Plants, Fish and pH

Adapted from: A Study of Water Quality, Chestertown, MD: LaMotte Company, 1968.

Grade Level: advanced

Duration: 45 – 60 minutes, plus preparation time

Setting: classroom or laboratory

Summary: Students measure pH to determine how animals and plants affect it with photosynthesis, respiration, and decomposition.

Objectives: Students will gain an understanding of the chemical reactions that occur during respiration and photosynthesis, as well as link biotic and abiotic components of an ecosystem.

Related Module Resources:

- "pH Test #1, #2, #3, #4, #5" Activities
- "pH People" Activity
- HANBOOK: pH & Oxygen sections
- FIELD MANUAL: p.33-35
- pH Information/Fact Sheet
- pH Scale Poster

Vocabulary: aerobic respiration, decomposition, pH, acidic, basic, neutral, alkalinity

Materials (Included in Module):

- plastic wrap
- 20 or more clear cups

Additional Materials (NOT Included in Module):

- goldfish (5 **minimum**)
- aquatic plant, such as Elodea (20 three inch pieces at **minimum**) This is commonly found at pet stores, so pick it up when you buy your fish.
- distilled water
- source of sunlight/sun lamps
- pH meter from your kit
- aquarium set up for your new goldfish class pets
- Dissolved Oxygen Test Kit

ACADEMIC STANDARDS (ENVIRONMENT AND ECOLOGY)

7th Grade:

4.6.7.A Explain the flows of energy and matter from organism to organism within an ecosystem.
- Identify the relationship of abiotic and biotic components and explain their interaction in an ecosystem

4.6.7.B. Explain the concepts of cycles.
- Identify and explain cycles within an ecosystem.
- Analyze the role of different cycles within an ecosystem.

4.6.7.C Explain how ecosystems change over time.
- Explain how specific organisms may change an ecosystem

10th Grade

4.6.10.B. Explain how cycles affect the balance in an ecosystem.
- Describe an element cycle and its role in an ecosystem.
- Explain the consequences of interrupting natural cycles.

12th Grade

4.6.12.A Analyze the interdependence of an ecosystem.
- Analyze the relationships among components of an ecosystem

ACADEMIC STANDARDS (SCIENCE AND TECHNOLOGY)

7TH Grade

3.2.7.B Apply process knowledge to make and interpret observations.
- All subsections apply

3.2.7.C Identify and use the elements of scientific inquiry to solve problems.
- All subsections apply

10th Grade

3.2.10.B Apply process knowledge and organize scientific and technological phenomena in varied ways
- All subsections apply

3.2.10.C Apply the elements of scientific inquiry to solve problems
- All subsections apply

12th Grade

3.2.12.B Evaluate experimental information for appropriateness and adherence to relevant science processes.
- All subsections apply

3.2.12.C Apply the elements of scientific inquiry to solve multi-step problems
- All subsections apply

BACKGROUND:

The pH of a waterway naturally fluctuates because of the processes of photosynthesis, respiration, and decomposition. Aquatic animal life (fish, insect larva, snails, and bacteria) obtain energy for growth and function by taking in oxygen from the water and by obtaining carbon and hydrogen found in organic matter they eat. **Aerobic respiration** is the process by which cells use oxygen to free the energy stored in the chemical bonds of food molecules. When the energy is released, carbon dioxide (CO_2) and water are released also at the same time.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$

glucose, oxygen, carbon dioxide, water, ATP, heat

Oxygen is consumed and carbon dioxide is produced. This is also the case with the process of **decomposition** (break down of organic matter). When carbon dioxide is respired or decomposed into water, it can combine with a water molecule to form carbonic acid (H_2CO_3). The carbonic acid can dissociate (break apart) producing bicarbonate ions (HCO_3^-) and hydrogen ions (H^+).

$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+$

carbon dioxide, water, carbonic acid, bicarbonate, hydrogen

The hydrogen ions are significant because it is the amount of hydrogen in the water that determines pH. More hydrogen ions in the water lowers the pH or makes the water more acidic. Therefore, the rate at which carbon dioxide is respired or decomposed into the water can be indirectly measured by investigating the rate at which water becomes more acidic. The relationship is more apparent in a closed aquatic environment (aquarium, small pond) with limited outside influences (pollution, Loch Ness Monster splashing).

There is something that can help use the carbon dioxide before it has the chance to form carbonic acid and change the pH – plants and photosynthesis. For growth and photosynthesis, aquatic plant life, from the smallest algae to the biggest rooted weed, needs carbon dioxide, water, and light energy. This process produces oxygen (useful to aquatic creatures) and organic compounds (glucose and other sugars, starches, proteins) that contain the carbon from the carbon dioxide.

