[SQUEAKING]

[RUSTLING]

[CLICKING]

JOHN DOLHUN: Welcome to the ferrocene lecture. We are going to do a demonstration at the start because I'm going to be talking about additional reactions during this lecture. And I want you to actually see one happen. So I've got Amanda Trainor, who is manning the fire extinguisher. Amanda just had her fire extinguisher testing. So she is ready to go. And Dr. Sarah Hewett will actually assist me with the bromine that we're using.

Bromine and me go way back because I made bromine when I was in high school. In the parents of my-- in my parents' home-- in the basement. The whole place filled up with reddish brown gas. And back in those days, the chemistry sets had real chemicals in them. So what we're going to do is we are going to cook some bacon. And we are going to crack the glycerol. And we going to make this unsaturated compound acrolein. Then we're going to throw it into the bromine. And the bromine should add across the double bond-- an addition reaction.

This is the acrid smelly stuff that you smell when you cook bacon. This is the burned bacon fat smell that you smell. It's colorless, flammable, and very poisonous. So let's go. We're going to start this. So I'm using a creme brulee torch. It's my wife's. She's probably out of her mind now looking for it. So we're cooking the bacon. And we're going to get that bacon fat-- the glycerol-- broken down. Ready? And here we go.

So we've thrown the bacon into the bromine. You can start to see the color disappearing. Color is adding across the double bond of the bacon. And I present to you bacon dibromide. Good stuff.

[APPLAUSE]

Thank you. I actually don't eat a lot of bacon anymore after doing this demo knowing that stuff is so nasty and a cancer producer too. So all right. Let me get this hot lab coat off.

So Emil Fischer and Geoffrey Wilkinson win the Nobel Prize in chemistry back in 1973 for their independent work looking at these organo-metallic sandwich like compounds. It all started here in 1951 with a paper published by Pauson and Keely, "In Nature," where they took a Grignard like reagent cyclopentadienyl magnesium bromide. And they tried to get an oxidative coupling of this ring hoping to make fulvalene.

Instead, they got this stable orange complex. Empirical formula C10H10Fe. Right after this paper came out the fellow on the right, Geoffrey Wilkinson, who was at MIT, had just moved to Harvard. And both him and Woodward at Harvard looked at this paper and said, wait a minute. With these sigma metal carbon bonds they're saying that this complex actually is stable at very high temperatures up to 400 degrees.

So that these bonds would disintegrate at those temperatures. So they were skeptical of this structure. So they immediately said, well, let's do an addition reaction. Look at all the double bonds here. Should easily be able to do an addition reaction and add across those double bonds. They got no reaction. So then they said, OK. Just for the fun, let's try a substitution reaction. For a substitution reaction you need an aromatic system such as benzene. An electrophilic aromatic substitution reaction involves an electrophile, which simply substitutes itself for a hydrogen on the aromatic ring and gives you your product.

So they tried a substitution reaction and they actually got a reaction. Now they were a little bit more puzzled because look at cyclopentadiene. Is it aromatic? How many pi electrons are there? Four. Good. And what is Huckel's rule? Anyone know Huckel's rule? Yeah? Sean?

AUDIENCE: Pi electrons are at the aromatic.

JOHN DOLHUN: OK.

AUDIENCE: So this would be [INAUDIBLE] aromatic.

JOHN DOLHUN: That's one way to look at it. So Huckel's rule is 4n plus 2. Right? 4n plus 2 pi electrons where n is a 0 or any positive integer from 1 up. If you put 0 in there you get two electrons. That obviously has four. If you put one in there you get six.

So this definitely does not observe Huckel's rule. It's not aromatic. Most of these types of hydrocarbons like this have PKAs that are greater than 50. But it turns out that cyclopentadiene has these hydrogens on there that are slightly acidic because its conjugate base is very stable-- stabilized by resonance.

So if we take a-- where did I put my chalk, here. If we take a base here, come in and abstract one of those protons, what we're going to get is this anion. And this is the cyclopentadienide anion. This has six electrons. Now if you look at this system-- all of these SP2 hybridized carbon atoms now have electron density that they can share all around that entire ring. So this is an aromatic system.

