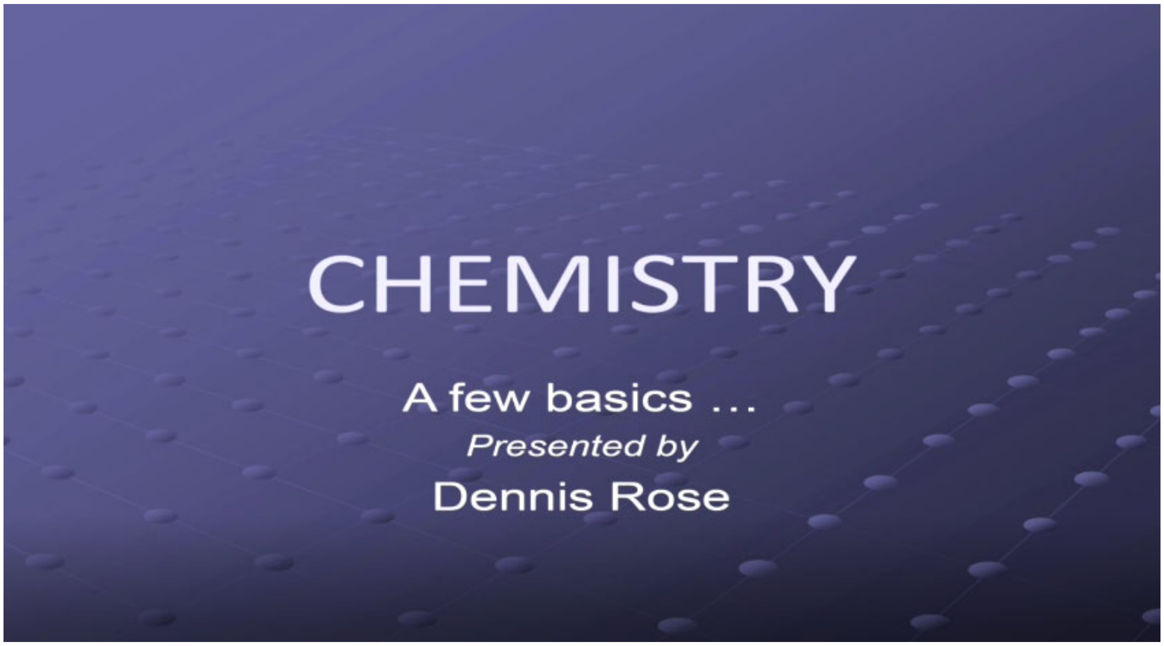
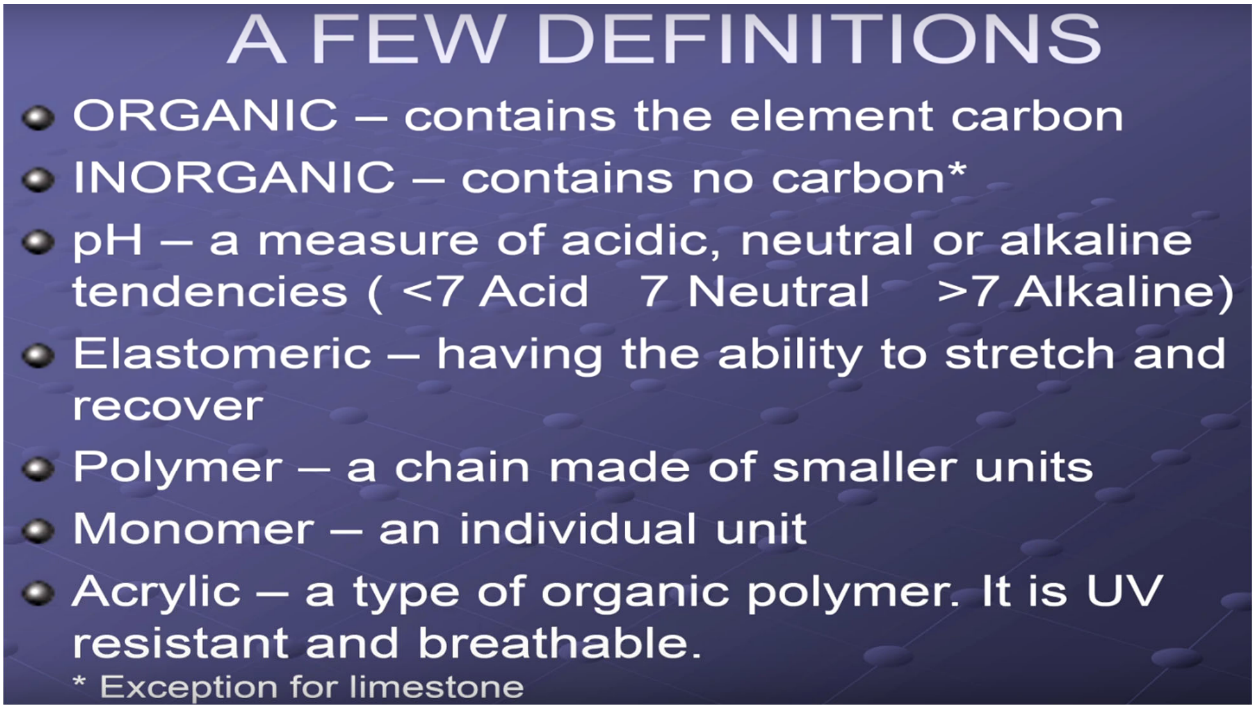


The reason for chemistry as a topic in our seminar, a format in series, is because it was the advent of invention and proliferation of the use of polymers in our society that enabled the new systems, such as exterior insulated and finished systems (EIFS), direct applied systems (DEFS), and our ICF systems. Almost all of the new cladding systems are possible only because of the new construction polymers that have come out.

I believe it's important for you as inspectors to know about the properties of these different polymers, why they're used the way they are, and, more importantly, some of the basics and a few of the definitions that will lead us into a discussion about this polymer chemistry. So, if you'll bear with me for a little bit, this is not a terribly long presentation, but I promise to make it interesting for you.



We are going to start with a few definitions, though, and that is not the interesting part. A few definitions:

Organic: The word organic in our public sector, we have our own definition of the word organic. It is a healthier, pesticide-free, and antibiotic-free food, but in chemistry terms, organic means it contains the element carbon.

Inorganic: Conversely, inorganic means it contains no carbon.

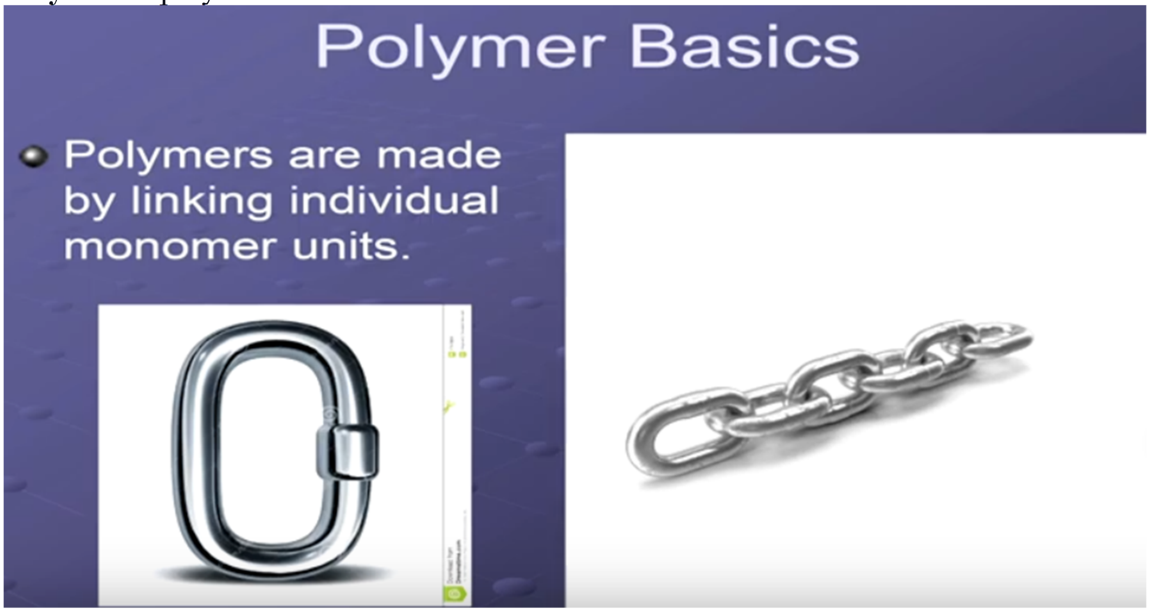
pH: this is something we should understand. We deal with it all the time, but there's one factor that I want to bring home. We know that it is a scale, a numeric scale; we know that 7 is approximately neutral, it is about the pH of our own blood, and it is a measure of the acidity or alkalinity of liquids, most often aqueous liquids or water-based liquids.

The thing I want you to take home with you is that it is not a linear scale; it is a logarithmic scale. What do I mean by that? Let us say that we have a weak vinegar solution of about a pH of six (slightly acidic), and we add more acid to it and bring it down to a pH of five. That is ten times more acidic. We add more acid and bring it to a pH of four, that's 10 times 10 times more acidic, or 100 times. We go to three; that's one thousand times versus the pH of 6.

Keep in mind that when you get into these extremely low numbers around pH of two or three or very alkaline numbers around 13 or 14, you are dealing with extremely aggressive chemicals. When we talk about lime in Portland, cement that have pH's up around 12 and 13; these have a great power to do some type of caustic burning damage.

