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13 - Hydrophobic Interactions

Repelling Waters: The Art of Hydrophobic Interactions

Video 13 - Transcript

Hello everyone, Welcome to video number 13. Today we're going to be exploring hydrophobic interactions. Now, hydrophobic interactions describe the relations between water and hydrophobes, which are low water soluble molecules. Hydro - that prefix refers to water, and phobe, that suffix refers to fear. A hydrophobe is a molecule that does not like or fears water. Hydrophobes are generally non polar molecules and usually have a long chain of carbons that do not interact with water molecules. The mixing of, for example, oil and water is a good example of this particular interaction, that is hydrophobic interactions. Now the common misconception is that water and oil don't mix because the van der Waals forces of attraction that are acting upon both the water and the oil molecules are too weak. However, this is not the case. The behavior of an oil droplet in water has more to do with the enthalpy, and the entropy, than the intermolecular forces of attraction at play. Now, non polar substances like fat and oil tend to clump up together rather than distributing itself within a medium of water, because this allows the oil or fat molecules to have minimal contact with water. Take for example this image here. This indicates that when the hydrophobes come together, they will have less contact with water. The large circles indicate, let's say, an oil or fat droplet. Initially, we have a fair amount of water molecules surrounding each one. In this case, 5 & 5. When the fat droplets come together, we see that there is less interaction in all. In this case, we're showing you 6 water molecules - where we have less interaction between the hydrophobic system, which is our oil, and our hydrophilic system, which is our water. When a hydrophobe is placed in an aqueous medium, hydrogen bonds between water molecules will be broken. This is an endothermic reaction. Now, an endothermic reaction, as we might know, is one that is not extremely favorable. So, to make room for the hydrophobe, water molecules do not react with the hydrophobe. Water molecules that are distorted by the presence of the hydrophobe will now make new hydrogen bonds. These may compensate for the previous ones broken before. This results in something called a clathrate, which is an ice-like cage structure. A clathrate cage - ice like cage structure, is basically formed around the hydrophobe. This orientation makes the system more structured with a decrease in the total entropy, otherwise known as "disorder" of the system. When we have a decrease in entropy, we're saying that the change in entropy is less than zero. This decrease in entropy is relatively large and it is unfavorable. Basically, systems tend to want to increase in their disorder. An increase in disorder is favorable. A decrease in disorder is unfavorable. According to the Gibbs energy formula, which is written here, we have the change in Gibbs free energy is equal to the change in enthalpy minus the temperature multiplied by the change in entropy. Just for reference, temperature in the Gibbs free energy equation is measured in Kelvins. In this case with a small unknown value of delta H, which is our enthalpy, and a large negative value of delta S, which is our entropy, The delta G will in turn be positive, and a positive Gibbs free energy indicates an unfavorable reaction. The mixing of the hydrophobe and the water molecules is not spontaneous. Now, the hydrophobic interactions between hydrophobes it turns out that these are spontaneous. When hydrophobes come together and interact with each other, the enthalpy increases, so the delta H is positive, because some of the hydrogen bonds that form from the clathrate cage will be broken, but tearing down a portion of the clathrate cage will cause the entropy to increase. If delta H is a small positive value and delta S is a large positive value, then what happens is delta G turns out to be negative. Therefore, hydrophobic interactions are spontaneous. A large negative Gibbs free energy indicates a spontaneous reaction. Hydrophobic interactions are relatively stronger than other weak intermolecular forces that we've described before, such as hydrogen bonds and van der Waals forces. The strength of hydrophobic interactions depend on several factors. The main ones are temperature. As the temperature of a system increases, the strength of the hydrophobic interactions also increases. However, at extreme temperatures, hydrophobic interactions will tend to denature or break up. The second factor that determines the strength of a hydrophobic interaction is the number of carbon atoms on the molecule. Generally speaking, molecules with greater number of carbon atoms will have stronger hydrophobic interactions. The third main factor is the shape of the molecule, or in this case the hydrophobe. Aliphatic, which is another term for straight chains - aliphatic organic molecules have stronger interactions than aromatic ones - aromatic, referring to our cyclic or ringed compounds. This is because branches on a carbon chain will reduce the hydrophobic effect of that molecule. Linear carbon chains can produce the largest hydrophobic interactions. This is so because the carbon branches produce steric hindrance, so it's harder for two hydrophobes to have very close interactions with each other in order to minimize their contact with the water. Hydrophobic interactions are very important in biology. You will find them over and over again when you look at the forces that govern the three dimensional folding of proteins, for example. They are also important in the interaction and the formation of bilipid layers which exists in all of our cells. That's all for today. I'll see you in the next video where we're going to be looking at the differences between polar and non polar bonds. And we're going to be describing the variation in regards to electronegativity differences and the continuum of bonding across the various bonds.