And what would Geoffrey Wilkinson and Woodward said was, OK, so let's take two of these, make kind of like a sandwich structure-- six electrons on the bottom, six electrons on the top, and six D electrons from iron in the center. So you've got 18 electrons. That's kind of a magic number for an inorganic chemist because it's got that noble gas configuration. So the D electrons from the iron are pi bonding with the P electrons from the hydrocarbons.

This is a complete reversal of the classical way of looking at ligand metal bond coordination. Everybody used the sigma bonds. No one ever thought about pi bonds. Can I have two volunteers? Yes. Come on up. Come on. See if you can come over to the front of the table here. And you are?

AUDIENCE: Aisha.

JOHN DOLHUN: Aisha. And?

AUDIENCE: Maya.

JOHN DOLHUN: Maya. OK. Aisha and Maya. So let's see what mama packed me for lunch today. Oh good. I got two pieces of bread here. Correct. OK. So Aisha, why don't you hold the bread-- one hand like that and stagger the other one and put a space between it and turn toward this way. Yeah.

Turn so it's-- yeah. Put the crust facing the audience on one and away from the audience on the other. Maya, take the orange. And now let's see. Let's fix this a little bit. So there we go. And come down a little bit. Now Maya, come in. Put the orange right there. There it is.

[LAUGHTER]

A molecular sandwich. That's ferrocene-- the two cyclopentadienide anions and the iron atom in the middle pi bonding with all their electrons. Congratulations. Thank you.

[APPLAUSE]

Maya, do you like the orange?

AUDIENCE: Sure, thank you.

JOHN DOLHUN: I know you don't want the bread, but oh, look. There's something else. Here.

AUDIENCE: Thank you.

JOHN DOLHUN: OK. So we just figured out how ferrocene is put together. Now we have to make it. And to make ferrocene you need cyclopentadiene. But this stuff is not commercially available because it has a half life of 12 hours.

What it does is it spontaneously adds to itself in this reverse Diels-Alder type reaction to make the dimer. So let's look at the Diels-Alder reaction for a moment. If you're taking organic now, this is the Mona Lisa of all organic reactions discovered by Otto Diels and Kurt Alder in 1928. And they both won the Nobel Prize in 1950.

You need a diene-- an unsaturated hydrocarbon with two double bonds-- and a dienophile-- a substituted alkene-- to make this substituted cyclohexene type derivative. What you've got is four pi electrons here, two pi electrons here, and this is called a 4 plus 2 cyclo addition. And this reaction just goes. You don't have to do it. You put them together and it goes because you're making these sigma bonds, which are much more energetically stable than the pi bonds you're starting with.

But look at our system. We have these two cyclopentadiene rings. We don't have a dienophile. We've got two dienes here. And this thing still goes spontaneously-- adds to itself to produce the dimer and other higher polymers. So how are we going to make this? We're going to crack the dicyclopentadiene in the hood. The TAs are going to do this for you. It's highly flammable-- the product. Cyclopentadiene is highly flammable so they're going to cool it in ice.

The other thing is, this is very smelly. So don't wear your silk clothes and your wool clothes to lab when you're making this stuff. So you're going to be going over to the hood to get your allocation. The main thing you have to be aware of is when you get your needle and you put it in and you pull your 0.3 mLs-- whatever you need for your reaction vessel-- that you don't grab on to the syringe with your fingers because the warmth of your fingers will dimerize this right in the syringe before you inject it into your reaction vessel.

We're going to heat this up to about 180 degrees, collect the fraction that comes over between 38 and 41 degrees. That's our cyclopentadiene. Now we're going to be using no air techniques in some of the experiments that we're doing. Why do you think we need to use no air techniques? Yes? Alex?

AUDIENCE: There are things in the air like oxygen that are reactive.

JOHN DOLHUN: Very good. There's oxygen in the air that's very reactive so some of the chemicals you're using like iron chloride tetrahydrate could be oxidized. We've also got that cyclopentadienide anion here, which-- this guy-- which actually decomposes in the air. So it's very important to have this atmosphere. So how are you going to do that? Pretty simple. We're going to be working with these little vessels. They're called Assem vials. They have septums on them.

