JOCELYN: Hi. Jocelyn here. And today we're going to go over fall 2009's final exam, problem 10.

As always we're going to start by reading the question. You have 333 milliliters of alkaline solution at a pH equal to 9.9. You wish to neutralize this by reacting it with 222 milliliters of acid. What must be the value of the pH of the acid?

So first off let's write down the information that was given and the information that he's asking for. So we have 333 milliliters of a solution with pH equal to 9.9. And he's asking you what must the pH be if you want to put in 222 milliliters in order to completely neutralize that basic solution. And the key here is to recognize what neutralize means. And a neutralization is when you take acid, or protons, and base and it reacts to form water, thus creating a neutral solution.

So the next step would probably be to figure out how much excess hydroxide we have in this solution. And then we can figure out how much hydrogen we need to react with that hydroxide and to form water in order to completely neutralize this solution.

So first step is to find out what our concentration of OH minus is. And we do that by remembering a few things about acid/base solutions. Right? We know that if you have the pH plus the pOH it equals 14. And this is from the equilibrium constant of this neutralization reaction. And then we can figure out what the pOH is because we're given the pH of our initial solution-- 9.9-- and that equals 4.01.

Now using the definition of pOH, which is that the pOH equals the negative log of the concentration of the OH minus, we can rearrange that and get that our OH minus concentration equals 10 to the negative pOH. Right? Just using our log rules there. So this gives us that our current concentration of the hydroxide ion is 10 to the negative 4.1.

That gives us the concentration of the hydroxide, but what we really want to know, if we're going to use our neutralization reaction here, is we want to know how many moles of hydroxide we have in that solution. And we can just do that with stoichiometry. Right? The concentration is in moles per liter. And we know-- so our moles hydroxide equals our concentration, which is 10 to the negative 4.1 moles per liter. Times-- if we want to get rid of that liter unit we multiply it by our volume, which is 333 milliliters, converting it from milliliters to liters. And this gives us 2.65 times 10 to the negative 5 moles of OH minus in solution.

So that's just the first step of this problem. Now that we have the number of moles of OH minus we need to find the number of moles of H plus necessary to react with this excess hydroxide, and then we will be able to find the concentration of hydrogen, or protons, in that second solution.

So first off we're going to look at our neutralization reaction over here and realize that it's a one-to-one stoichiometric ratio. That means in order to react with 2.65 times 10 to the negative 5 moles of hydroxide, we need the same number of moles of hydrogen. So over here I'm going to say that this also equals the moles of H plus needed.

All right. Now that we have our moles H plus needed, we need to do the same process here but in reverse. So first we need to find the concentration of protons that we have. So given that we want to only have 222 milliliters of this solution, right? So we have-- and we just divide that by our volume, 0.222 liters. Right? Because we divide by 1,000 to convert from milliliters. And that equals 1.19 times 10 to the negative 4 moles per liter.

So this is another problem where you could get the answer but not actually be answering the question. Right? Because this is the concentration of protons that we need, but now we need to convert that to pH.

So moving over here we'll just write the final steps. We know the definition of pH is the negative log of the concentration. And so because we know the concentration of protons we know that the-- we just need to plug this into our calculator and we get our answer, which is a pH of 3.92. Put a box around that one because it's our correct final answer, and you'll be good to go for this part of the problem.

Now moving on to part b we are asked, name the conjugate base of each of the following.

So we'll just start part b right here. And the first thing to recognize is what does a conjugate base mean. And in an acid/base pair, or when you have a kind of dissociation of an acid, in the most simple terms we can think about it just losing a proton. In the leftover molecule, that's the conjugate base right there. So in this problem we're asked if the molecule loses a proton, what is the resulting molecule? Ion, basically.

So part i we have HPO4, and that will dissociate to hydrogen phosphate ion. Simple enough. This is your conjugate base. So that's your answer for part i.

Moving to part ii. We have CH3NH3 plus. So it's kind of like an ammonia ion but not quite-- sorry, ammonium. And we know that this dissociates by losing a hydrogen off of the nitrogen, because that's where the positive charge is. It makes more sense there. And we get-- sorry, keeping the same order as above-- a proton plus. And this would be your conjugate base.

If you were a little bit confused on this one it might help to draw the Lewis structure, and you would see that the formal charge does actually reside on nitrogen and, therefore, it makes sense that the nitrogen would lose a proton. In addition, if you think about the ammonia/ammonium ion relationship you know that you have NH3 going to NH4. And in this case we just have one of the hydrogens replaced with a methyl group, and so you can make the analogy there that, oh, the hydrogen would come from the nitrogen in that case.

All right. So hopefully this was pretty straightforward. As long as you're comfortable with what a conjugate base is and what the dissociation reactions look like for acids.

So now on part c we are asked to classify each of the following as a Lewis acid or a Lewis base. Now first we need to remember what a Lewis acid and a Lewis base are. So if you remember from lecture or in your reading, we know that a Lewis acid is an electron-pair acceptor and a Lewis base is an electron-pair donor. These definitions are just a little more general than the classic proton acceptor or proton donor.