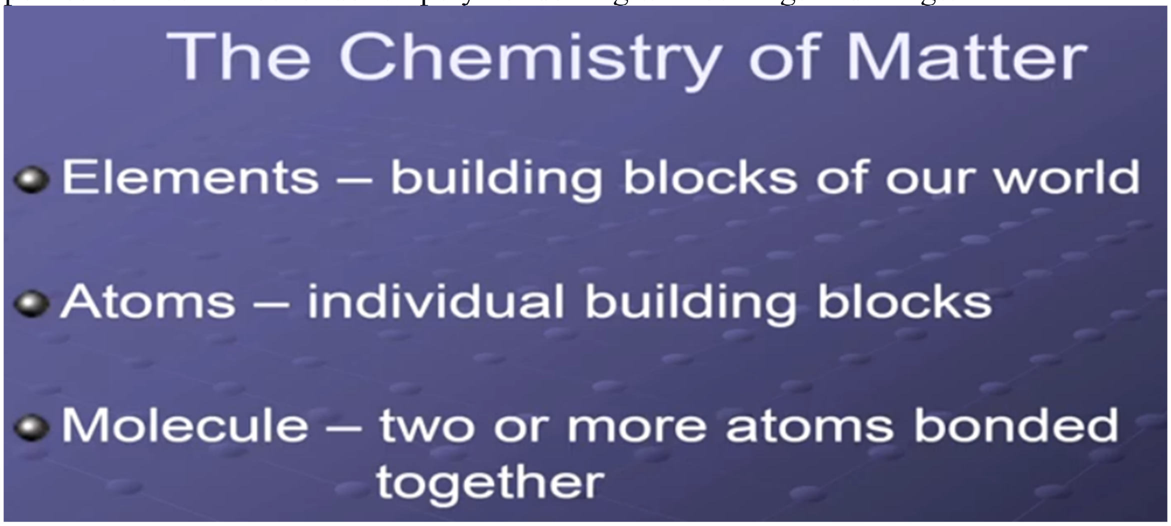
Elastomeric: We throw this term around, and that simply means the ability to stretch and recover. Important, in several properties of coatings where we want the coating to be able to bridge some crack movement, there is a type of crack protection that Rohm and Haas came out with, it is an elastomeric coating called Zero Point Crack Protection. If you coat the wall and a crack develops later, it'll still heal that crack with this ability to stretch and recover. But it's most important in our caulk sealants, which seal our penetrations; these are our isolation joints with the ability to stretch, recover, and be waterproof.

Polymer: a polymer is a chain of smaller units. What are the smaller units?



Monomer: The smaller units, we call them monomers. One individual unit is a monomer.

Polymers (continued): And let us talk about polymers. One type of polymer we talk about is the acrylic class, which is very commonly used in our construction industry. We will get more into this later, but it has some nice properties of being ultraviolet-resistant and breathable, which means it allows water vapor to transfer through it. It is also very weather-resistant. These are nice properties to have in a construction polymer dealing with coatings and things.



Elements: Elements are the basic building blocks of our world. They are the little individual things that we can use purely as an individual element or we can combine them together to make all the materials of the world around us.

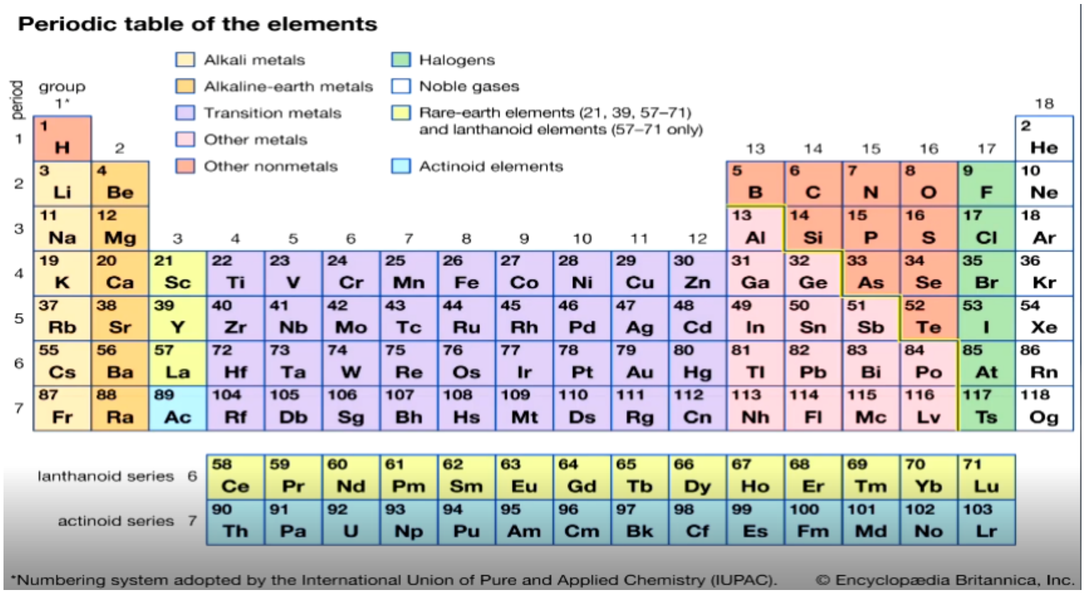
Atoms: An atom is an individual building block. They are our little tinker toy things that we can extend. So, you might ask, how big is an atom?

Well, if I had an orange here and I wanted to observe an atom, I would need to blow this up to about the size of the Earth, which is about 5 billion times magnification. Then, the atom would be the size of an orange that we are looking at. We look at it, but what do we see? It is kind of this wispy little cloud in our hand.

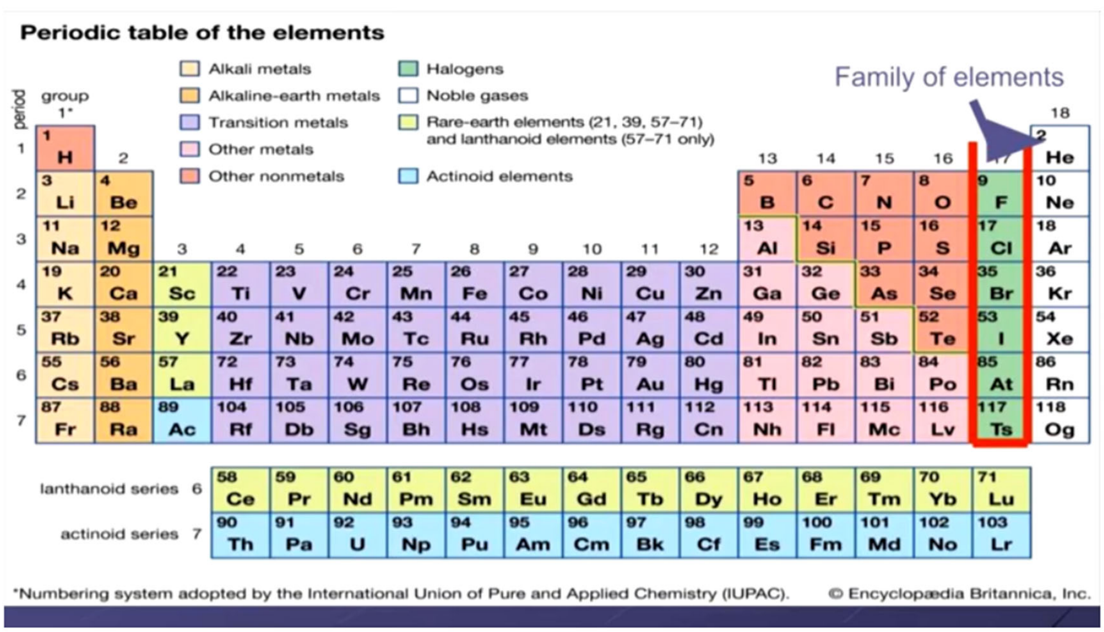
Well, that does not look very solid; let us take a closer look. We blow this up to the size of a 14-story building, and what we see is nothing. Looks maybe like a little ghostly gray fog. But we take a stronger look, and we go close, and in the dead center of the 14-story building, we see a grain of sand, and that is the nucleus. And then around us is this wispy cloud, and we freeze-frame it and look closely. What is this cloud made of? This really fast-moving little particle that is smaller than the size of a wisp of dust. It is an electron. Do we ever deal with electrons? Who uses electricity every day? All of us. So, electrons, that is what we are dealing with around the atom. We are looking at this 14-story building, and we realize it is almost all empty space, and that is the fact of our three-dimensional world. What is there, and the fact that my hand will not go through this, is the electromagnetic repulsive force from this electron sphere.

Now that we are dealing with chemistry, it is this electron sphere that is interacting with our other building blocks that will stick them together. When we stick these atoms together, we make molecules: the electrons are going to go one way or the other, or they are going to be shared equally. If they go one way or the other, we end up with a polar molecule. That means it is now charged; it has a little electrical field. One end will be positively charged, and the other part will be negatively charged. If it is shared, it is going to be neutral; there is no charge, and that is going to be like our fats and oils. Our polar charge is going to be like salt and acids and bases, like sodium chloride. So that is how you wind up with this charge property.

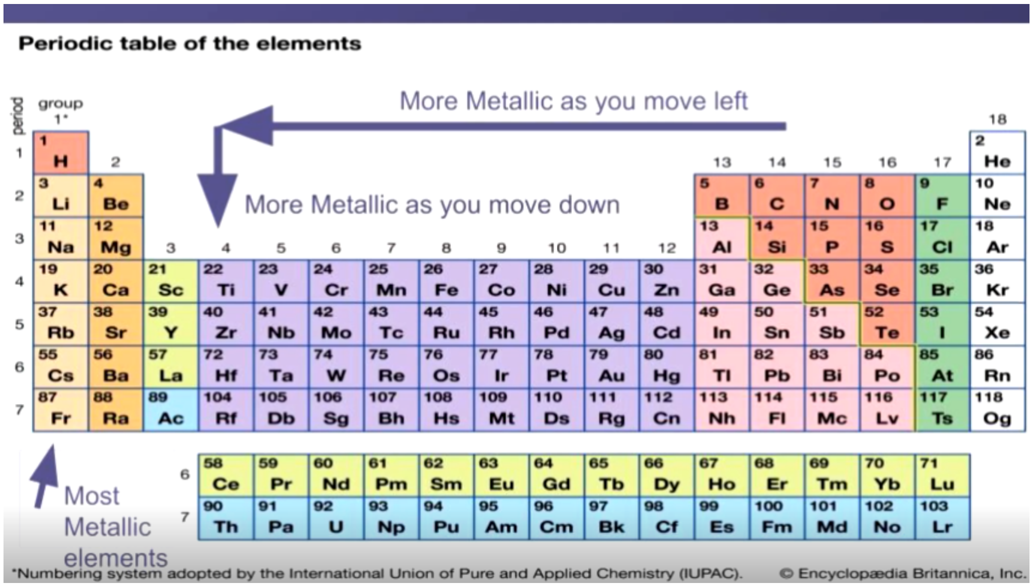
Periodic Table: Here are our building blocks; there are two things I want you to remember about this to take forward in life; in chemistry, there are two simple things: the position of these elements, and the relative position on this tells you a lot about their properties. What do I mean by that?