So you'll put your reactants in there. And then you'll simply take a vent needle, put a vent needle in into the septum. Don't push the vent needle down too far. If you push it down too far, your liquid might shoot up through the vent needle. Then you're going to go over to the hood.

You're going to pull out the nitrogen line. Nitrogen will be flowing. You'll stick the nitrogen line in. Now you're bubbling nitrogen in. And this can go down into the liquid, bubble, get it refreshed. Then you're pushing out the air through the vent needle.

After a couple of minutes, take the vent needle out. And then pull out the nitrogen line. Now you effectively have a nitrogen atmosphere for your reaction. So this is the reaction scheme for the synthesis of ferrocene. Notice there are two reactions going on here. You'll actually have two of these little asam vials. In one of them you're going to have KOH and dimethoxyethane. The KOH you'll have to mass out at the balance area. And you've got to work kind of quickly with this because KOH is very hygroscopic. It picks up water very quickly.

In the other vessel you're going to put iron chloride tetrahydrate dimethyl sulfoxide. And then you're going to shake those vessels. You're going to work out in the lab. You seriously-- you will be sore after this lab for about an hour of working out. Once you shake them well, your iron chloride tetrahydrate should dissolve. But the KOH will not dissolve. So don't worry about that. Do you see KOH? It's OK. Once you get everything dissolved you take your iron chloride-- or your KOH dimethoxyethane vessel over to the hood and you get your cyclopentadienide and you inject it.

You put that back under an inert atmosphere. And then you start shaking it some more. After about five minutes you have this beautiful pink color, which is your cyclopentadienide anion-- sometimes called the Cp ligand that's forming in your flask. Let's just stand back for a moment and take a look at that top reaction. Who can tell me the driving force of that reaction? Why does that reaction go? Alex?

AUDIENCE: It's an acid base reaction.

JOHN DOLHUN: It's an acid base reaction. Yeah. Yeah. What else up there do you see that just pushes that so fast? Alex?

AUDIENCE: Resonance.

JOHN DOLHUN: Resonance. OK. Yeah. You're making something that has resonance forms. Yes?

AUDIENCE: Creating the aromatic ring.

JOHN DOLHUN: Giselle, right?

AUDIENCE: Yes.

JOHN DOLHUN: Yes. You're creating an aromatic ring. Very good. So you're going from a non aromatic system to an aromatic system. That is a big push. OK. So once you make this, then what you're going to do is you're going to take your other vessel with the iron chloride dimethyl sulfoxide and you're going to start doing injections. You're going to do four injections into this system.

After each injection-- when I did this I usually put my system back under an inert atmosphere. And then I'd shake it. Then I'd do another injection. Shake it. Inert atmosphere and so on. And then finally, what you've made is you made ferrocene. So once you get down here you're ready to take a look at that ferrocene.

So what you're going to need is you're going to need a small beaker-- about a 30 mL beaker. And then you half fill it with ice. So we're going to have ice in the beaker. And you're going to add to the beaker about 4.5 mols of 6 molar HCl. And then you'll add your ferrocene from your asam vial. You're going to add your ferrocene.

And when you do that, you stir it up with your stir bar. And you can use a little bit of dimethoxyethane methane to wash out your asam vial. Get everything out, washed out into that beaker. And your orange crystals should float to the top.

Once you get your orange crystals, you're going to set up a little mini Buchner funnel system such as this. And inside of this there's a baby piece of filter paper. You want to be sure that you wet this filter paper and put it in wet. Otherwise if you don't, if it's dry, your product will go under it and end up in the flask. So wet the filter paper, pour your product in. This is hooked up to the vacuum in the lab. And it will just draw your product and you'll have your filtrate will come through.

Now the filtrate that's coming through is going to be a bluish green color. What do you think the filtrate could be? Anyone? I know you know Alex. Anyone else? Alex, go for it.

AUDIENCE: Iron 3.

JOHN DOLHUN: Iron 3. Oxidized ferrocene. Interesting. So you actually started with ferrocene.

