# Teacher Guide: pH Analysis: Quad Color Indicator

## Learning Objectives

Students will…

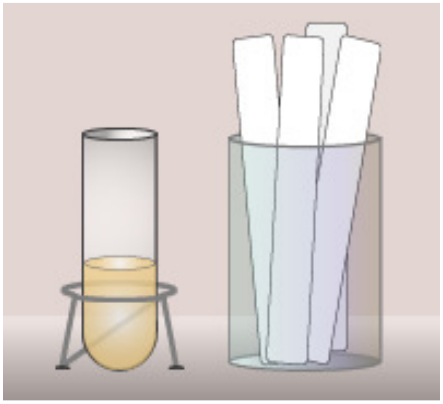
- Use four-color pH paper to find the pH of a variety of substances.
- Describe some of the qualities of acids and bases.

## Vocabulary

acid, acidic, alkaline, base, indicator, neutral, pH

## Lesson Overview

The *pH Analysis: Quad Color Indicator* Gizmo™ allows students to measure the pH value of a variety of household substances using a four-color indicator paper. Two types of pH indicator are available: 0-14 paper and 4.5-7.5 paper.



*(Note: This Gizmo was designed as an alternative to the pH Analysis Gizmo. The only difference between the Gizmos and associated activities is the type of pH indicator paper shown. We suggest you use the Gizmo the matches the type of paper found in your classroom.)*

The Student Exploration sheet contains two activities:

- Activity A – Students measure pH using 0-14 indicator paper.
- Activity B – Students measure pH using 4.5-7.5 indicator paper.

## Suggested Lesson Sequence

1. **Pre-Gizmo activity** (5 – 10 minutes)
   Practice using pH indicator paper to measure the pH of various substances. (Students should wear aprons/lab coats, goggles, and latex gloves if they are handling strong acids or bases.)

   After measuring pH, ask students to describe some of the common properties of acids and bases. For example, some bases such as soap are slippery to the touch and have a bitter taste. Acidic foods tend to be tart or sour. (Do NOT taste strong acids or bases.) Strong acids can corrode metal, while strong bases help to break down organic matter such as a hairball that is blocking the drain in a bathroom sink.

2. **Prior to using the Gizmo** (10 – 15 minutes)
   *Before* students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
   As students are working or just after they are done, discuss the following questions:
   - Which of the substances in the Gizmo are acids? Which are bases?
   - Suppose you could only afford one type of pH indicator paper. Would you buy 0-14 paper or 4.5-7.5 paper? Why?
   - Based on what you have seen in the Gizmo, predict whether the following substances are acidic or alkaline:
     - Grapefruit juice [acid]
     - Laundry detergent [usually a weak base]
     - Sweet tart candy (dissolved in water) [acid]
     - Antacid [weak base]

5. **Follow-up activity: Cabbage pH indicator** (30 – 60 minutes)
   An *acid-base indicator* is a substance that changes color when the pH changes. Along with commercial pH paper, several natural substances can be used as indicators. The most well-known natural pH indicator is red-cabbage juice. Boil red cabbage leaves for several minutes in a small amount of water. Pour the red juice into a large beaker and use this juice as a pH indicator. The cabbage juice turns pink in an acid and green or yellow in a base. (See the **Selected Web Resources** on page 3 for details.)

   Other natural substances can also be used as indicators:
   - Red beet juice changes from red to yellow in strong bases.
   - Curry powder and turmeric are spices that contain a bright yellow pigment that changes from yellow to red in bases (pH > 8.5).
   - Blueberries turn red in strong acids (pH < 3).
   - Strong black tea becomes lighter in color when acids are added.

## Scientific Background

An *acid* is a substance that, when dissolved in water, produces an excess of hydrogen ions ($H^+$). The chemical formula of an acid often begins with H, as in HCl (hydrochloric acid), $HNO_3$ (nitric acid), and $H_2SO_4$ (sulfuric acid). Weak acids such as lemon juice are sour in taste and can burn the skin or eyes. Strong acids corrode metals and can help break down foods.

A *base* is a substance that can accept hydrogen ions. Many bases are *alkalis*: they produce excess hydroxide ions ($OH^-$) when dissolved in water. The chemical formula of an alkali usually ends in OH, as in NaOH (sodium hydroxide) and $NH_4OH$ (ammonium hydroxide). Weak bases such as soap are bitter in taste and slippery to the touch. Strong bases are poisonous and can break down organic materials such as hair and skin.

Acids and bases react to form water and a salt. For example, hydrochloric acid (HCl) reacts with potassium hydroxide (KOH) to form water ($H_2O$) and potassium chloride (KCl):

$$HCl + KOH \rightarrow H_2O + KCl$$

The *pH scale* measures the activity of hydrogen ions in solution. The definition of pH is as follows:

$$pH = -\log_{10} a_H$$

In this formula, the term $a_H$ stands for the activity of hydrogen ions. The value of $a_H$ depends on the concentration of hydrogen ions and a coefficient that depends on the properties of the dissolved substance. Because of the negative sign in the formula, a smaller pH corresponds to a *greater* activity of hydrogen ions. The formula is also logarithmic, which means that a tenfold increase in hydrogen ion activity produces a one-point decrease in pH. For example, an acid with a pH of 2 is 100 times more acidic than an acid with a pH of 4 (and 10 times more acidic than an acid with a pH of 3). Substances with a pH below 7 are acidic, those with a pH above 7 are alkaline (basic), and those with a pH of exactly 7 are neutral.

**Cultural Connection: Kitchen chemistry**

Acids and acid-base reactions have many uses in cooking. Some examples include marinades, brines, and leavening agents.

When meat is cooked, heat causes protein molecules to uncoil, or become *denatured*. This process generally causes the meat to become firm in texture and opaque in color. Proteins can also become denatured when exposed to acid. This effect is the basis for *ceviche* (seh-VEE-chay), a popular seafood dish in Latin America. In ceviche, the raw fish is “cooked” without heat by a marinade of lemon and lime juice.

Ceviche is an example of the ancient art of pickling food. Pickling refers to storing food in an acid solution, or brine, with a pH below 4.6, low enough to kill harmful bacteria. Some foods are pickled by adding vinegar. Other foods, such as sauerkraut, produce their own brine when salt is added to the food to draw out water. Anaerobic respiration by microbes in the developing brine produces lactic acid, thus lowering the pH of the brine to a safe level.

Baking powder is a mixture of baking soda, cornstarch, and a dry acid. When baking powder is added to moist dough, the acid reacts with the baking soda, producing bubbles of carbon dioxide. The gas bubbles are trapped in the dough and expand as the dough is baked. This results in a lighter and fluffier texture for cakes, muffins, and other baked goods.

**Selected Web Resources**

Acid-base basics: http://www.chem4kids.com/files/react_acidbase.html
Acids, bases: http://www.files.chem.vt.edu/RVGS/ACT/notes/Notes_on_acids_and_bases.html
The pH scale: http://www.hbci.com/~wenonah/hydro/ph.htm
Cabbage juice indicator lab: http://www.middleschoolscience.com/cabbage.htm
Natural indicators: http://www.pharmainfo.net/reviews/natural-ph-indicators-review
Pickle science: http://ezinearticles.com/?Pickles---Science-in-Your-Kitchen&id=1051549

Related Gizmo:
*pH Analysis*: http://www.explorelearning.com/gizmo/id?432