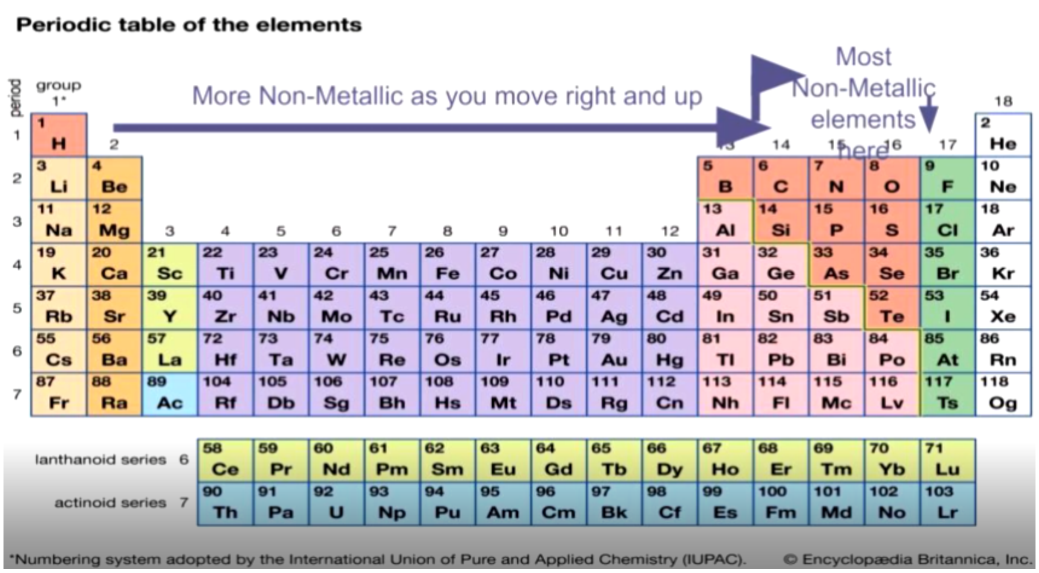
These vertical columns are called families, and a family of elements all have similar properties. They are not exactly the same, but they are very similar. In this family down here we have fluorine, chlorine, bromine, and iodine; this family is called halogens, and they all act very similarly. In fact, when we disinfect swimming pools and spas, we not only can use chlorine, we can use bromine, and we use chlorocarbons and fluorocarbons for refrigerants, so they all are similar in the way they act.

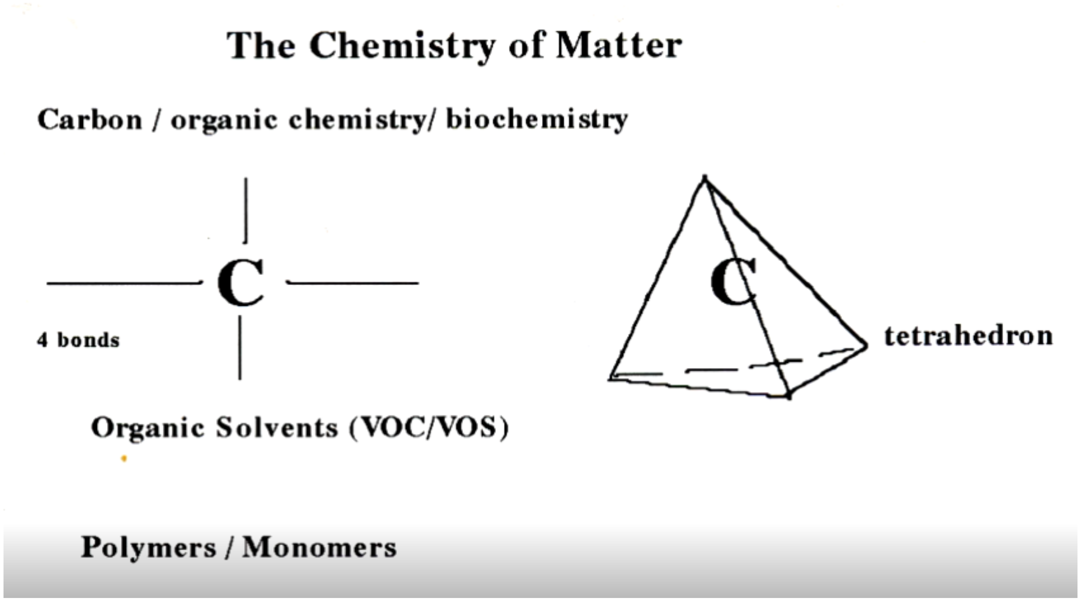


The other thing to remember is that as you move to the left side, you become more metallic. Conversely, as you move to the right side, you become less metallic, more non-metallic, and as part of that, as you go from top to bottom, you become more metallic, and as you go from bottom to top, you become less metallic. Now, the thing to remember is you have metallic versus non-metallic; the most metallic elements are over here.

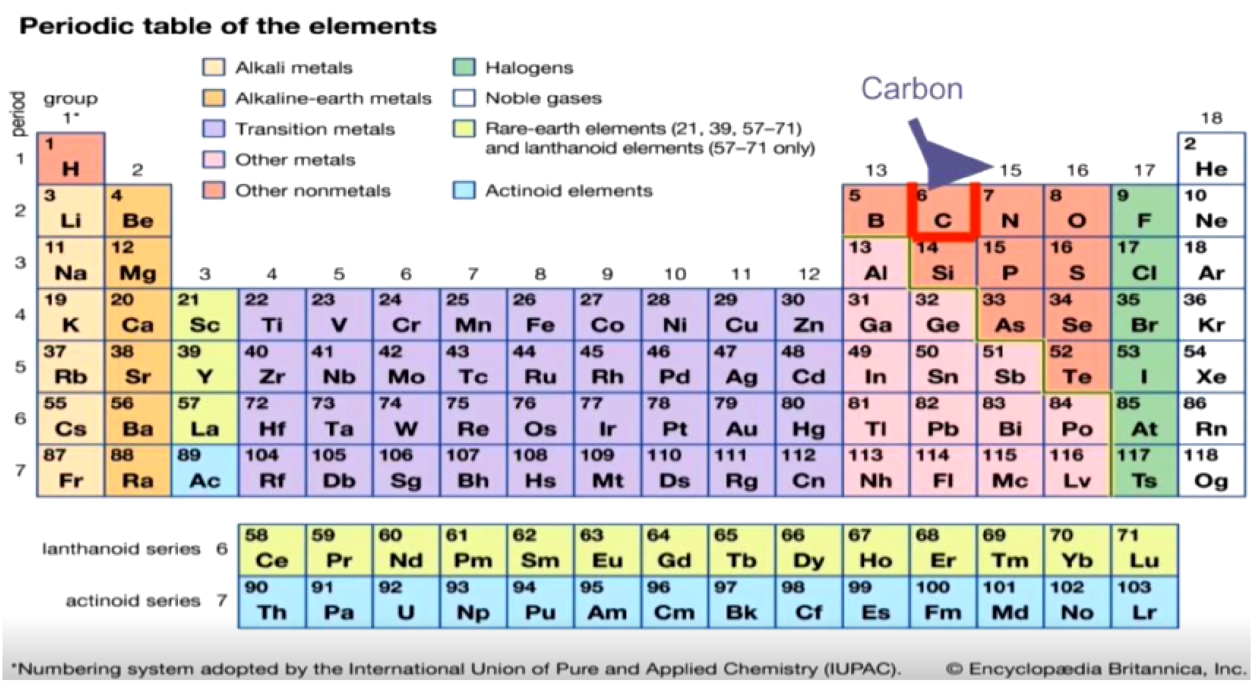


The least metallic and most non-metallic are over there. These are extreme opposites, and you may gather on your own that if you react to one of these with one of these, you are going to get a very polar type of molecule - a salt, an acid, or a base. Sure enough, we will put sodium with chlorine and we will get salt. And put it in water, and it becomes ionized right away. Now, in the middle here, we have our elements that are more sharing. They are not sure they are metal; they are not sure they are non-metal.

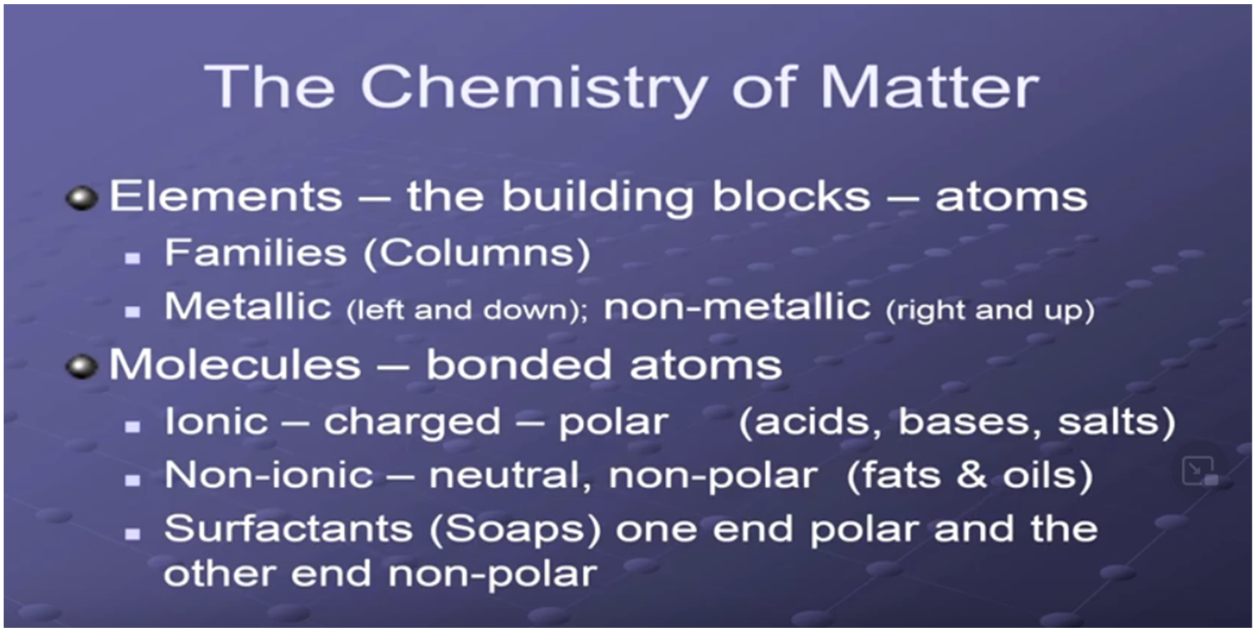




Carbon is our brainchild in this area. Carbon does these sharing nonpolar bonds, and it loves to link with itself, and that is the basis of our polymer chemistry and it is also the basis of our life forms on this planet. Carbon is life.



