PROFESSOR: Hi, I'm Jocelyn, and today we're going to go over Fall 2009 Exam 2, Problem number 5. As always, we're going to read the problem first. Which compound do you expect to have the higher boiling point: HF or ammonia? Justify your choice with an explanation, using narrative or cartoons or both that makes reference to the operative chemical bonding. So first, we are trying to figure out which has a greater temperature of vaporization, or boiling point; and we're looking at HF and ammonia. Now when we're talking about boiling points, we're talking about breaking a certain type of bond, and that type of bond is intermolecular bonds. We're not going to be breaking the actual molecular bonds bonding hydrogen to fluorine or nitrogen, we're breaking the bonds in between molecules of HF or ammonia, and so what types of bond do we have to look at?

And Professor Sadoway, in class, went over a couple of different types of intermolecular bonds. And I'm going to write them down in order of increasing strengths. So the weakest intermolecular bonds we have are Van der Waals. The next is induced dipole-dipole. Next we have dipole-dipole, and finally a special type of dipole-dipole is the hydrogen-bond, which is the strongest. So here we're increasing strength. Van der Waals is an induced dipole-dipole. That means that although your atom or molecule does not have a net dipole, the electrons can shift, and at some point will cause a difference in polarity between different sides of the molecule. Induced dipole-dipole is two different molecules interacting: one that has no net dipole and one that does. Dipole-dipole: pretty self-explanatory. You have two molecules that have dipoles, and they are interacting. And then hydrogen-bond is when you have hydrogen bonded with x, where x is nitrogen, oxygen, and fluorine. We call that a hydrogen-bond, because these are really, really strong dipole-dipole interactions and cause much different behaviors in molecules, and so we, kind of, separate it out at the subset.

So now that we've reviewed intermolecular bonds, let's go back to the problem. So we were asked to figure out the difference, or which one has a higher vapor pressure, or temperature of boiling, so that's a relative thing. And as we now know that we need to look at intermolecular bonds, a good place to start is with the Lewis structure, because that will tell us if we have dipoles or not, and then we can see what the strongest intermolecular bond is that we need to break to boil these molecules.

So starting with HF, we have hydrogen bonded to fluorine. We know that fluorine has a much higher electronegativity than hydrogen, so we're going to have a net dipole. Well, we have a polarized bond and a net dipole towards fluorine. This causes there to be a partial positive charge on the hydrogen and a partial negative

charge on the fluorine. So what is our strongest intermolecular bond that we have for HF? Going back to our list of bonds, we see that we have a dipole, so we might first think about dipole-dipole. However, we need to remember about hydrogen bonds, and here in HF, we have hydrogen bonded to fluorine, and so that would be our strongest interaction. So let's write that down to keep track.

Now for ammonia, we have nitrogen bonded to three hydrogens, and again we have a difference in electronegativity, and so each of these bonds is polar. And because of the asymmetric geometry, we will have a net dipole, and each of these have a partially -- sorry, the hydrogens have a partially positive charge, right, because they are less electronegative, and the nitrogen has a partial negative charge. So, which is our highest or strongest intermolecular bond that we have here. Again, we have a net dipole, and so we have dipole-dipole interactions, but because hydrogen is bonded to one of the special three atoms, we have hydrogen bonding, and that is the strongest. So, that is what we care about.

So now, we're, kind of, at a roadblock here; both have hydrogen bonding, which is the strongest intermolecular bond. So how do we decide which one is actually going to be stronger than the other, and therefore, have the higher boiling point. Well even though they're both hydrogen bonds, they will have difference in strength, and that's going to depend on the partial positive and partial negative charges, because all of these interactions are due to coulombic attraction. In fluorine, we know that fluorine is the most electronegative element and has a higher electronegativity than nitrogen, so just to keep track of our thought process here: this will cause the partial positive on hydrogen to be larger in the HF than in the ammonia, and so from this we can say that the hydrogen bonding in HF will be stronger than the hydrogen bonding in ammonia, and therefore, the t evaporation of HF will be greater than the t-- the boiling point of ammonia.

So now we're going to move on to Part B.