry ice is solid carbon dioxide. When you add it to water, it bubbles. And part of every bubble of carbon dioxide dissolves. When it does, it forms carbonic acid. Let's look at that equation.

So there's more and more carbonic acid in the water. And this acid reacts with the sodium hydroxide until there's none left. So the solution becomes acidic.

So we saw our bromothymol blue turning from blue to yellow as the solution became more acidic. And we saw our phenolphthalein turn from pink to colorless as it became more acidic. Now, let's watch again what happens in the final set of cylinders.

[WHOOSH]

BASSAM SHAKHASHIRI: All right. So now I ask you to focus your attention on this cylinder. Actually, you can focus your attention on anything you want to, OK? You can even not pay attention if you want to. We live in a free country. But if you want to follow the experiment with me, I want you to focus your attention on this one and tell me, count them out, how many different color changes you see as I drop the dry ice in there.

I'm listening to you on the radio. One. Wow, I heard wow. What kind of a count is that? Three so far. Three different color changes. But you know, I'm listening to you on the radio. You want me to appreciate what you're seeing, so what were the color changes that you saw? Why couldn't you say those, right? You see how we have to help our brain make the right observations and make the right reporting.

[WHOOSH]

JESSICA HARROP: OK, so in the final set of cylinders, Dr. Shakhashiri has a mixture of indicators. This created the color changes that occurred as the solution became more and more acidic. There were three changes that we saw. It went from purple to blue to green to yellow.

[MUSIC PLAYING]

All right, that's it for me today. I'll see you next time.