With photosynthesis and respiration/decomposition processes ongoing in a waterway, there can be a balance in the amount of carbon dioxide produced and taken up, helping to maintain a constant pH. However, in nature, this balance can shift slightly. During daylight hours, plants are photosynthesizing using carbon dioxide and raising the pH, but at night respiration occurs, adding carbon dioxide and lowering the pH. A pH of a contained aquatic environment with plants is often highest in late afternoon and lowest right before dawn. This assumes that decomposition rates are not exceeding photosynthesis rates.

Experiments using aquariums can be used to demonstrate the carbon dioxide – pH relationship.

OVERVIEW: Students study the relationship between carbon dioxide and pH in water by experimenting with aquatic creatures that add carbon dioxide to water and plants that remove carbon dioxide from water.

PROCEDURE:

Teacher Preparation:

Go shopping. Buy lots of goldfish and some kind of aquatic plant, such as Elodea, that can ideally be cut into smaller segments. Elodea is commonly found at pet stores, so pick it up when you buy your fish. The number of fish and amount of plants will depend on

how many experimental trials you are going to have the class conduct or how many lab groups you have.
Per set of 5 experimental cups – you will need 2 fish and 15 inches of Elodea/plant.
You also need to purchase distilled water if not readily available at your school.

***NOTE: Fish need to acclimate to water temperatures or they undergo unnecessary stress. Therefore, it is important to make sure that the water the fish is in originally and the water that it will be transferred to are the same temperature. Let all water become room temperature.

You also need to decide what clear plastic cups you are going to use for the experiment. There are two sized plastic cups provided in the module, the smaller cups will yield better results but is more stressful to the fish – it is up to you.

Student Instructions

1. Calibrate the pH meter using the instructions in the Test Kit Instruction Section of the Module Resource Guide.

2. Label 5 clear plastic cups (#1,#2,#3,#4,#5). Fill the 5 cups with distilled water (no chlorine!) to about 1 cm below the rim. All cups should have the same volume of water.

3. Measure and record the pH of each cup using the instructions in the Test Kit Instruction Section of the Module Resource Guide. Record pH on the data sheet.

4. Add the following contents to the 5 cups and record the time that you placed the contents in each cup:
   Cup #1 – add nothing, just water (control)
   Cup #2 – 1 fish
   Cup #3 – 1 plant, three inches in length
   Cup #4 – 3 plants, each three inches in length
   Cup #5 – 1 fish and 1 plant (3 inches in length)

5. If possible, place cups in the sun or under a light to promote photosynthesis in the plant cups.

6. Measure the pH of each cup after approximately 10 minutes, 20 minutes, and 30 minutes has elapsed. This time elapsed should be based on your initial times for each cup. Record data on data sheet.

7. Your teacher may indicate to your group that your 5 cups will be used to continue the experiment. These cups should be placed in a lighted area. Cover all with plastic wrap. Place the wrap **directly on top** of the water, rather than simply covering the top of the container. This will prevent gas exchange with the air. The pH of the cups will be measured 1 hour later and 3 hours later. Your teacher will measure the pH after 1 hour and 3 hours or have another class do it.

Teacher Note:
You may elect to make a set of 5 cups 3 hours ahead of time (measuring the initial pH) in order for the class to take a "3 hours elapsed" pH reading.

8. Follow instructions from your teacher for cleaning up your experiment.

9. When your group is finished collecting your data, you should create a graph that shows all five of your cups results. This will make it easier for comparisons to be made.

DISCUSSION:

Discuss the results with the students. How was the pH of the fish cups affected? *They should have a lower pH, becoming more acidic because the fish were respiring CO_2 into the water. The CO_2 can combine with a water molecule to form carbonic acid (H_2CO_3). The carbonic acid can dissociate (break apart) producing bicarbonate ions (HCO_3^-) and hydrogen ions (H^+). The hydrogen ions lower the pH.*

How was the pH of the plant cups affected? *They should have become higher pH because photosynthesis removed CO_2 from the water. But this may not have been evident until a few hours elapsed.*

How would you account for a plant cup that became more acidic? *Plants respire in addition to photosynthesizing, especially at night. If the plant cup became more acidic, respiration {which produces CO_2 that will eventually form H_2CO_3} occurred too much to be balanced by photosynthesis {which produces CO_2} – see the Background section for more information.*

During the night or a really cloudy day, how would the presence of plants affect the water? *Because they cannot photosynthesize without light, the plants would take up less CO_2 , allowing it to form carbonic acid and dissociate adding hydrogen ions. Plant respiration would also add CO_2 to the water.*

What would happen to the cup's pH if the fish dies or the plant dies and remains in the cup? *Decomposition is like aerobic respiration in that it will produce CO_2 into the water and potentially lower the pH.*

Did the pH remain constant in the control cup? Did the pH remain constant in the cup with 1 fish and 1 plant? Did you expect the results that you obtained from these cups?