Right below carbon is silicon. It is slightly more metallic, which is why it is used in the Silicon Valley. It can also form polymers, just not life forms on this planet as far as we know yet. So that is all I want you to take with you regarding the periodic table.



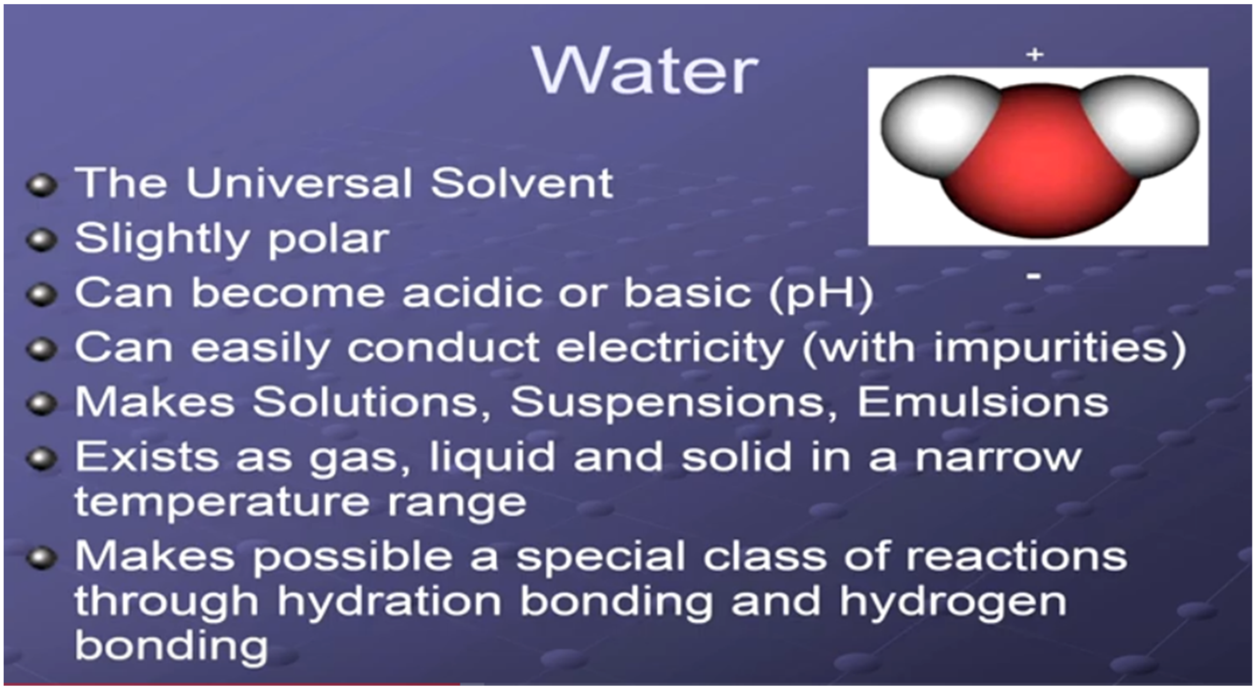
Review:

Elements: Elements are the building blocks. Families are all similar. Metallic to the left and down, non-metallic to the right and up.

Molecules: Molecules are bonded atoms. By the way, oxygen in our atmosphere is O2; is it a molecule or atom? Molecule: correct. If it were a single oxygen, it would be nascent oxygen, but diatomic oxygen in our atmosphere is a molecule. Two or more of anything, even the same thing, is a molecule.

> Ionic, charged, or polar are three different words that are used for the same thing. That is where our electron buddies are on one side or the other: acids, bases, and salts.
>
> Non-polar, Ionic, or neutral are all shared, and these are our fats and oils, non-charged.
>
> Lastly, the surfactant is a collapsed term from the words surface, active, and agent. What a surfactant is, we are going to cover in a couple of more slides, but a surface-active agent is a long molecule that has a polar end on it, and then it has a long non-polar tail, so it is friendly with the Hatfields and McCoys at the same time. You can bring them together, and everybody gets along. The oils hang around the non-polar end, and the polar molecules like water hang around the other end, and all of a sudden, instead of water and oil, we have an emulsion; that is how that works.
>
> Why that is important is because our polymers, when we make them, buy them, and use them, are in this milky form before they dry and become clear; they are emulsions.
>
> What do we use every day that is an example of an emulsion? Milk. That is milk fats in a water emulsion. It is all accomplished through surfactants.

We can teach an entire course on water, but we are only going to spend like two minutes on it.



The molecule of water looks like a Mickey Mouse hat. We know it is H2O; it has two hydrogens that are slightly offset to one side, which makes that side a little bit more positively charged, and the bare oxygen down on the bottom is a little bit more negatively charged. So, we have a **slightly polar material.**

In chemistry, if we were on a quiz show and they said, "Can you tell us what is the universal solvent?" Well, we would answer "water," and we would be right and win that prize. It is called the **universal solvent.**

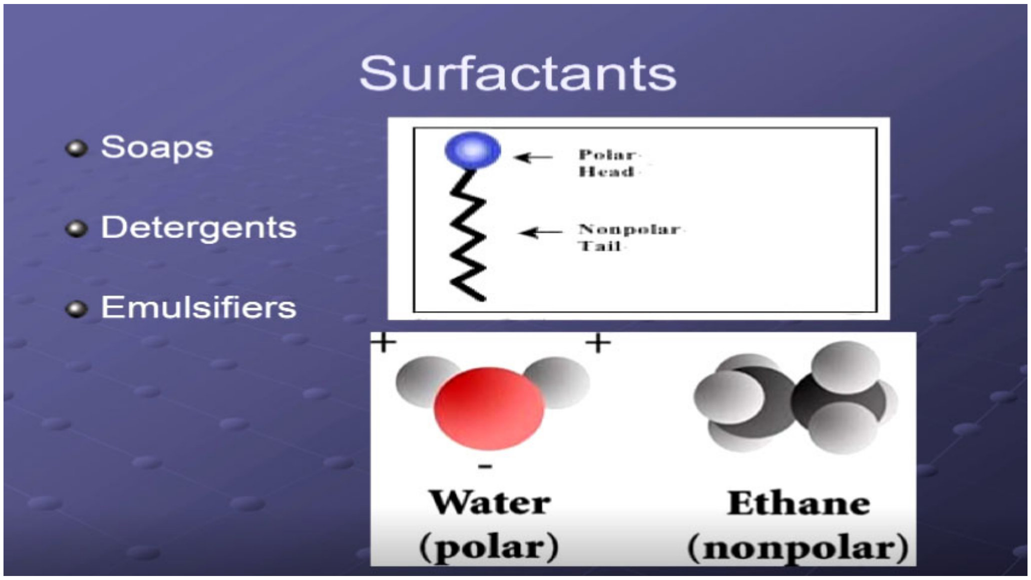
It can become acidic or basic, depending on what we mix with it.

It can easily conduct electricity with impurities. Distilled water does not conduct electricity. You need ions in there for that to happen.

Make solution suspensions and emulsions; we have already discussed that they exist as a gas, liquid, and solid in a narrow temperature range, which is wonderful for what we do on the planet and for life support here.

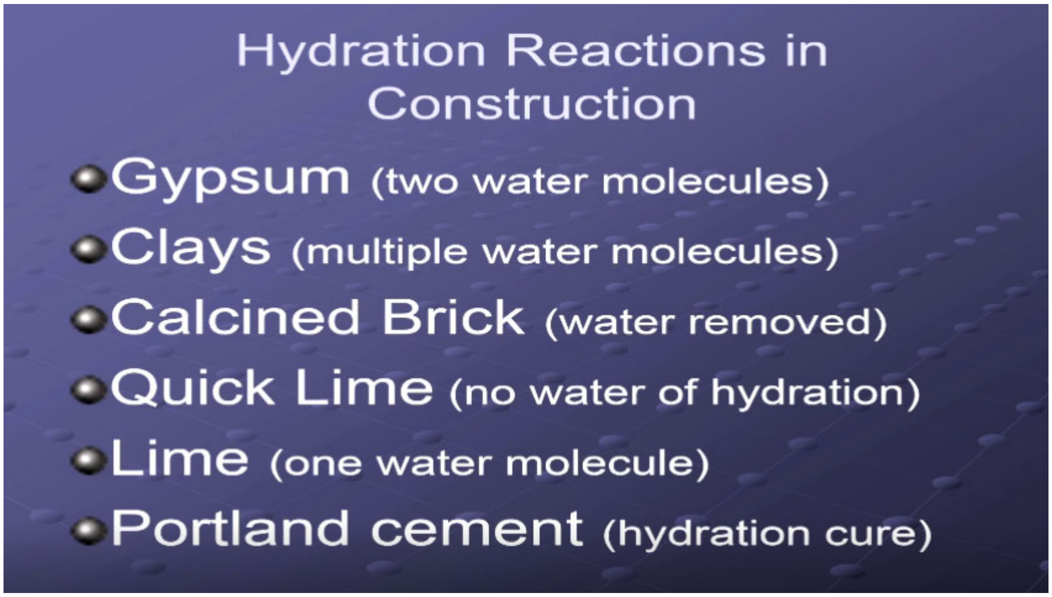
It also makes possible a special class of reactions through what we call hydrogen bonding or hydration bonding, where water can change molecules' characteristics without being destroyed. It still exists as water, loosely bound. These are called hydration reactions.

