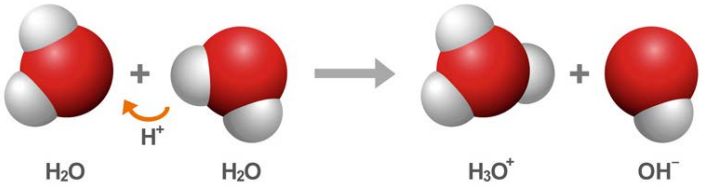
5th Grade - Lesson 3.4
Chemical Reactions and Color Change
Teacher Background

In Lesson 3.4, students investigate the effect of an acid and a base on a pH indicator made from red cabbage.

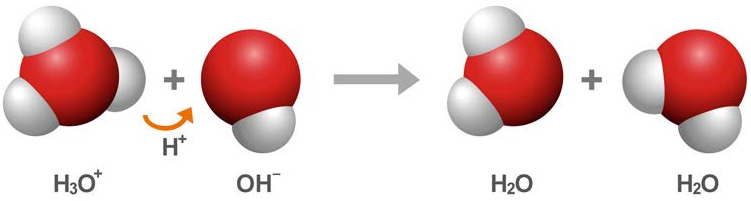
Water Molecules Transfer Protons

Acids and bases and their effect on pH is really about water. We think of water as H_2O, but water molecules are constantly reacting with each other and changing. When two water molecules react, a proton from a hydrogen atom in one water molecule transfers to the oxygen atom in the other water molecule.

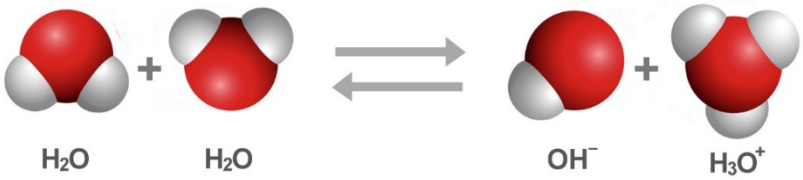


For the water molecule that gained the proton, it's like gaining another hydrogen atom (but without the electron). So that water molecule changes from H_2O to become the ion H_3O^+ (hydronium). It is "H_3" because there are now three hydrogen atoms and "$^+$" because there is an extra positive charge since there are only two electrons but three protons associated with the three hydrogen atoms within the molecule.

The water molecule that loses the proton changes from H_2O to become the ion OH^- (hydroxide). It has only one "H" because it lost a proton, which is like losing a hydrogen atom, even though it left the electron behind. It has a "$^-$ " because it now has one more electron than proton.

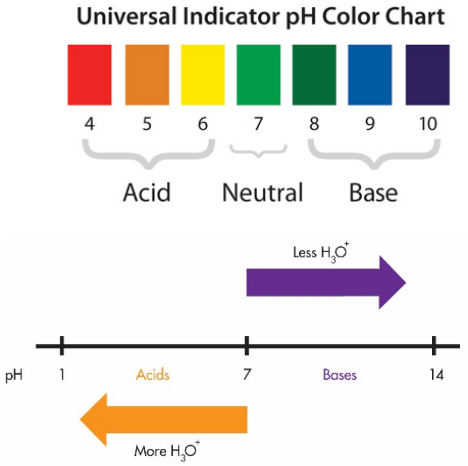


But the H_3O^+ and the OH^- also react with each other. In this reaction, the extra proton in the H_3O^+ is transferred back to the OH^- to form two water molecules again.



So, in pure water, both of these reactions happen at the same time and result in small but equal concentrations of H_3O^+ and OH^- at any given time. The arrows pointing in both directions indicate that this process happens back and forth, at the same rate.

