An Introduction to Matter and Measurement

Properties of Matter

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All the world's a stage. Well, to a chemist, all the world's a laboratory. And this happens to be one of my favorite laboratories, a local brewery and pub. Excuse me for a second. It's delicious.

It's here that we're going to begin our journey to becoming scientists and chemists, and the first step is to realize that scientists, from the beginning of time, have tried to categorize the world. And, in particular, what we're going to do is categorize matter, and matter is anything that has mass. This is a very reductionist approach. In other words, break it down into pieces that you can get your mind around. And the first division that we're going to make is the physical state or phase of an object. And three categories are solid, liquid and gas, categories you're perfectly familiar with already, but let's go ahead and show you examples. And these examples are all over the place. They'd be in your kitchen, in your bedroom, wherever. It just happens to be that this is our laboratory today.

So here's our first object. It's a glass. Ignore the liquid inside for the moment right now, and this is what we call a solid. So a glass is a solid. It has fixed volume and shape and, if we turn it over, it's still going to have exactly the same volume and shape. Let me do that for you. I hate to pour away good beer, but excuse me for a second. So now we have a glass, and we could turn it over, we could it sideways, whatever, and it's still got exactly the same volume. Other examples of solids are things like beer spoons, and salt that's used for coating the rim of Margarita glasses, and, let's see, I've got some straws here. These are all examples of solids.

Now let's look at an example of a liquid. So here's a liquid. Here's some water. It flows. And the thing that distinguishes a liquid from a solid is that the liquid has fixed volume, but it doesn't have fixed shape. So it's shape is dictated by the shape of the container. Excuse me for a second. Let me reach over and grab another container. Here's a tulip glass, and you can see that this volume, when placed into a tulip glass, the shape of the liquid is dictated by the shape of the glass. So that's what distinguishes a solid from a liquid.

And now let's draw another beer, because I threw mine down the drain, because a beer provides a nice segue to go from liquids to gases. You know that in a beer there are little bubbles that rise out once you've poured the beer. And those bubbles are a gas, carbon dioxide, and that's what gives it the bubbly fizziness. Same is true of soda water, exactly the same substance gives rise to the bubbles in Coke or Pepsi or whatever. And the thing about a gas that distinguishes it from a solid and a liquid is that the volume and shape of a gas is entirely dictated by the shape of the container. So it doesn't have fixed volume and it doesn't have fixed shape. It's sort of hard to talk about that when the gas is leaving the glass and going out into the atmosphere, because the shape of the container is just the whole planet. But, if we instead consider a sample of gas inside a balloon, and this balloon is left over from a party last night, you can see that the gas on the inside of the balloon adopts the shape of the balloon. And if we change the shape of the balloon, for instance, doing that, then the gas goes along for the ride. In this case, the volume is not even necessarily fixed. It's probable, since we increase the pressure, and you'll understand this relationship later on, increasing the pressure decreases the volume. So the total volume of this balloon has gone down and the gas just goes along for the ride. So it's volume and its shape are dictated by the container. Go through your world and you can categorize it into solids and liquids and gases. You probably already do this subconsciously, I'm sure.

There are other ways that we can divide the world, and we're going to see some of those in the next segment.

Another way that we might divide the world is into mixtures versus pure substances. Let me give you some examples. Here we have a beer, and it's a mixture of various carbohydrates, and carbon dioxide and water. Hopefully, no artificial coloring. Oh, here's another mixture. It's cranberry juice, so it's got some sugars, and Vitamin C, and water and all kinds of different things in it. So what is a mixture? Well, a mixture is something that is separable by a physical technique. And physical techniques are things like crystallization, or distillation, or filtration. For instance, if you wanted to separate the orange bits out of this orange juice, make pulp-free orange juice, we could filter this. We could take a piece of paper, and form it into a cone, and pour this in and we would filter the little bits out, and then it wouldn't be cloudy anymore, because we would have, using a physical method, separated out all of the solid bits. Well, it turns out that even things like water, tap water, are mixtures. This tap water contains water, but it also contains some sodium ions, some chloride ions, probably some dead bacteria, hopefully not too many live bacteria, maybe some chlorine to help purify it. And so to get something that is a pure substance, you typically have to go to the laboratory and make it or buy it as a pure substance. Here I have some distilled, dionized water. So this water was dionized by a process that takes the ions out of it, takes the sodium out, takes the chloride out, and then also it