And in the process of oxidation-- and you've got some HCl in there. So you've got chloride there. So what we've made here is-- you've made what's called ferrocenium chloride.

Why do you think we made that? What does that represent? Looks like we lost some ferrocene probably because we didn't keep that right inert atmosphere all along the way.

So think about how you would take this and get ferrocene back from it. I'll let you think about that a little bit. If anybody comes up with a great idea and wants to do this on day four when there's no lab going on, let me know what you need. OK?

So now, we've made our ferrocene. We've got our crude ferrocene and we're going to purify it. And we're going to purify it by sublimation. Definition of sublimation is the amount of energy and kilojoules per mole that we need to add to one mole of a solid to take it from the solid to the gas directly.

Hess's Law defines the enthalpy of sublimation as the enthalpy of melting plus the enthalpy of vaporization. But for this to hold, both of these steps would have to be taking place at the same temperature, otherwise Hess's Law is just an approximation. I brought some carbon dioxide in. Can you see this? It's subliming. It's going from the solid-- and this is very cold stuff. This is about minus 78 degrees. I'm going to burn my hands. So I'm doing this very quickly. OK.

You can't see the sublimation when it gets into the air. But I'm going to put it in this cylinder so you can actually see the bubbles of sublimation that are taking place.

AUDIENCE: Woah. Cool.

JOHN DOLHUN: So there's another definition of sublimation that we can use. We can define it as heating a solid below its triple point to the gas and then collecting that vapor on a cold surface. And that's exactly what you're going to do with your crude ferrocene.

You're going to take a biological culture dish, sprinkle some of your ferrocene in there, cover it, put it on a hot plate, and then fill up a beaker with ice. Put the beaker on top of it. Turn the heat on. Keep it under 100 degrees. And after a few minutes, you'll see orange ferrocene start to sublime up inside of the culture dish. And then your crystals will form on the bottom of the cold part of the dish and hang off the dish.

It's quite a dramatic reaction. And this sublimation is really great because oftentimes the things that you're trying to purify are more volatile than the impurities that they contain. So it's very clean to actually get a pure substance from sublimation.

Couple precautions-- when this reaction is over, if you take your beaker like this and you lift it up, you're going to lose all your product. It'll fall right off. You'll have to start over. So the trick is to slide the beaker off very gently.

The other thing you don't want to do is you don't want open this dish when it's hot. Why wouldn't we want to this when it's hot? Alex?

AUDIENCE: [INAUDIBLE]

JOHN DOLHUN: Yeah. The toxic ferrocene would go up all around us. We'd be breathing again. So keep this closed till it's cool. Then open it up, scrape your crystals off. So now, you've made your ferrocene. So what we'd like to do is we'd like to write a reaction. And then you're going to calculate the limiting reagent, the theoretical yield from your starting materials.

You'll take your actual yield and calculate a percent yield. Let's just do a-- just to review-- a general equation for that. We'll do 2A plus B going to C plus D. And we're going to have 0.9 moles of A and 0.5 moles of B. And I want to know how much C can be formed theoretically from my starting materials.

First thing to do is look at the equation. The equation is talking to you. What is it saying? It says for every 2A I need one B. All right. How much B do I have? 0.5. So how much A do I need? 1. I don't have enough. That's your limiting reagent. Right?

It's going to run out before anything else. So A is going to determine your product. So now again, take a look at the equation. It's talking. For every 2A, you make one C. How much C am I going to make from 0.9 moles of A? 0.45. Very good.

So my theoretical yield is going to be 0.45 moles of C. Now what you can do now is you're going to actually do the reaction. You'll mass out how much you actually got so you'll know what your actual yield is. So you can calculate a percent yield, which is your actual over your theoretical times 100. Pretty simple.

You're also going to have to determine the melting point of the ferrocene. And I'm going to tell you that if you take your melting point tube and you stick it in the melt temp and you're watching it, you'll never see it melt. Think about that. Think about what you're going to have to do before you put that melting tube into the melting point machine because you know ferrocene sublimes. Right? Just going to disappear on you. Think about that.

