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17 - pH

The pH Factor: Illuminating Chemical Equilibrium

Video 17 - Transcript

Hi everyone. Welcome to video number 17. So far in this video series, we have been looking at a large number of concepts - Atomic structure, electronic configuration; we've looked at the different types of bonding - inter- and intramolecular forces of attraction. We have looked at the range of electronegativities that bonds can display to result in either purely ionic bonds or purely covalent bonds with polar covalent bonds falling somewhere there in the middle. We also looked at functional groups. Today we want to shift gears a little bit and we want to go into a concept known as pH. In humans, one way to ensure what we call homeostasis, which is essentially the maintenance of a constant internal environment - involves the maintenance of the pH levels in our blood between 7.35 to 7.45. Now I will say that in certain organelles in our cells, for example the lysosome, the pH values are much lower, e.g. 4.5 But in general, our blood serum needs to be at around this value. Now, lower pH values are associated with conditions known as acidosis. And we can have two types of acidosis, either metabolic or respiratory acidosis. Acidosis, low pH values. On the other side, higher pH values are associated with alkalosis. Again, we can either have metabolic or respiratory alkalosis. Now, in general, pH in our bodies is maintained using buffer systems. A buffer is essentially a mixture of either a weak acid with a base or a weak base with an acid. So pH, which is what we want to explore today, is commonly known as the potential of hydrogen, and it is a measure of the acidity or the alkalinity of a particular solution. Now I'm sure we've met pH in everyday life. For example, we know that the pH of pure water is around 7. Generally speaking, water is around 7. We have our acidic solutions being below 7, We have our alkaline, otherwise known as basic solutions being above 7. An acid is defined as a substance which donates H+ ions in concentration. Essentially, if we have a substance that is a proton donor or an H+ ion donor - this is considered to be an acid. If we have a substance that accepts H+ ions, this is known as a base. The strength of an acid is essentially determined by the extent to which it ionizes in solution. This is in turn dependent on the stability of what we call the conjugate base, or the ions that are formed in solution once the acid has dissociated. Because we're looking at biological systems, we know that biological systems are comprised of organic molecules. We can have two types of acids. We can have organic acids and inorganic acids. You may be more familiar with inorganic acids such as hydrochloric acid or HCl, sulphuric acid or H2SO4. But for living systems, we're more so concerned with organic acids. These generally tend to be weaker acids than inorganic acids. That being said, if we think back to the functional groups that we looked at in the previous video, carboxylic acids, that functional group, these tend to be weak acids. We also have some alcohols that are also weak acids. Now, at the other end, if we think about amines and amides, these are considered to be weak bases. Okay? If we go back to our pH and the definition of pH - we said that pH is essentially the potential for hydrogen. Mathematically speaking, pH can be determined using this equation - pH is the -log of the H+ concentration of the ions in that solution. Now if you look in your scientific calculators, you'll see the logarithmic function sometimes also written like so. Okay? Basically what that means is that the pH scale is a logarithmic one. An increase or decrease of an integer changes the concentration of the H+ ions in solution by ten, okay? By a factor of ten. For example, if we think about the pH scale which runs 1-14 - we have 7 as neutral somewhere in the middle. A pH of three is ten times more acidic than a pH of four. Likewise, a pH of three is 100 times more acidic than a pH of five. If we think about some common solutions that we may have met in everyday life, stomach acid has a pH of about one. Tomatoes have a pH of about four. If we think of black coffee, a pH of about five. Pure water, we said, has a pH of about seven. If we think of baking soda - pH of about nine. Household ammonia, which is a cleaning agent, has a pH of about 12. These are just some general pH values of substances. As you go through your study of biology, you're going to meet different parts of the body, different cells, different tissues that will have to maintain a specific pH value or pH range in order for the enzymes within those cells to work optimally. Of course, today we're going to focus on the buffer that is present in our blood serum in order to maintain a pH of 7.3 to 7.4. In order to understand how we maintain the pH in our blood at a specific level, we have to appreciate the role of buffers. As we said before, a buffer is either a mixture of a weak acid and a base, or a weak base and an acid. In biology, there are three main relevant systems that are responsible for the maintenance of pH in specific parts of cells. The carbonic acid or carbonate system is present in our blood, and this is what is responsible for maintaining the pH there between 7.3 and 7.4 We also have what we call phosphate buffers, which are responsible for maintaining inter- and intracellular pH. We also use proteins as well, which comprise of specific weak acids and bases in order to act as our buffering agents. But today, we want to focus on this first one, which is our carbonic acid/ carbonate buffering system. This here is the equilibria that is set up amongst the components of this buffer. Here we have carbon dioxide, this is of course, water, Here we have carbonic acid, which in this case is our weak acid that is comprising our buffer, Here we have the bicarbonate ion, Here we have a hydrogen ion. The bicarbonate ion in this case is our weak base. Okay, I should say this is our base, and this is our weak acid. These two components make up the buffer. But we're showing you the relationship between carbon dioxide specifically, and this buffer system. The reason for showing this relationship is because the respiratory system can play a very important role in regulating the pH of our blood. Of course, we inhale and exhale CO2 as a regular part of breathing. If for example we have a situation where our blood pH needs to be adjusted, we can actually regulate this via adjusting the rate of respiration or breathing. We spoke a little bit about respiratory alkalosis and acidosis, and we also mentioned metabolic acidosis and alkalosis. Now, other than the respiratory system playing a role in this equilibrium that we've set up, the kidneys also plays a role in, as much as it regulates the excretion of our bicarbonate ion. This is how we have the respiratory component, via our lungs, and we have the metabolic, via our kidneys. These two aspects allows our bodies to regulate pH effectively. If we think about when we are, let's say anxious or nervous, and we begin to what we call hyperventilate - this is where, of course, we are going to be inhaling and exhaling very rapidly, and this is called shallow breathing. Now, this system or situation will lead to this equilibrium being shifted this way. Okay? Because we're exhaling so frequently, we're actually going to decrease the concentration of carbon dioxide in this equilibrium. Now, based on the Chatelier's principle, if we impose a change on a system, the system is going to move in such a direction to oppose that change. Because of our shallow breathing, we are decreasing carbon dioxide - then what's going to happen is this equilibrium is going to shift to that direction. That is going to cause the bicarbonate ion to be consumed and by extension, our hydrogen ions to be consumed. If we're removing too many hydrogen ions, then what that causes is respiratory alkalosis. Okay, on the other side of things, respiratory acidosis, this is going to be caused by, for example, pulmonary disease - any situation where you have, for example, pneumonia or asthma - basically where the lungs are not working properly - and we are not able to remove CO_2 effectively - that is going to cause a build up hydrogen ions, and therefore an increase in the pH of our blood. I hope that you now have a better understanding of what pH is, the formula that we can use to calculate it, the scale that we use, 1 - 14, the pH of common everyday solutions, and the role that buffers play in the maintenance of pH or homeostasis in our bodies. That's all for today. I'll see you guys in the next video, where we will be looking at acid/base reactions.