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was distilled, so anything that's nonvolatile would have been separated from the water as well. And this came from a laboratory. Even something like table salt is a mixture. This happens to consist of salt, which is sodium chloride, but they add something in, probably to keep it from caking, yellow presiative soda. In order to get pure sodium chloride, we'd have to go to a laboratory, and then we would get a reagent bottle that had pure sodium chloride in it. So much of what occurs in your world is a mixture.

Can we subcategorize mixtures into other subclasses? And one way to divide mixtures is whether they are homogeneous or heterogeneous. And a homogeneous mixture is something that's uniform throughout the bulk. So going back to our cranberry juice, cranberry juice, except for the bubbles that we see up around the top, is uniform throughout the bulk. And we call that a homogeneous mixture. The beer, with the exception of again the foam that's on the top, and these drops on the outside, they're condensation, but that's another example of a homogenous mixture. How about a homogenous solid mixture? Well, this salt is a homogenous solid mixture. It looks like a white solid, but you can't see where, and we could not determine, measure really, but where this other contaminant is, this yellow presiative soda, so this is what we would consider a homogeneous solid solution. Gold, 14 karat gold, is another example of a homogenous solid solution.

How about a heterogeneous solid solution? Well, or a heterogeneous mixture, excuse me. Here's an example. This is a Balance bar and it's got various bits of whole grains, and nuts, and dried fruit. And this is clearly a heterogeneous mixture. It's clearly identifiable where the nut starts, and where it ends, and where a piece of dried fruit begins and ends. So we could separate the heterogeneous mixture into its components just by looking really closely. And that's what we distinguish between a heterogeneous mixture and a homogeneous mixture.

All of this, again, is another way that we can separate those objects, that matter that is in our world and, in the next segment, I'm going to show you yet a third way, something that's more intrinsically chemical than these ideas.

We're here in the brewery portion of the building to finish our discussion of categorizing matter. And what we're going to do here is illustrate the idea of subdividing pure substances into two subcategories that consist of elements and the one that consists of compounds.

Now, elements are the fundamental building block of matter. And we're not ready to really talk about what that fundamental building block is, but you can imagine that there is such a thing. Now, if there is such a thing, we can categorize substances into those that consist of a single building block versus those that consist of several different kinds of building blocks. Let's look at an example. And an example would be this copper kettle here, in which the grain and water are cooked together. If this is pure copper, then it consists of a single type of building block. And it happens that that kind of building block is called a copper atom. Now, if we look over here, we have a cylinder of pure oxygen. And a cylinder of pure oxygen consists of building blocks that are oxygen atoms. So all of the gas on the inside, obviously not the container, but the gas that's inside consists of a single kind of building block, what we call an oxygen atom, and then the oxygen atoms are put together to form what we call oxygen gas.

Let's take a look at this over here. We have a gallon jug, and this gallon jug consists of or contains a solution of phosphoric acid. And phosphoric acid consists of the hydrogen building block, and the phosphorus building block, and the oxygen building block. And then, because it's a solution, there's also the building blocks of the water that make up the bulk of the solution.

Now, all of this discussion about compartmentalizing might seem like a waste of time, because you were probably already familiar with the idea of a solid, a liquid, a gas, a mixture, elements and compounds. But why it's powerful is that in what you're going to view after this, and really the rest of this product, what Professor Harmon and I are going to do is compartmentalize. You're going to see a unit on solids, and liquids, and a unit on gases, and a liquid on solutions. So this is really the way we break up the pieces of the ideas that we're trying to convey to you so that they make more sense, so you can get your mind around it so that we can have a discussion about the world around us.