The first part is asking us about the cyanide ion. And to kind of clarify it for yourself and because we're asked about Lewis acids and bases, which are to deal with electron pairs, it might be helpful to draw the Lewis structure. So for this molecule a good Lewis structure looks like this, and it has a net negative charge. And you can see that we have a couple of lone electron pairs there that aren't involved in bonding. And because it has a net negative charge you can imagine that these electron pairs would want to kind of grab onto something else that's a little bit more electron positive. And because of that we know that this is actually a Lewis base. It acts as a base and would grab something like a proton and thus become more, I don't know, stable in some cases.

All right. Moving to part 2. We are asked about water, which is a molecule that we deal a lot with in acid/base chemistry. Again, you might be able to answer this right off the bat, but we're going to look at the Lewis structure here. Water has two lone pairs. So that means it could very well act as a Lewis base. Hopefully that makes a little bit of sense. Right? Because these electrons can go and grab something like a proton and form the hydronium ion with a positive charge, thus acting as a Lewis base.

It's important to remember that even though we're creating an acid in the hydronium ion, this water molecule in converting to the acid acts as a Lewis base. However, we also know that water can lose a hydrogen and accepts those electrons to form the hydroxide ion, and thus acts as a Lewis acid. So in the case of water either Lewis acid or Lewis base was a correct answer in this case.

Now moving on to part d. We will go over here, I think. I'm sorry. d, not b. Again, it's going to be about acids and bases. Consider the effect each of the following substances has on the ionization of the weak base ammonia. For each state whether the substance, one, suppresses ionization, two, enhances ionization, or, three, has no effect on the ionization of ammonia. In each instance give a reason for your choice.

Going back to the first part of this question we see that it's asking us about the ionization of ammonia. A good place to start from here would be to write down the reaction, just so we have that on our paper, in our mind, ready to think about it.

So we have ammonia-- and aqueous means that it's in water, right? And that is reacting with water to form the ammonium ion-- sorry-- by adding a proton and a hydroxide ion. OK. So this is the reaction we're asked about. Now we need to look at each of the three substances listed and decide how it affects this ionization.

So number i, we have KOH. Again, a good place to start is to write what happens to potassium hydroxide when it goes into water. And we know that KOH is a strong base and will dissociate into potassium plus hydroxide. So we see that it produces hydroxide. And this should indicate to you that, well, it has the same product as one of the products of the ionization of ammonia. And if we remember back a little bit before this section, we know that if you have the same ion in solution it will definitely affect the solubility, or ionization. So that's one way to think about it, is that I now have a common ion effect that will, because there's more hydroxide in solution now, it will push this reaction, this equilibrium, back to the left.

Another way to think about that is Le Chatelier's Principle. Kind of the same thing, although it's a little bit more versatile, I think, so pretty easy to think about. Right? If you add a product your reaction will shift to the left. If you add a reactant your reaction will shift to the right. So here we're adding a product, our reaction will shift to the left. Same as a common ion effect, these two combine to decrease, or both suggest that we will decrease, ionization. Moving to the second part of this problem. We're asked about hydrogen chloride. Again, let's look at what that does in water. We know that it's a strong acid, so it will dissociate into hydrogen, or protons, and chloride. Now this one's a little bit trickier because we don't have either of these ions in our initial ionization reaction, but if we think about the fact that ammonia is a weak base we can write an additional ionization reaction. So that additional would be ammonia reacting with a proton to form ammonium. Right? So this is another way that the ammonia molecule would be ionized. And we can see that if we add protons from this acidic molecule there we will increase the ionization, because it will allow the ammonia to work more as a base because of this reaction here. So we are increasing ionization.

Another way to think about this is completely valid and kind of the same thing, but if we look at this ionization reaction here where the hydrogen chloride is dissociating into protons and chlorides we can recognize that these protons will then react with the hydroxide that is produced in the initial ionization reaction. This will result in a decrease of hydroxide in solution, right? And so by Le Chatelier's Principle we know that a decrease in a product causes the reaction to shift towards the product, to make more hydroxide. So that's just another way of thinking about the same process, and it results in the same conclusion that addition of hydrogen chloride increases the ionization of ammonia.

OK. Moving to part iii. We have ammonium chloride, and this will dissociate into ammonium and chloride. And even if you're not sure how much it will dissociate, it will still dissociate to some amount. So it will have at least a little bit of an effect on our initial ionization reaction. So here we see the dissociation produces ammonium ions, and just like the first case that is one of the products in our ionization reaction. And so Le Chatelier's Principle, common ion effect, whatever you want to call it, tells us that it will shift the equilibrium to the left and decrease ionization.

So with that we're done with problem 10 from the final. It had a lot to do with acid/bases, so hopefully you feel more comfortable with them after this.