Let us go a little bit forward.



This is back on the surfactant again. It is a good picture of an illustration of a surfactant soap, molecule, detergent, long nonpolar tail, and polar head, and for water and oil together, we can bring them together that way through this intermediary chemical.

So, let us talk about hydration reactions. These are extremely important in our construction industry materials; extremely important.



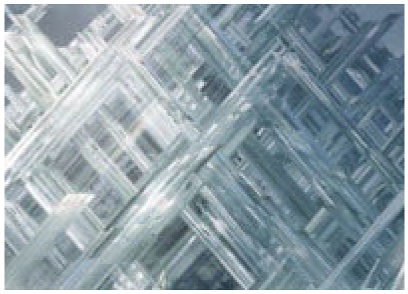
Gypsum: Gypsum is one of the largest used materials in the construction industry. It is present in most of our sheathings in drywall and our exterior sheathings such as siliconized core gypsum sheathing, like DensGlass, for example, and gypsum is calcium sulfate with two water molecules: dihydrate. The interesting thing about that is that gypsum has an extremely good fire resistance, so gypsum sheathings of proper thickness are the materials that give walls the one- and two-hour ratings that are necessary to satisfy building codes for certain types of buildings with human occupancy. Engineers and a few chemists decided that one of the reasons this is possible for gypsum is because of these waters of hydration. As the temperature climbs and the fire is burning, the gypsum absorbs that energy and releases its water molecules at a high enough temperature. But in releasing the water molecules, it literally absorbs some of that energy and that energy is heat. So, it is robbing heat from the fire to do that. Then, once the molecules are released, we have this steam vapor in the air, and now the fire has to get rid of that, and it carries away more energy. So, in essence, these fire ratings are a fire time duration. It is how long this rage is protected by this wall system. That whole process buys the time to get these ratings. Are we cool with that? It is kind of neat, right?

Clays: Clays have multiple waters of hydration. We know how clays work; they are more loosely bound, and clays will absorb water, they will swell, and a lot of different varieties of clays, and then they could dry out, and you will see them crack and stuff. But if we have a wet clay and we form it into a block and then take it to high temperature and burn it, calcine it, we make brick. It will no longer rehydrate, but we build with it and we have a nice, firm, fireproof building material.

Quick Lime: Quick lime is calcium oxide that is not experienced very much in construction. You can buy quick lime. Quick lime is extremely alkaline. It is up around a pH of 13. It will burn you. It reacts with water and gives off heat; it is an extremely reactive alkaline material. Normally, quick lime is slaked, which means that it has water absorbed on it, which is one water of hydration. The lime that we normally deal with, mason's lime, horticultural lime, and agriculture lime, is still alkaline but not as reactive; that's one water of hydration.

Portland Cement: Another big product that is a hydration cure is Portland cement. Of course, Portland cement plus aggregates and extenders, we have stuccos, plasters, and concrete. This is the largest manufactured-produced material on the planet per capita. There are multiple tons of Portland cement and, by extension, concrete and stuccos, produced per man, woman, and child on this planet, more than any other material made. Yet, ironically, very few people know what it is, how it is made, and how it works, and I find that a sad statement about our education system. We exist up here in the higher Tech and we know so little about the basics. Well, we are fixing some of that right now, right?

Portland cement actually has a very high component of quick lime in it, calcium oxide. In addition, it contains some very active aluminum and iron silicates and a lot of other minerals. It is a hodge-podge of minerals. It is ground after it is made in a kiln; the clinker is ground to a very fine powder, but when it sees water, it emits, and the hydration reaction immediately begins to create an expansion process that is in the form of rhombic crystals. The rhombic crystals, you can watch this under a microscope, grow out, and if you have seen the Superman movie. He has this Fortress of Solitude where these rhombic things are growing out of the ground, and they all interlock to make this big fortress; that is what Portland cement looks like as it is curing. As these crystals interlock with one another, you go from this plastic putty that can take any form and, as it sets, is an extremely hard, fireproof, durable, microbiological resistant, freaking awesome building material; that's Portland cement in our plasters.

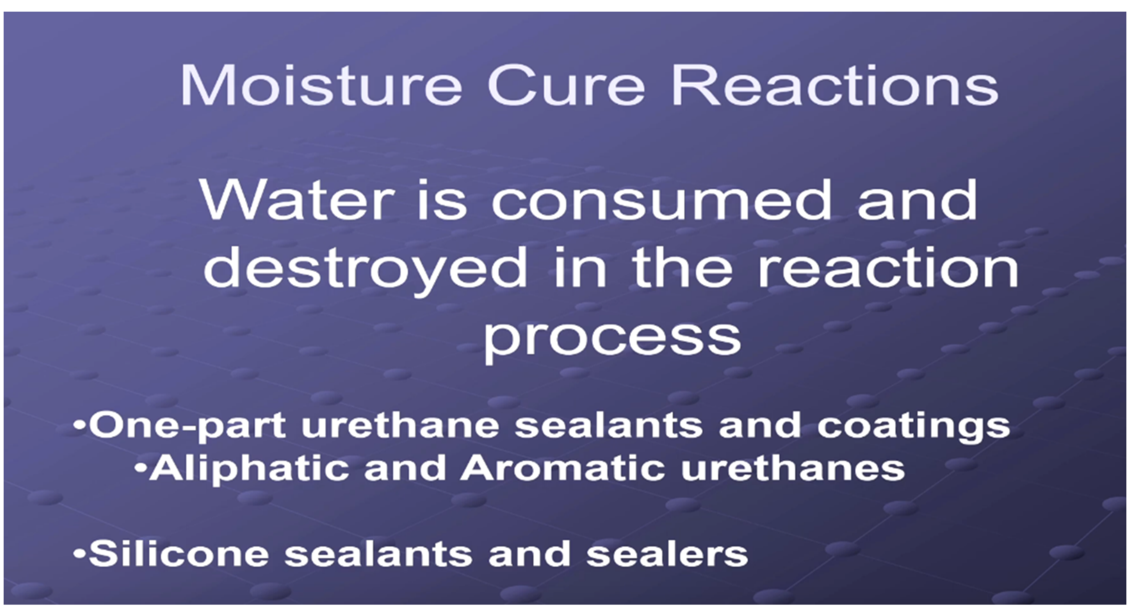
 

With the Advent of polymer chemistry, we can add one property to Portland cement that it doesn't have. If you were doing a thin coat of Portland cement, what would be that one property that you would add to it that does not exist?

> *Flexibilty. Yes! Raise your hand. Who said that? Oh, dude. You are one of the instructors. I was looking for, okay, all right. I really hate it that I have got to give you a prize. All right. Yeah, I have got a prize up here for you. I am going to give you a wet mill gauge.*

The polymer adds resilience and a little bit of elongation, just a tiny bit of flexibility to Portland cement. So, I have got an EIFS with the Portland cement base coat and the mesh, and normally, Portland cement, when you mix it with water and let it dry out, if you were to bend it, it would break. But with polymer modification, look what we have now. Our board is breaking, but not our coating. We have resilience now, and that makes this whole type of thing, with the polymer in there, makes this whole thing possible.

Moisture Cure Reactions: In the hydration reactions, the water is not destroyed; it links there, and there is a loose bond that alters the properties of the molecule, but the water stays intact. If you put energy back into it, you can get the water back. But in moisture cure reactions, the water is destroyed. It is gone; it is cleaved. In the construction of products, we have a couple of moisture cure reactions that we deal with all the time.

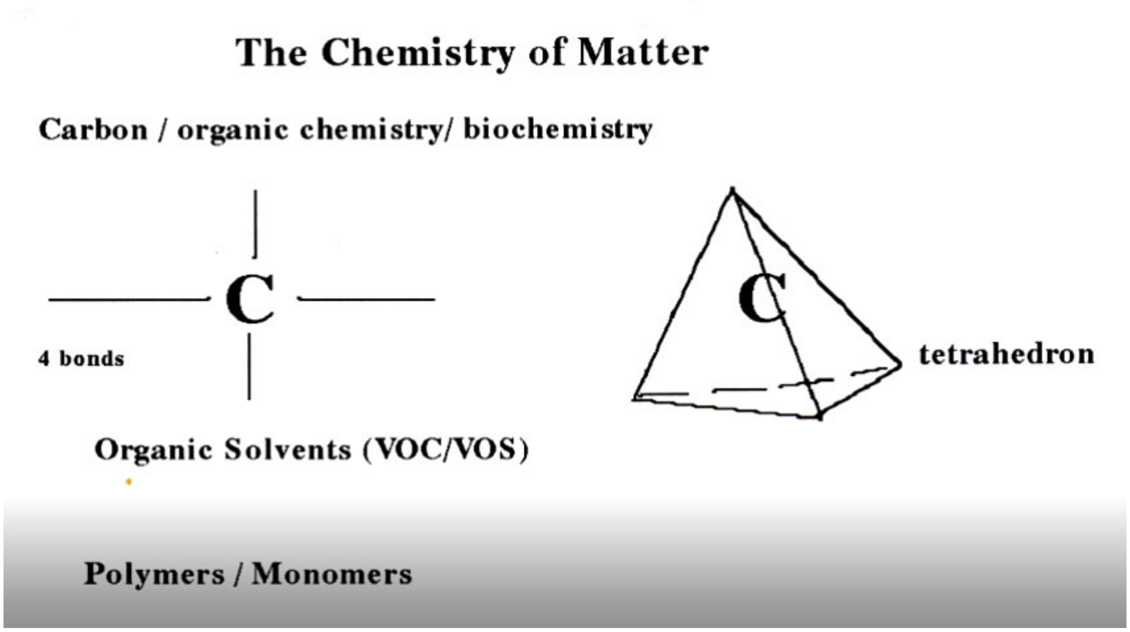


The first is with these one-part urethanes, you can get coatings, but there are a lot of one-part urethane caulk sealants, and they use moisture in the air to polymerize and cure. Now, with urethanes, keep in mind that there are two types. Now, what I am about to tell you is worth the cost of admission just by itself.

