JOCELYN: Hi. Jocelyn here and we're going to go over fall 2009 exam three problem number three.

As always, let's read the question first. Calcium ammonium phosphate dissolves in water according to the dissolution equation, for which the value of the solubility product, ksp, has been determined to be 4.4 times 10 to the -14. Calculate the solubility of the compound in water. Express your answers in units of molartiy, ie moles of the compound per liter of solution.

So the first thing we want to do is write down what the question's asking. Part A-- how much calcium ammonium phosphate can dissolve in water?

And we're going to call this cs-- or the saturation concentration.

Next we need to figure out how to find this out, right? So it gives us that the ksp-- 4.4 times 10 to the -14. So we need to know something about the ksp and although it's called the solubility product, it's the same as other equilibrium constants. So equilibrium constants tells us about the concentrations at equilibrium and therefore the maximum solubility.

Looking at the equation, we have calcium ammonium phosphate dissolving-- which is a solid-- dissolving into calcium ions, ammonium ions and phosphate ions. As with every equilibrium constant, we can write down an equation relating to the concentration of the species. So our ksp is the product of the concentration. And a common mistake made on this problem was that people included-- students included the calcium ammonium phosphate solid on the bottom as you normally would-- where you would normally put the reactant. However, remember that for equilibrium constants, we don't put solids in there because the activities don't change-- or the concentration doesn't change. It doesn't really make sense to add it in.

So here we just look at the solvated ions and we see that we have a 1:1:1 molar ratio here. That's going to make our life a little bit easier.

So now we need to figure out what the solubility of the compound is and to do that, we want to look at this chemical equation. We see that for one mole-- so one mole of calcium ammonium phosphate dissolved gives you one mole of the calcium ion, the sodium ion and the phosphate ion. Thus, we can say the amount of calcium ammonium phosphate dissolved, which we called Cs, is going to be equivalent to each of these concentrations.

Because we're asked for how much of the compound is dissolved, but we're given the ksp, which is in terms of the concentrations of these solvated ions. I'm sorry. This doesn't equal the product. These are all equal.

Now we can plug the Cs into our ksp equation that we had before. So instead of the concentration of calcium ions, we have-- it's equal to the concentration of the compound dissolved. The same goes for the ammonium and the phosphate, because again, we have 1:1:1:1 stoichiometric coefficients. And we can be a little more concise. Now it's just a matter of solving for the saturated concentration.

So doing some algebra here. Then we plug in the numbers. And we get that the solubility of calcium ammonium phosphate is 3.53 times 10 to the -5 moles-- molar, sorry. So that means 3.53 times -5 moles per liter of water. That's not very much. So we can say generally or relatively this calcium ammonium phosphate is not that soluble in water.

So let's move on to part B. Part B says, calculate the solubility of calcium ammonium phosphate in 2.2 molar calcium bromide. Express your answer in units molarity. Assume that in water, calcium bromide completely disassociates into calcium 2 plus cations and bromide anions.

This is basically asking us for the same value. It's asking us for the solubility of calcium ammonium phosphate, but under slightly different conditions. So we want to write those conditions down.

Now we have to ask ourselves why would the fact that we have a concentration of calcium bromide affect the solubility of calcium ammonium phosphate? And the thing to remember here is the common ion effect, right? 2 molar calcium bromide will-- when dissolved in water, the concentration of calcium from just the calcium bromide will be 2.2 molar, right? Because we're told that it completely disassociates. So if we look at the disassociation reaction, we see that for every mole of calcium bromide, we get one mole of calcium and two moles of bromide.

So having calcium bromide will alter our answer from the previous problem because the ksp will always be the same. It's an equilibrium constant, right? So even though it has to do with calcium ammonium phosphate, we have to take into account that we already have calcium in the system.

So before we start plugging in any numbers, we should think about this problem. Do we think that already having calcium in the system will increase or decrease the solubility of the calcium ammonium phosphate? Hopefully we can agree that it would probably decrease the solubility because you already have those calcium ions. So putting more calcium ions into the water is going to be harder and therefore less calcium ammonium phosphate will dissolve.

Now that we know what kind of number we're looking for, we can start doing the actual calculation. So again, we'll start with our equation for the ksp, which for calcium ammonium phosphate has not changed. I'm just going to

rewrite it on this board here. But now instead of having each of these be equal concentrations, we already have some calcium in the system. So we need to take that into account. And I'm going to call the saturation concentration Cs star because we're under different conditions, right? The calcium bromide does not contribute any ammonium or phosphate ions so those concentrations will just be determined by how much of the calcium ammonium phosphate dissolves. From before, we can use what we found in part A to simplify this a little bit. So in part A, we know that without anything else, without a common ion effect, that we have decided will decrease the solubility. We have 3.35 times 10 to the -5th molar solubility. Therefore, we can say with good certainty that our saturation concentration with the common ion effect will be much, much less than 2.2 molar because 2.2 molar is much greater than our pure solubility.

Going back to our equation over here, that means we can have-- and now we have a fairly simple algebraic problem. Dividing by 2.2 and then taking the square root, we get that the saturation concentration under these conditions-- 2.2 molar calcium bromide-- will be 1.41 times 10 to the -7 molar.

And going back to our answer from part A, we see that this is indeed a lower solubility. There's less calcium ammonium phosphate that can be dissolved and that makes sense from our previous thought about this problem.

And so now that you've found the answer, box it and we're done.