So now we are going to take our ferrocene and we're going to do a Friedel-Crafts electrophilic aromatic substitution reaction. We're going to take the ferrocene and we're going to a acetylate it. And normally this Friedel-Crafts reaction is usually done with a very strong Lewis acid. Usually they use aluminum chloride.

But aluminum chloride is very difficult to work with. You take that stuff and you're walking around with it in the lab. It's producing hydrochloric acid gas. So it reacts with the water vapor in the air. It's nasty. So we have decided to use a much weaker Lewis acid-- phosphoric acid.

The good thing is that this cyclopentadienide anion is more reactive than benzene. So we can get away with this weaker Lewis acid. So we've got acetic anhydride phosphoric acid. There are no solvents in this reaction. We're reacting these two things with the ferrocene. What do you think the phosphoric acid is reacting with? Anyone? Yes?

AUDIENCE: Is it activating [INAUDIBLE] carbonyl?

JOHN DOLHUN: Yes. It's actually activating something to produce an electrophile, which is good. And that's what we need for this reaction. So it's actually reacting with the acetic anhydride. And here it is here. You can see the mechanism of this. Pretty simple.

The acetic anhydride phosphoric acid react. And you make acetic acid-- vinegar. That's one of the products. And then you also make this very stable acylium ion. And this acylium ion is actually-- it's resonance stabilized. So we can actually take a pair of electrons from oxygen, come down here, and we can throw the positive charge out onto the oxygen here.

This is a very stable system. This is your active electrophile for this electrophilic aromatic substitution. It's your carbonium ion. So here we've got the carbonium ion. And here's our cyclopentadienide-- the carbanion. And this carbanion literally throws its electron density out to that a acylium ion and captures it by the normal steps of electrophilic aromatic substitution. You're just substituting an electrophile for a hydrogen on the ring. And you potentially can make these two products.

So what you've got here is you've got-- you either could make the monoacetylated or the diacetylated. Now after you see this mechanism-- let's go back here one more time. Why can't we put more than one of these acyl groups on these rings? Why can we only make the mono and the di as potential products? Yes?

AUDIENCE: [INAUDIBLE].

JOHN DOLHUN: Very good. The acyl group is an electron withdrawing. So if you can imagine these groups pulling electrons away from the ring, it's creating all these positive positions here. And the electrophile is positive. So the electrophiles would be repelled away from the other positions. This is a deactivating group here. Great. Now we've got our products, but we'd like to know how many products we've got. Did we make the monoacetylated or the diacetylated?

So what we're going to use is we're going to use a technique called thin layer chromatography. How many of you have done thin layer chromatography? Oh wow. Number of you. OK. So what we've got is we've got these little slides. They're almost like microscope slides.

They have a nice clear surface on one side. On the other side they have a solid absorbent. And the solid absorbants that we use are alumina-- Al_2O_3-- and silica gel-- SiO_2 times x water.

You notice both of these solid absorbants have polar bonds. You've got AlO bonds here. You've got SiO bonds here. What that means is the solid absorbant is going to-- any polar system that you put on this plate is going to stick to that solid absorbent more.

We're also going to have a mobile phase. It's going to carry our components by capillary action up the plate. We're going to be spotting this plate with our product. And then we're going to watch the spots move up the plate and separate by partitioning. And what does that mean?

In all of these chromatic distributions it's all about the distribution of the solute between the stationary solid absorbent and the mobile phase. And so you can get this distribution constant, which actually should be a constant ideally over a wide range of solute concentrations. Let's say we had a distribution constant that was very high. What would that mean in terms of the spot on the plate? Yes? August?

AUDIENCE: It wouldn't move very far because most of the material is the solid [INAUDIBLE]

JOHN DOLHUN: Good. It wouldn't move very far on this plate. It would be sitting there attached to that solid absorbent. And if you had a column and you were trying to separate the material, it would move slowly through that column as well. Good. So this is what we're going to do. Going to use a little jar like this to run these TLC plates. Let me just get some board here.

So you are going to take a TLC plate. And about 1 centimeter from the bottom you're going to draw a line with a pencil-- a straight line-- so use a ruler because if the line is crooked your spots are going to be going in different directions. We have rulers in the stockroom.