> **Aliphatic urethane:** So, the first type is an aliphatic urethane. That is a mouthful, but all that means it is straight chain carbons. Straight chain. No double bond, no fancy rings. Straight chained, almost as if you had a straight chain oil. Aliphatic: aliphatic urethanes are UV resistant. They are more expensive to make, and they are harder to find, actually. They are more difficult to make, and they are more expensive when you go to buy them, but they are UV resistant.
>
> **Aromatic urethane:** The aromatic urethanes have cyclic double-bonded ***ring Benzene rings and all kinds of Napa rings*** as part of their chain. They are a lot easier to compound and formulate with, and they are not UV-resistant. Mostly, you will get these aromatic urethanes. They will try to protect them by putting in a lot of pigment to block the ultraviolet light, but you are better off with the aliphatic ones if you can get it.
>
> **Silicone:** Silicone sealants are always also moisture cure reaction, so that is destroying the molecule. It is using moisture out of the air.

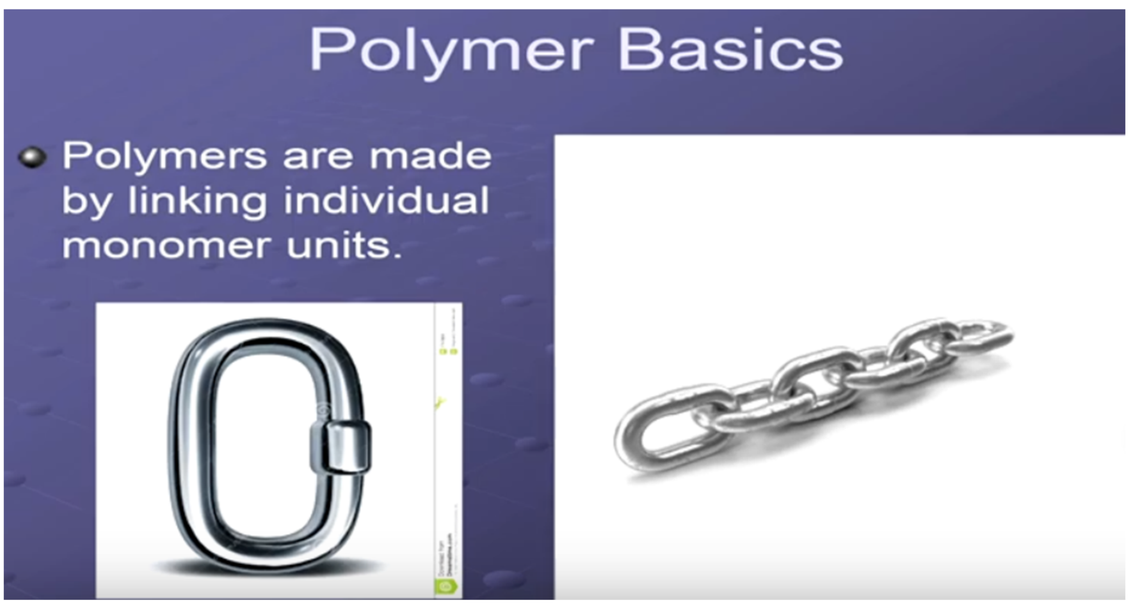
One last thing about these types of moisture-cure reactions is the following. If you put your sealant over a wet surface and you have too much water available, you will wind up with blisters because you get off-gassing of by-product gases like carbon dioxide, and you will wind up getting a failed sealant. So, it can't have too much moisture when applied. Conversely, if it is totally arid, you have very, very low humidity, these things are going to have a difficult time curing. It is going to take quite a while.

The Chemistry of Matter: Carbon



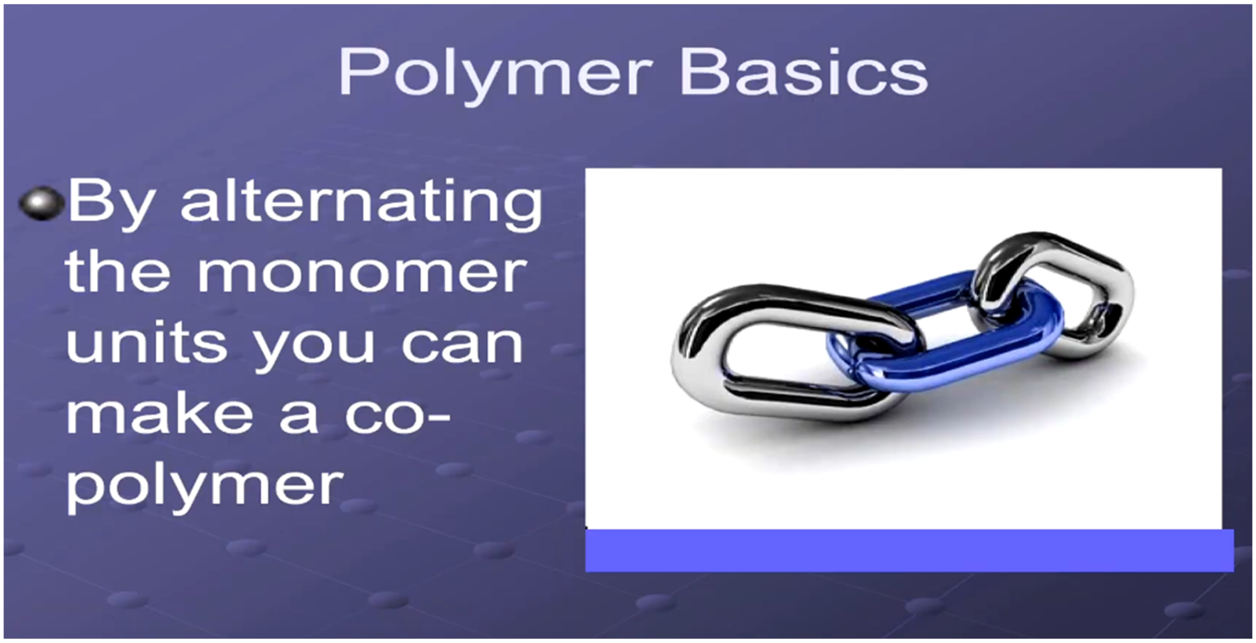
Carbon is the basis of our polymer chemistry, and carbon has four bonds; it likes to share; if I am a carbon atom, I look like this in three-dimensional space. The angles of the bonds go off in a tetrahedron, but because I cannot make that yoga pose, I am just going to do it this way. This makes everything possible. It is the chemistry of life and things like that.

Polymer Basics:

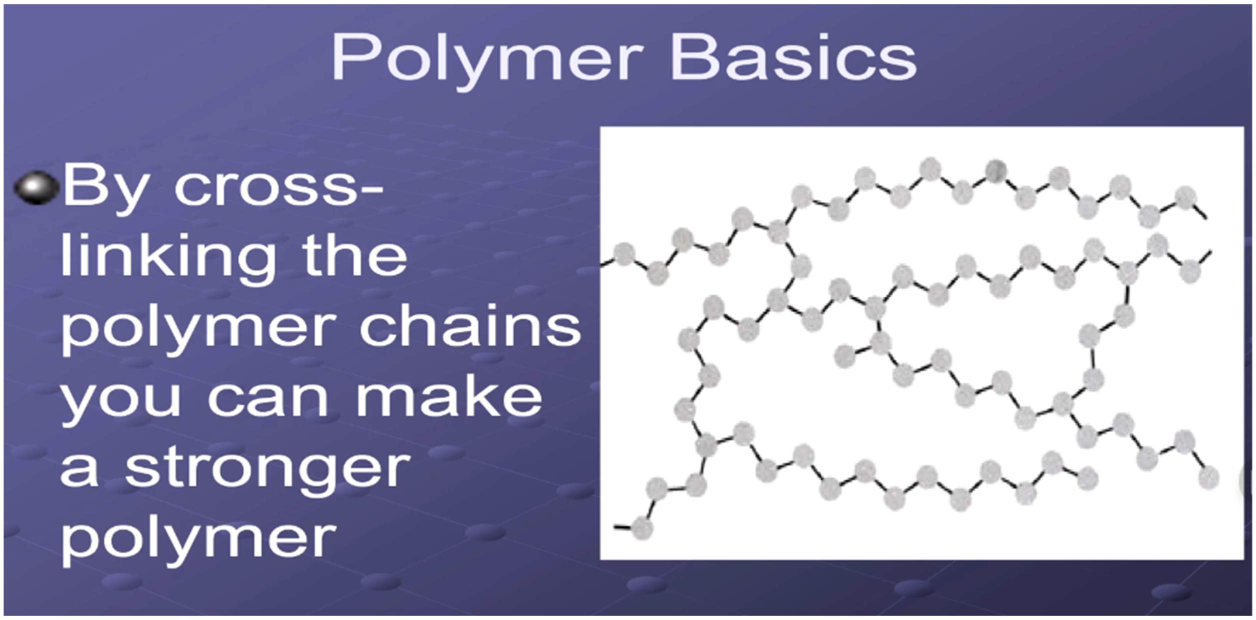


Let us talk about polymers and monomers first. Remember we said that a monomer is an individual unit, and if we link these units together like a chain, we make a polymer. What happens if we use different units?

