pH People

Adapted from: "Where Are the Frogs?" in Project WET: Curriculum & Activity Guide. Bozeman: The Watercourse and the Council for Environmental Education, 1995.

Grade Level: basic

Duration: 10 – 15 minutes

Setting: classroom or field site

Summary: Students become the atoms in water molecules to act out changes in pH.

Objectives: Students will gain an understanding of the concepts behind pH, recognizing what happens at the atomic level, and understanding how water is acidic and basic.

Related Module Resources:
- "pH Test #1, #2, #3, #4, #5"
- pH Information/Fact Sheet
- pH meter
- Hach pH kit
- pH paper
- HANBOOK: pH section
- FIELD MANUAL: p.33-35

Vocabulary: dissociate, ions, pH, neutral, acidic, basic, alkalinity

Materials (Included in Module):
- 20 hydrogen ion (H+) labels
- 10 oxygen ion (O^{-2}) labels
- 30 "e" labels (name tags)

Additional Materials (NOT Included in Module):
- additional labels if needed

ACADEMIC STANDARDS (ENVIRONMENT AND ECOLOGY)

7th Grade:
4.1.7.B Understand the role of the watershed.
- Explain factors that affect water quality and flow through a watershed

4.3.7.B. Describe how human actions affect the health of the environment.
- Explain how acid deposition can affect water, soil and air quality.

12th Grade
4.1.12.C Analyze the parameters of a watershed.
- Interpret physical, chemical and biological data as a means of assessing the environmental quality of a watershed

BACKGROUND:

Water molecules (H2O) are made up of two hydrogen atoms attached to an oxygen atom. However, water molecules sometimes **dissociate** or break apart. The water molecule splits into a hydroxide ion (OH-) and a hydrogen ion (H+). **Ions** have unequal numbers of protons and electrons. If an ion has more protons than electrons, it will have a positive charge. On the other hand, if it has more electrons than protons, its charge will be negative. Very few water molecules dissociate, but life processes depend on the small number that do.

When water dissociates, it produces an equal number of hydrogen ions and hydroxide ions. If another compound that dissociates is introduced, the ions of water and of the compound can react or combine with each other. Ions of hydrogen are more likely to react with other dissociated compounds, but hydroxide ions can also. Examples of compounds that dissociate and react with these ions include sulfuric acid (H2SO4) and calcium carbonate (CaCO3).

pH is a measure of the concentration of free hydrogen ions, which will indicate whether a solution is acidic or basic. Specifically, pH is equal to the negative log of the hydrogen ion concentration (pH = -log10[H+]). The numerical value does not have a unit (like mg/L) per se, but must be listed alongside the term pH. The values for pH are arranged on a scale from 0 to 14. A pH of 7 indicates the solution is neutral and the concentration of H+ is equal to the concentration of OH-. Values of pH less than 7 are considered acidic (more H+ are present, less OH-). Values of pH greater than 7 are considered basic (less H+ are present, more OH-). Because pH is determined based upon a log scale, each unit change in pH indicates a ten-fold difference in the concentration of hydrogen ions. For example, water at pH 5 is ten times more concentrated with H+ than water at pH 6.

The pH of water is very important to water quality because it controls the types and rates of many chemical reactions in water, and aquatic organisms have a specific pH range in which they can live.

OVERVIEW: Through a simulation, students represent the components of water to gain a better understanding of pH.

PROCEDURE:

1. The class should be divided into thirds. The students from one group will represent oxygen atoms and those from the remaining two groups are hydrogen atoms. Give them the appropriate labels. Have them hold the labels in front of them. The hydrogens should also each get one “e” label to represent their electron. Also hold this label up.

2. Form groups of three – two hydrogens and one oxygen – to represent water molecules. The hydrogens should stand one either side of the oxygen. The class now represents water that has all molecules intact.

3. Explain to the class that water molecules do not always stay complete. Sometimes molecules will break apart or dissociate. Have two or three of the groups break up into hydroxide (OH-) and hydrogen (H+) ions.

4. Have each lone hydrogen ion give his or her “e” to the hydroxide ion. This represents an electron that has been lost by the hydrogen ion and gained by the hydroxide. Explain that hydrogen is a positive ion (possessing one proton and no electrons) and hydroxide is a negative ion (possessing an extra electron).

5. Explain that the class now represents a neutral water sample ($pH = 7$) because there are equal numbers of OH- and H+. Tell the students who split apart to recombine (back to water) and have another two or three groups dissociate – the solution still remains neutral ($pH = 7$).

6. Tell students that a compound or element that attracts the OH- has been added to the solution. Remove three or four hydroxides (OH-) from the mix. Tell students that there are now more H+ than OH-. Explain that this makes the solution acidic ($pH < 7$).

7. Have the hydroxides (OH-) go back in solution. Some things react with the hydrogen ions, so remove some hydrogen ions. Explain that the solution is now basic ($pH > 7$).

8. Sometimes things are added to water that add hydrogen ions. For instance, acid rain (sulfuric acid H_2SO_4 or nitric acid HNO_3) will dissociate (break down) and produce extra hydrogen ions (H_2SO_4 □ $2H^+ + SO_4^{-2}$; HNO_3 ► $H^+ + NO_3^-$). So this time, you the teacher, grab a bunch of hydrogen ion labels and add yourself to the group. Who better to be acid rain than the teacher.

9. Explain that there are compounds that can attach to extra hydrogen ions in the water. For instance, carbonate (CO_3^{-2}) and bicarbonate (HCO_3^-) are present in many Pennsylvania waterways. Because they have a negative charge and are unstable, they are eager to find an extra hydrogen or two to combine with. Carbonate (CO_3^{-2}) will react with a free hydrogen ion (H^+) to form bicarbonate (HCO_3^-). Bicarbonate will react with a free hydrogen ions to create carbonic acid (H_2CO_3). This reduces the number of free hydrogen ions in the water, thus raising the pH. **Alkalinity** is a measure of the ability of a water system to resist changes in pH (gets rid of extra hydrogen ions that are added). See the Alkalinity Information Sheet for more information on this process.

DISCUSSION:

What is pH actually measuring? *pH is a measure of the concentration of free hydrogen ions (H^+).*

How might more hydrogen ions be added to water, making it more acidic? *Additions like acid rain (nitric or sulfuric acid dissociates producing extra hydrogen ions), acid mine drainage, or an industrial pollutant that has a low pH. Also, a compound may be added that attracts the hydroxides (OH-).*

EVALUATION:

- Explain what basic and acidic mean on an atomic level.

EXTENSIONS AND MODIFICATIONS:

- Draw the water molecule or create models of the water molecule.
- Use this as an introduction to any of the "pH Test" activities.
- Discuss how acid rain dissociates adding extra H+ to water. Discuss how alkalinity can buffer against the extra H+.

NOTES (TEACHERS, PLEASE WRITE ANY COMMENTS ABOUT THIS ACTIVITY BELOW):

Activity Version: November 2021

Hydrogen
(H^+)

Hydrogen
(H^+)

Oxygen
(O^{-2})

Oxygen
(O^{-2})

If you have become a hydroxide ion (hydrogen person + oxygen person) both of you display this label together

Hydroxide Ion

(OH^-)

If you have become a hydroxide ion (hydrogen person + oxygen person) both of you display this label together

Hydroxide Ion

(OH^-)

Photo copy onto the back of the hydrogen sheet

e

Electron

e

Electron

e

Electron

e

Electron

e

Electron

e

Electron