Garden-Variety Indicators

In any reaction where there is a change in pH, an indicator is a useful tool. As the pH of a solution reaches certain values, the color of the indicator changes, sometimes dramatically. An excellent example of this color change occurs during the process of titration. Titration is a laboratory procedure used to determine the unknown concentration of an acid or base. During titration, an acid of known concentration is added to a base of unknown concentration (or vice versa) that has been mixed with an indicator. The reaction reaches its endpoint when the moles of hydroxide ions equal the moles of hydronium ions in the solution. At this point the indicator changes color, alerting the scientist that the endpoint has been reached. Then the volumes of each component solution and the known concentration can be used to calculate the unknown concentration.

Acid-base indicators are usually weak acids or weak bases that have different colors in the acid and base forms. If HIn is the acid form of the indicator and In^- is its conjugate base, then the solution can be described by the following equation when it is at equilibrium:

$$HIn \leftrightarrow In^- + H^+$$

If a solution has the color of HIn, it is acidic; if it has the color of In^-, the solution is basic. The color changes seen during a titration are a good illustration of Le Chatelier's principle at work: When a system at equilibrium is stressed, the system will react in a way that restores equilibrium. If the system is acidic, equilibrium shifts to the left and HIn is produced. If the solution is basic, however, equilibrium shifts to the right and In^- is produced. Each shift is indicated by a color change. The color stops changing once equilibrium has been reached.

Litmus indicator is made from a creepy-looking lichen.

An acid-base indicator can easily be made from red cabbage.

Indicators have been used throughout the history of chemistry, and they are quite commonly found in nature. One indicator that has been used for centuries is litmus paper. You may be familiar with this tool, which is made of paper that has been dipped in litmus dye, allowed to dry, and cut into strips. Litmus paper is red in acidic solution and blue in basic solution. For centuries, this indicator has been extracted from *Roccella tinctoria*, a lichen. The compound in litmus that changes color when protonated is *7-hydroxyphenoxazone*. Another, more common, indicator can be found in red cabbage. You can't find a more common, everyday material than cabbage. Red cabbage contains a compound classified as an *anthocyanin*.

Anthocyanins are water-soluble, colored compounds that are present in most plants. These compounds can be used as indicators but also can provide coloration for fruits and flowers. Anthocyanins are red in acid. They turn purple under neutral and mildly basic conditions and turn green or yellow in strong base. In nature, the bright reds and purples in flowers attract pollinators. Meanwhile, the same colors in fruits attract animals that help propagate seeds. Anthocyanins also provide a sort of "sunscreen" that protects vulnerable leaves from too much sunlight. In fact, this explains why many of the first small leaves of spring have a reddish color.

The concentration of anthocyanin varies greatly among plants. Because of this, some plant juices make better indicators than others. Besides red cabbage, plants with high concentrations of the pigment include geraniums, poppies, roses, blueberries, black currants, and rhubarb stems. Red cabbage is usually the choice suggested for a homemade indicator. For this, you will need a red cabbage, a knife or grater, a blender, and a coffee filter. Chop or grate about a cup of the cabbage and put it in a blender with a cup of water. Turn on the blender, and gradually increase the speed to high. Strain off the juice using a coffee filter, cloth, or anything that will trap the cabbage bits. Keep the juice in the refrigerator and throw out the chopped cabbage, or use it to make coleslaw.

Try out the cabbage indicator with some common household solutions. Some of these might provide interesting results:

- baking soda and water solution
- window cleaner
- lemon juice
- vinegar
- soft drinks

Add a tablespoon of the indicator to these liquids and see what happens. Then take one of the bases (green or yellow solutions) you have colored with indicator and watch the color changes as you make stepwise additions of acid. Next, watch the reverse color change as you add base to acid. Another colorful example of an indicator in nature is the hydrangea flower. The color of a hydrangea blossom can tell you whether y0ur soil is acidic or basic. Some strains of hydrangea are blue in acidic soil and bright pink in basic soil (the opposite of red cabbage colors). The plants need aluminum to make the pigment that colors the flowers blue, but they cannot absorb aluminum if the soil is too basic. In this case, the flowers are pink when they bloom.

Hydrangeas are pink in basic soil and blue in acidic soil.

Color changes in nature are often related to survival mechanisms used by organisms in the world around us. Luckily for us, the color change also helps us enjoy and understand our world.