Polymer Basics, Co-Polymer



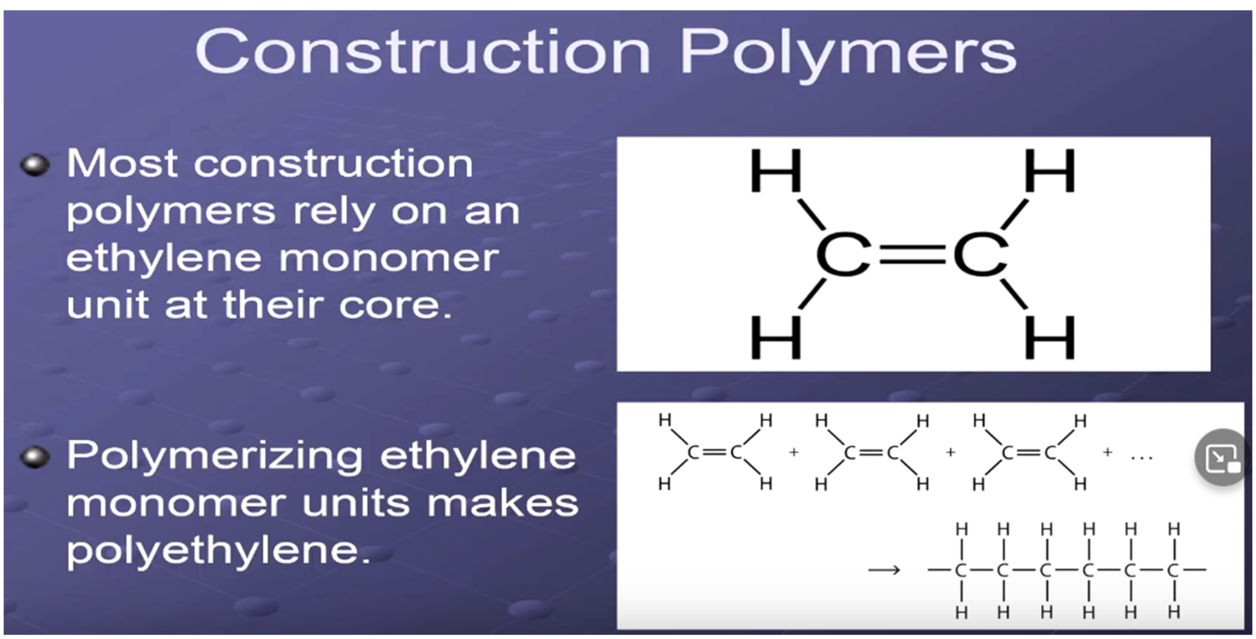
Well, if we alternate the monomer units, we make a copolymer. When you see that term in a product description, that is what that is. But what happens if we have a chain and then we link these chains together, almost making a net? If we do that and we actually cross-link these chains, we increase the physical properties and performance of the polymer. That all makes sense, right? Okay.



Construction Polymers

We are going to start out with a monomer unit, and I am not trying to glaze your eyes over with chemistry, but just stick with me here. It is not too complicated. We are just dealing with two carbons, and I need another carbon atom up here. Come on up here, carbon atom. We are going to have two carbons, which is called an ethylene monomer, and our shoes are hydrogen atoms, which means it is saturated, and we have two double bonds (hands touching) that look like this. These are those electrons, those wispy electrons, and we are sharing them. When we polymerize with other ethylene, one of the bonds breaks, and we go boom!

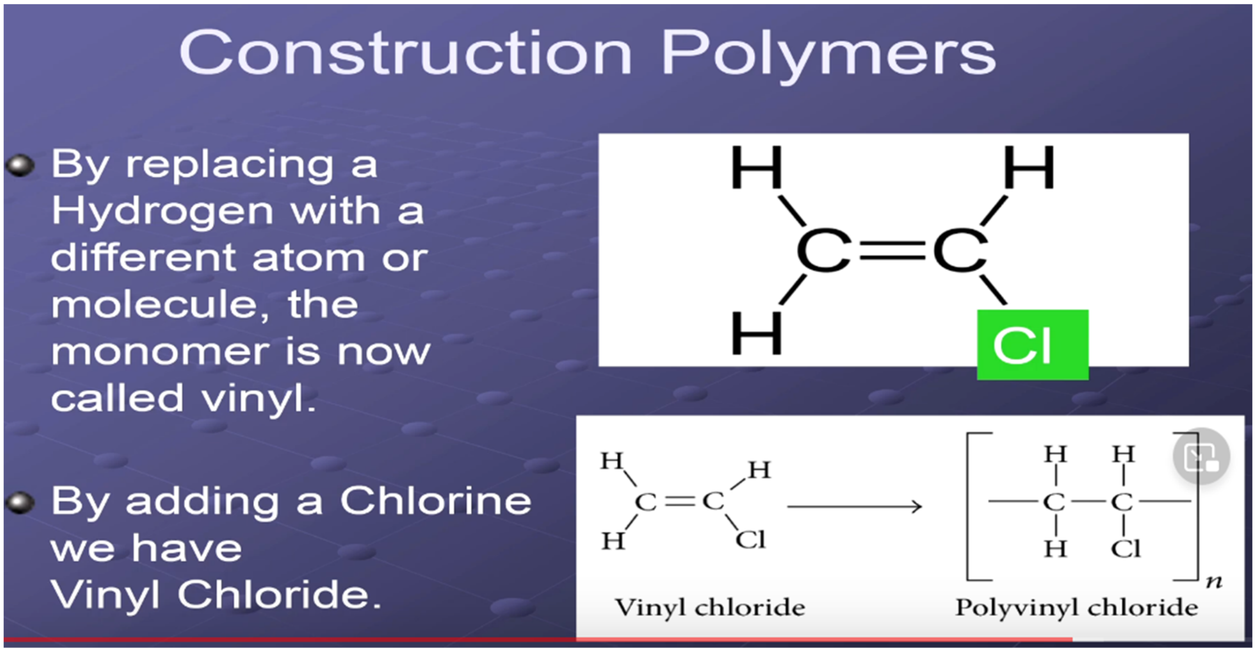
And the chain goes ethylene, ethylene, ethylene, and here is the drawing, (thank you carbon atom, lovely carbon atom, let us give her a hand), and we wind up with polyethylene, or polyethylene plastic, which we use a lot in the construction industry.



Here, we have either polyethylene, sometimes polypropylene, here are fastener heads, and our five-gallon plastic pails, polyethylene, and polyethylene everywhere.

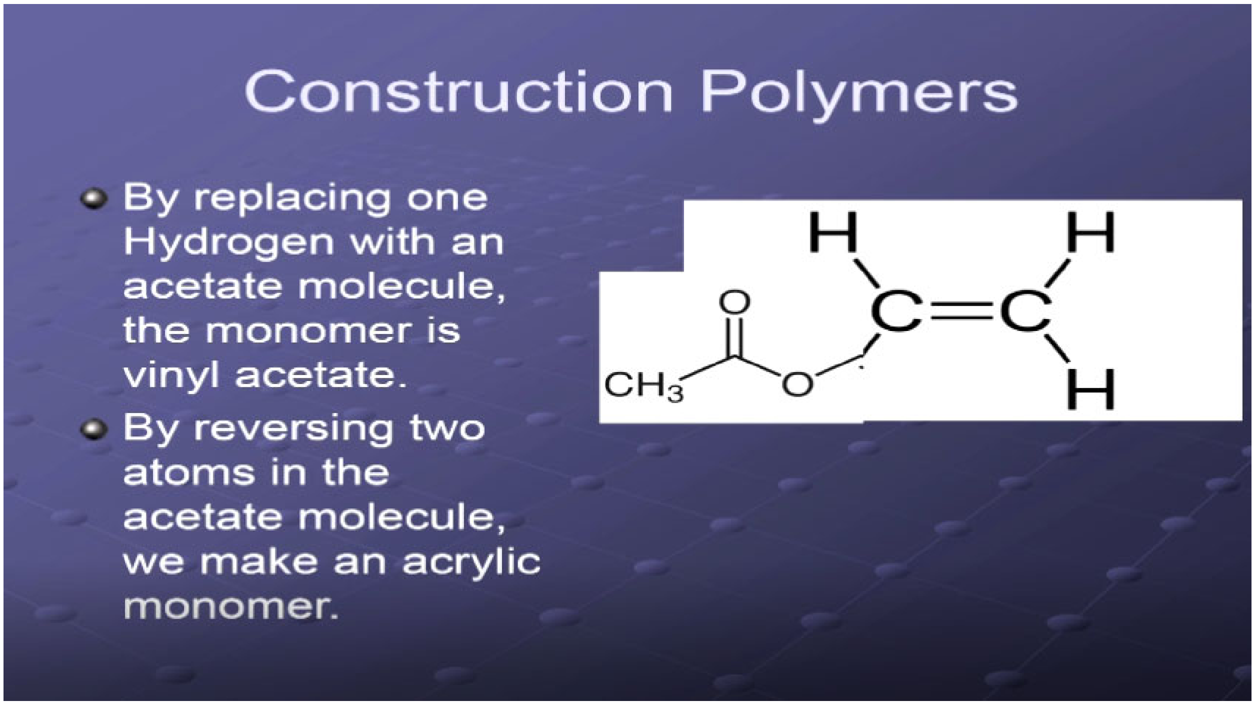
We have polyethylene, and congratulations to my audience; we just made our first polymer. Now, let us see what else we can do. You are going to see how simple this is, and you are going to wonder, I could have done that; those guys make a lot of money doing this stuff. Yeah, it's true.

Construction Polymers



We replaced one of the hydrogens with a chlorine atom, just one of them. If I did this with her (my carbon atom) again and on my right foot, I would have a chlorine atom instead of hydrogen; we no longer call this ethylene. As soon as we put a functional group on it, that is called a functional group even though it is one atom; this is called vinyl, and in this case, it is vinyl chloride. If we polymerize that the way we just did before, we have made polyvinyl chloride or PVC. Now, lo and behold, here is our drainage track, PVC and other components, all kinds of trim pieces, and a lot of the piping in our houses, right? PVC. Now we are cooking. *What else can we do*?

