

Stoichiometry

Mole Theory

Introducing Conversions of Masses, Moles, and Number of Particles Page [1 of 2]

My guess is that you've all seen a periodic table at some point, something that looks like this. It's got the elements on it and there are typically numbers above the top, and then another set of numbers below. And my guess is you're not entirely clear on what those numbers represent. So that's what this lecture is all about.

Let me take a little piece of the periodic table. Here's just fluorine. Nine is the atomic number, F is the atomic symbol, and the numbers that appear below the fluorine, this is the molar mass. That is, this is the mass of one mole of these atoms. Now, you might think, "Why do we need something like that?" And the answer is we define the mole so that we can have a connection between the atomic molecular scale and something that we could measure in a laboratory. In other words, it's hard to count particles, but, using the concept of moles, we can count particles effectively – and I'll show you that in a second – by just weighing. And, while I'm on the subject, let me point out that, when I say "weigh", I really mean determine the mass. So weight and mass are not exactly the same thing. And when I say "weigh", which is sort of the way scientists talk, what they really mean is determine the mass. The unit of mass is grams, weight is actually a force, but we won't go there. Just remember that this represents grams.

All right, so what is the definition of the molar mass? The molar mass of anything is the mass in grams of one mole of that element. And it could be compound, as well. So the molar mass of a compound would be the mass in grams of one mole of that compound. So we just looked at fluorine. The molar mass of fluorine is 18.9984, and then units on molar mass are grams per mole. And the molar mass of potassium is 39.0983 grams per mole. Now, the really cool thing about molar mass is they're additive. So, if we wanted to calculate what's the molar mass of potassium fluoride, 1 mole of potassium fluoride represents 1 mole of potassium and mole of fluoride in exactly the same way a dozen shoes represents a dozen shoes and a dozen shoe strings. A mole of potassium fluoride represents a mole of potassium and a mole of fluoride, so that the mass of one 1 of KF is just the sum of 18.9984 and 39.0983, which is 58.0967. And again, the units are grams per mole. Let's look at a little more sophisticated example.

What is the molar mass of ethanol? Ethanol is grain alcohol. This is what you drink, if you're old enough. And to calculate the molar mass of ethanol, we add 2 times the molar mass of carbon, because a mole of ethanol contains 2 moles of carbon, plus 6 moles of hydrogen, so 6 times the molar mass of hydrogen, plus the molar mass of oxygen. We look up each of these numbers in the periodic table. Carbon is 12.001 grams per mole. Hydrogen is 1.0079 grams per mole. Oxygen is 15.994 grams per mole. Add these all up and the molar mass of ethanol is 46.069 grams per mole.

So here's our sample of ethanol that I showed you before, and I've colored it, because it didn't show up really well on the film before, and now it's sort of, well, purple, I guess. Of course, ethanol is a clear liquid, but, because we added some color, it's now colored, so you can see it. And how do we determine that this was 1 mole of ethanol? We weighed it. We weighed just the liquid, and the liquid has a mass of 46.069 grams. And so, it represents 1 mole of ethanol.

Now, just as we could convert from moles to numbers of particles, we can write down a conversion factor that allows us to move from mass to moles, or from moles to mass. And, once again, what want to do is create a factor of 1, because remember, you can always multiply by a factor of 1. So 1 mole of fluorine represents 18.9984 grams of fluorine. We do exactly the same trick we did before. If we divide both sides by 18.9984 grams of fluorine, we get this fraction is equal to 1. And if we divide both sides of this expression by 1 mole, we get that this expression is equal to 1. So these are our two conversion factors. And remember, you can always multiply an expression by a factor of 1, and what we want is we want the units to cancel out after we do the multiplication, so that we get our answer in the units that we desire.

How does this work? Here's a question. Actually, let's answer this question first. Suppose we want .9628 moles of iron and ask how much mass does this represent or, if we were going to weigh the sample, how much iron would we have to weigh out? Well, what does your intuition say? Your intuition says that we should end up with something, since this almost 1, we should end up with something that's really close to the molar mass of iron. We look up the molar mass of iron – so let's see, mass of iron. This is the mass that we want and it's equal to the moles of iron, 0.9628 mole, times – and we need a conversion factor. Moles is here, so we want moles in the denominator, 1 mole. And, of course, this is 1 mole of iron. What does 1 mole of iron weigh? Well, we look it up in the periodic table and we find that the molar mass of iron is 55.845 grams or, another way of expressing it is that the molar mass is 55.845 grams per 1 mole. This is unit of 1. It's a conversion factor. If we multiply through or multiply this out, cancel the

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units, we get 53.77 grams, and this is the mass that is equivalent to .9628 moles of iron. So this is what we would weigh out if this is what we desired. Simple enough.

Let's look at it in the other direction. How many moles of ethanol are there in 57.3 grams of ethanol? And then ask the second question, how many molecules does this represent? How do we get from mole? Well, we can get from grams to moles using the conversion factor. Moles is equal to 57.3 grams times – what do we use here? Well, we want grams in the denominator and we want moles in the numerator. So 1 mole – and you'll recall that we calculated the molar mass of ethanol a little bit ago and it was 46.069 grams. So this is 46.069 grams per mole of ethanol. And we could write "of ethanol" and "of ethanol" here, but I think you understand what I'm trying to say. So if we multiply these two things out – and let's go back and use our intuition – if we had this mass of ethanol and 1 mole weighs this much, do we expect a number that's close to one and, if so, is it going to be a little bit bigger than 1 or a little bit smaller than 1? And the answer is this is clearly just a little bit more than 46, so we're going to be looking at a little more than 1 mole, and if we multiply this out, canceling the units, we get 1.246 mole. And this is moles of ethanol.

Now, how do we convert this to moles of particles or moles of molecules? We write molecules is equal to the number of moles we have times Avogadro's number. Avogadro's number is the thing that relates moles to numbers of particles. So in the denominator we want moles and in the numerator we want molecules. Remember, this could be atoms, it could be molecules, it could be grains of sand, whatever. Mole is the number of things and this defines what the number of things is. Now, we cancel out the moles and multiply this out and we get 7.503×10^{23} molecules.

Okay, so what's the use of a mole? It allows us to connect the atomic molecular scale with a macroscopic scale. In other words, we can weigh out 57.53 grams of ethanol and know that it represents 7.503×10^{23} molecules. We can't actually count molecules, but we know, because of this conversion factor, that we can get the number of molecules in the container by just determining the mass. And then finally, determining the mass similarly allows us to determine the number of moles, if we know what we're talking about, if we know what the compound is. And what we're going to see is that learning something or knowing something about the number of moles is going to be really useful when we're calculating things like percent yield and expected yield, and those sorts of things.