And then what you're going to do is you're going to take a spatula tip of your ferrocene and a spatula tip of your diacetyl ferrocene. And you put them into two little scintillation vials. And you go over to the hood. And what you're going to do is you're going to get some dichloromethane. And you're going to put a few drops of dichloromethane into your-- to dissolve your spatula tip.

And then you'll use the capillary tube to draw that up. And you'll come back and you'll spot your plate with the smallest spot that you can make and the darkest. One of the spots will be-- at least one will be ferrocene and one will be your acetylated ferrocene mixture.

That way you can see if there's any ferrocene still inside of your acetylation product. And then you're going to take tweezers and you'll lower this into the jar. You'll have your solvent in the jar. Put about 2 to 3 mLs of solvent. Don't put more than 2 to 3 mLs. I've seen students put 5, 10, 15 mLs in. It's way too much.

And then when this goes down into the jar, the solvent cannot come up and touch your spots or your line. If it does, you've got to start over. So you'll put it in the jar and then you'll kind of just close it. And you'll watch it. You'll watch the solvent move up. And then suddenly it's going to reach up here somewhere. Then you pull it out with your tweezers and you draw another straight line. This is the solvent front.

And what we're going to do is we're going to calculate what's known as an Rf value. It's called a retardation factor. And it's a unitless number. You'll measure from the starting line to the spot and then to the center of the spot and the starting line to the solvent front line. You'll divide that. You'll get this number. Ideally, we would like Rf values somewhere between 0.15 and 0.85, which means that we want to get our spots off the starting line but not all the way up to the solvent front line.

We have to pick the solvent. Let's start out by picking maybe something non-polar like hexane-- purely non-polar. C6H14. If we pick hexane as our eluent, what do you think is going to happen to the polar component that's sitting on your line there?

Who said that? Sean? It's not going to move at all. That's right because it's affixed to that solid absorbent and it's polar. It doesn't like this non-polar solvent. So it's going to sit on the starting line. So this would not be a good choice. How about if we pick something more moderately polar like ethyl acetate. Here's ethyl acetate.

So we're going to take this. And now we're going to run the plate with this. What's going to happen to the non-polar component? Think about this. Now you've got ethyl acetate for your eluent. You've got a polar solid absorbent and your non-polar component. What will happen to that? Anyone? Any of the TAs want to chime in on this? Yes, Sean?

AUDIENCE: Maybe it's too close to the solvent front?

JOHN DOLHUN: Yes. It's going to zoom all the way up to the solvent front. Very good, Sean. That's exactly what's going to happen. So that wouldn't be good, would it? We want something in between. We want to separate them, but don't want them all the way to the solvent front or don't want them off the starting line.

So here's what we're going to do. What I want you to do is I want you to try a combination of ethyl acetate and hexane. We'll do like a 1:1 mix. And then do a 4:1 mix. And then try a 1:4 mix. I want you to see which combination gives you the best separation on your plate.

And once you do that, then we're going to use that solvent to run the column. TLC is just going to tell us how many components are in our mixture. The column will let us separate them. So we're actually going to fill a column with aluminum oxide and collect our fractions. Here's a typical column. Let's pretend we have ferrocene and acetyl ferrocene in there. One of them is polar. One is non-polar. Which color is the ferrocene? Yes? Jesse? Yes?

AUDIENCE: Blue.

JOHN DOLHUN: That's you, right?

AUDIENCE: The ferrocene would be blue.

JOHN DOLHUN: Ferrocene is blue. Good. The non-polar is coming through first because it's not bound to the solid absorbent and it's just flowing right through. And you're a acetyl ferrocene comes after.

So what you're going to do is you're going to make a mini column. Here's an example. You're going to fill this with alumina-- about 7 to 8 centimeters of dry alumina. And then you're going to put a little layer of sand on top of it. About 5 millimeters or so of sand. You can see it here-- get an idea what to do.

And then you're going to dry load your sample on top of the sand. So how do we dry load our sample? So what you're going to do is you're going to take your acetylated product, take it over to the hood, and you mix in about 50 milligrams of alumina, and then you get our old friend out-- dichloromethane.