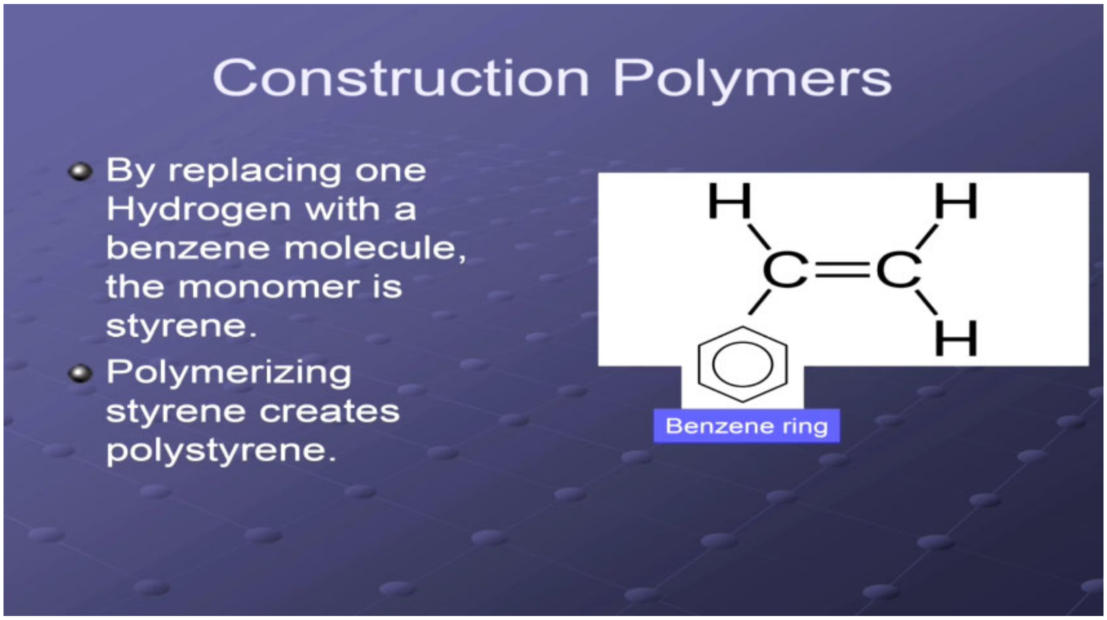
Construction Polymers



Okay, so we will replace hydrogen with a slightly bigger molecule. This is an acetate group, and of course, we have polyvinyl acetate. Let us say that we do not put an acetate on every ethylene group. We run ethylenes out and then put in acetate here; we run ethylenes out and put an acetate here so that the acetates are only every so often. We have made ethylene vinyl acetate, EVA, a spray dry polymer, and that is the polymer used in the base coat where all you do is add water; it is not the two-part kind anymore where you used to use the Primus and mix cement into it. It is all in the bag; those are EVA polymers in there. And look at us, we just built one. Cool. So, here is something really, really sexy. Watch this.

Small changes. See this oxygen double bond and this oxygen. Let us flip them. Let us put this double-bond oxygen here and the single-bond oxygen here. What do we have? We have an acrylate monomer. That is all we had to do. We polymerized that, we have polyacrylate, and we made an acrylic. We are going to do one more and then I am going to wrap this up.

Construction Polymers



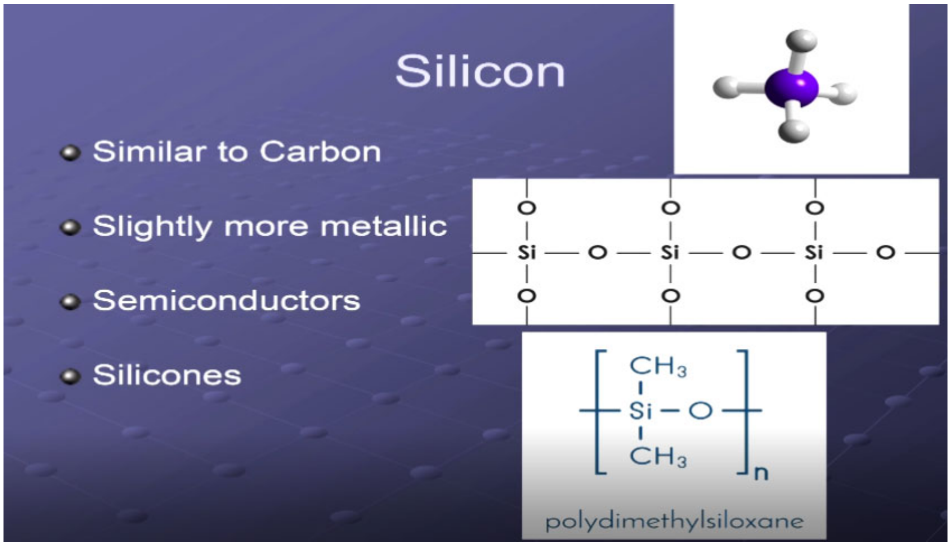
We are going to put a Benzene ring on here. A benzene ring is a six-carbon ring, so if I were standing up here with my other carbon atom, this Benzene ring would look like a beach ball on my foot (I mean or bigger, like one of those exercise balls, you know that you roll around with), and this benzene ring would be there, and all of a sudden this is called a styrene monomer. If we polymerize that, we have polystyrene plastic. If the polystyrene plastic is a clear, kind of brittle plastic. If we infuse it with some type of expanding compound, fluorocarbon, pentane, or something, or heat it so it expands, we can make expanded or extruded polystyrene from that polymer chain. So, where are we? Let us wrap this up a little. I am leaving out one little thing.

Emulsions

When we buy polymers, the polymers come in liquid form; they look like milk. It is in an emulsion. How is it that something that is in a water solution can be so waterproof when it is on the wall? I explain how that happens very quickly. The polymer is tiny, tiny little micron sizes called sols, s-o-l-s. They are little, tiny beads that hate water. Still, we have a surfactant, an Emulsion system, in the solution that keeps them all suspended, so much so that we can actually add pigment extenders and colorants and sand and make it a textured material, and the polymer is still happy. When we put it on the wall and it begins to dry, the polymer ***soles*** of the beads get closer and closer together, the emulsion collapses, and they stick together and film form. There are agents in there called film-forming agents (there is a technical term, do not worry about it) that help melt this film into higher-performance material. It takes time for some of these drying agents, so many coatings are more water sensitive early on until these slower evaporating things come off, but then we have our integrity, our film forming, and away we go. That is the importance of the surfactants. It is very difficult chemistry to balance all of that and get it to hold together.

Now, one thing that damages this is freeze-thaw. Early on, one freeze-thaw would just completely shoot a resin. Now they say, “Oh, we are freezing thaw stable for five cycles.” What does that tell you? Do not freeze it six times, right? It also tells you that each time it goes through a freeze-thaw, there is a reduction in performance properties. So, the freeze-thaw of these water-based materials is bad, very bad.

Silicon:

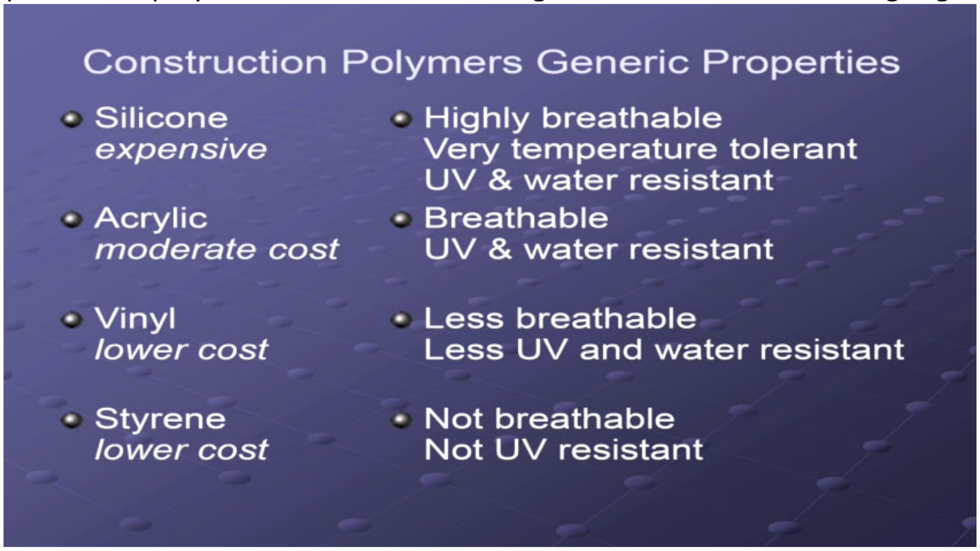


Moving on. Oh, I forgot about silicon. Got to do silicon. I am sorry, I am running over. They are going to fire me. Silicon has four bonds, just like carbon. If we bond silicon dioxide, one after another, together, we make quartz silica. We make glass. Quartz silica. Very brittle but wonderful performing. Great aggregate, acid-resistant, strong quartz silica. If we actually take these oxygens off the side chain and replace them with one carbon and hydrogen, we have now made a silicone. It totally changes the properties of this polymer. The silicone, now, here is our glass that I have made out of silicone. Try doing this with a quartz glass.

Totally different properties, right? Now we talk about temperature resistance with elongation and recovery, chemical resistance, and highly breathable, good chemicals. The problem with it is that it is very hard to coat and, you know, paint over, which is one of the downsides, and very expensive. So, let us get into our last slide.

Construction Polymers Generic Properties

Let us compare these polymers that we went through all the trouble of building together.



Silicone: We start at the top with silicone because it is the most expensive, but it has some really great properties. We know our silicone sealants are the best if we are going to use caulk sealants, right? And DOW All-Guard has a nice coating, a 20-year coating wall coating if you are willing to pay for it. Highly breathable, the most breathable, very, very temperature tolerant, probably down to -30, -50 degrees without getting brittle. It is called T-sub-g, which is glass transition temperature, which is a temperature at which a polymer becomes like glass and hardens. The lower the temperature, the softer it is and the more temperature tolerant it is.

Acrylic: Acrylics are at a moderate cost, and your main industry workhorse is for all types of things, including coatings and cement modifications. It is one of the more popular admixtures you can add to a cement mix to improve properties, such as breathable, UV-resistant, and weather-resistant.

Vinyl: We are going to step down into vinyl. Vinyl is cheaper, and this is a general rule. There are different kinds of vinyl and acrylics. Vinyl's are cheaper, less breathable, less UV, and water resistant. Often, your cheap interior paints are pure vinyl. Some people make a vinyl acrylic. I can sell a little cheaper than this guy, but you are trading off some of the performance properties.

Styrene: Styrene, not breathable at all, not UV resistant, worth of crap. Do you want to see how UV-resistant it is? Put some of the white foam on a wall and come back a few weeks later and see how yellow it is. That is UV degradation. Styrene is probably the lowest cost, and some people make styronated acrylics. Again, the trade-off of performance for cost.

That is the end of my talk. Thank you.