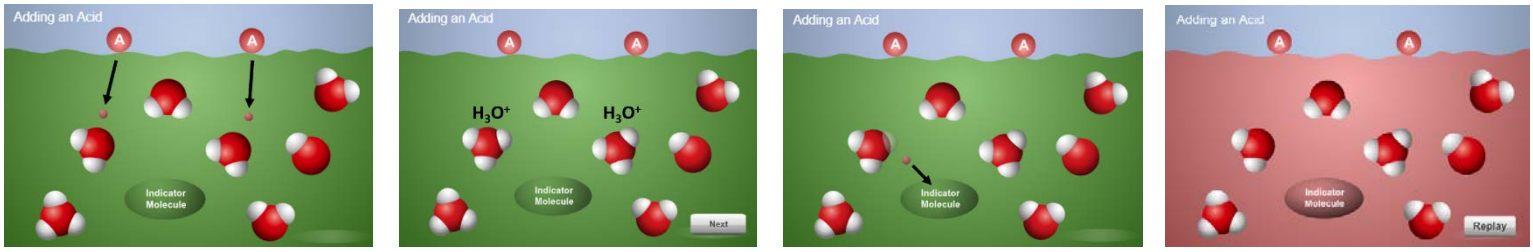
The pH Scale



The famous pH scale is actually a measure of the concentration of H_3O^+ ions in a sample of water. Because of the way the pH scale is set up, the higher the concentration of H_3O^+ ions, the lower the number on the pH scale. When water is neutral (neither acid or base) it has a pH of 7. If a solution has more H_3O^+ than OH^-, it is an acid and will measure a pH *lower* than 7. If a solution has less H_3O^+ than OH^-, it is a base and will measure a *higher* number on the pH scale.

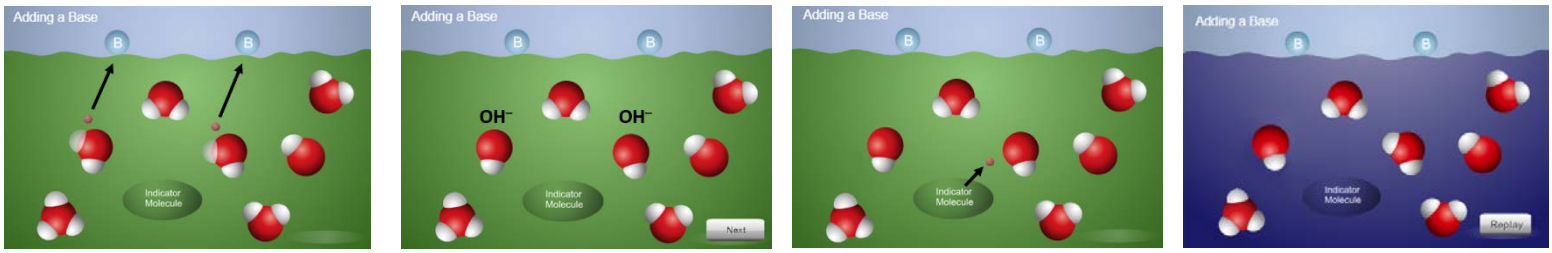
Acids Donate Protons to Water

Acids and bases are substances that interact with water and with a pH indicator in a special way. When an acid is added to water, protons from the acid molecules react with some of the water molecules. Since these water molecules now have an extra positive charge, they become positively charged ions (H_3O^+) and make the water acidic. A proton from these H_3O^+ ions is transferred to the indicator which causes a shape change of the indicator molecule and a color change.



Bases Accept Protons from Water

When a base is added to water, some water molecules lose a proton to the base. Since these water molecules now have one fewer positive charge, they become negatively charged ions (OH^-). These OH^- ions react with the H_3O^+ ions to form water. This reduces the concentration of H_3O^+ and makes the water basic. A proton from the indicator is also transferred to these OH^- ions which causes a shape change of the indicator molecule and a color change.



Note: The animation used in the lesson is a much simpler version and does not show these steps in this much detail. The animation in the lesson shows an acid donating a proton directly to the indicator causing a shape change and color change.

It also shows a base accepting a proton directly from the indicator, resulting in the indicator changing shape and color.