This is nasty stuff. It causes all kinds of cancers in animals-- laboratory animals-- liver, lungs, everything. So you've got to-- don't breathe this stuff. We're keeping it under the hood.

So you add minimal amount of dichloromethane just to get this all wet and a slurry. And then you use a nitrogen line to air dry it to get a nice powdery air dried product. And then you're going to pour your product on top of that top-- the layer of sand there. And then you're going to put another layer of sand on top of your product-- the final layer. And then you're ready to go.

What you're going to do is you're going to add your solvent that you picked from TLC that gave you the best separation because we want to separate these components apart so we can collect them. And the thing to remember is when you add your solvent, you're ready to go. Open the stopcock here. Otherwise, nothing is going to flow out.

And the other thing I suggest is get a little scintillation vials or use the baby Erlenmeyer flasks and make sure you weigh them and tare them before you do this reaction because you may have so little product it'll be very hard for you to scrape it out to get a weight at the end. But if you weigh the empty vial first, then you can weigh it and get a weight on it and you'll know your mess so you can calculate your yield.

Some things that can happen-- if you have bubbles in your column, start over because they're going to distort your bands coming through. If you don't keep the solvent on top of the top layer of sand throughout the whole run-- you have to keep a cushion of solvent flowing-- keep it above that top layer of sand-- your column will dry out. It'll crack and your bands will flow together. It'll make it difficult to separate the different colored bands coming through.

The other thing is when you make your column, what I do is tap it a little bit each time you put the sand and alumina in. Make it level so you don't have these kind of irregular surfaces that can cause distortions. So you're going to take your melting point, calculate your percent yields, determine the mass of the components, and that's pretty much all you need to do for that.

Now I want to show you what's happening with ferrocene today. This is really something with what's going on. It's been what? How many years? 51-- it's been almost 70 years. Right? OK. Some people have taken the penicilloic acid shell that was synthesized here at MIT by John Sheehan in the 1950s, and they acetylated it with ferrocene making ferrocenyl penicillin. And it actually overcomes some of the resistance that's developed by the penicillin antibiotics that have been around for decades.

Another thing-- someone has taken tamoxifen-- breast cancer drug that's been around for decades. It's become resistant to a lot of the breast cancers it's used on. They've taken the phenyl group off here, put ferrocene on, added and OH group, and created hydroxy-ferroccifen, which is also overcoming some of the resistant breast cancer.

It's really incredible. This is one of my favorites. What's the most vicious animal on the earth? The mosquito. Exactly. I mean, there are two million deaths by these mosquitoes with malaria every year.

Chloroquine has been the source, but it was discovered in the '30s. So a lot of resistance. Right? So what they've done to chloroquine is they've taken the scaffold here and they split it and inserted ferrocene made ferroquine. This is our fairy queen. That's good. Yeah.

Ferroquine-- this could be the first organo-metallic antibiotic on the market. Sanofi Aventis has pushed this through stage two clinical trials. I'm not sure where it is now, but I got this most recent paper here. So this looks very promising.

Testosterone dihydrotestosterone the nemesis of all men because the prostate gland, it grows and then you get cancer. All men will get cancer if you live long enough. So what they've done is they've made ferrocene derivatives of these hormones that block the receptor site to stop the growth. This is a good one. This is just happening. They took Sedaxane and they removed this group and attached ferrocene and created Sedaxicene. This is an anti-fungal agent. And it's relatively non-toxic.

And I mean, you know, these funguses are out of control. They've reached the end of the line on these fungicides that can stop them. So this is a great addition. I'm not sure where this is going to go. And then here is ferrocene attached to a zinc complex. And this rivals the drug cisplatin in terms of these MCF7 breast cancer cells-- knocking them knocking them out.

So there's a lot of good stuff happening with ferrocene. And be sure to take a look at the safety on the chemicals here. The TAs will go over this with you. And we'll see you on Thursday for a very important lecture. Probably the most important lecture in the course-- how to write a lab report. It's all about lab reports. And Dr. Sarah Hewett will be giving that. Thank you.