Why might you not see this CO_2 – pH relationship as easily in the waterway you study? *There may not be a balance between plant and animal life. This imbalance may be natural (death of aquatic plants in the late fall/winter or the addition of organic matter to decompose). The imbalance may be unnatural also (pollution inputs, nutrient enrichment, killing aquatic life, adding herbicides killing plants, adding organic inputs that increase decomposition rates).*

EVALUATION:

- Explain how carbon dioxide in water can lower the pH.
- Complete the aquarium experiments visual handout correctly.

- Correctly conduct the experiment and complete the data sheet.
- Correctly graph the data of a group's 5 cups or graph the data of the entire class for one experimental condition.
- Write the chemical equation for aerobic respiration and or the creation/dissociation of carbonic acid.

EXTENSIONS AND MODIFICATIONS:

- Do the experiment only with fish, measuring them at 10, 20 and 30 minutes. This will make the experiment simpler, but will not demonstrate how plants affect the water.
- Over a longer period of time, you could set up 2 aquariums, one with only fish and one with only plants and see if the pH levels differ between the two.
- Before discarding the sample treatments, do a dissolved oxygen test on the water to see if the fish water has a lower DO than the plant water.

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

Activity Version: November 2021

DATA SHEET: PLANTS, FISH, AND pH

Student Name_____ Date_____

Group's pH Data:

Initial Time	How much time elapsed (min.)	#1 Control pH level

Initial Time	How much time elapsed (min.)	#2 Fish pH level

Initial Time	How much time elapsed (min.)	#3 1 Plant pH level

Initial Time	How much time elapsed (min.)	#4 3 Plants pH level

Initial Time	How much time elapsed (min.)	#5 1 Plant 1 Fish pH level

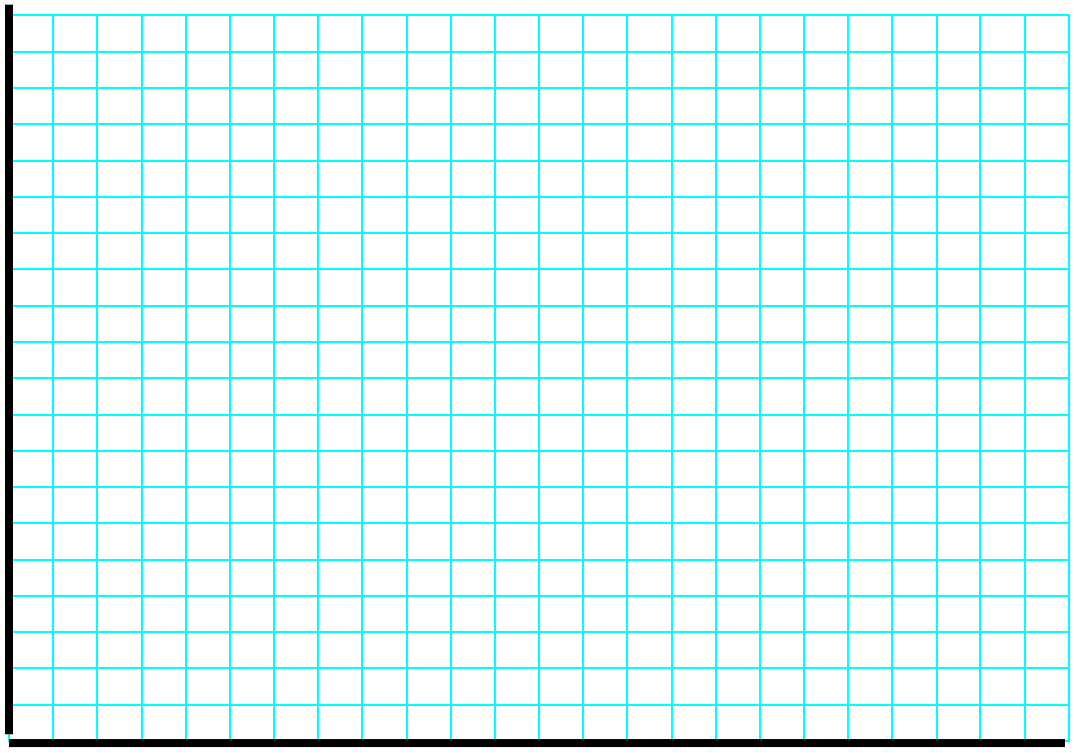
Notes:

GRAPHS: PLANTS, FISH, AND PH

**Optional to use, you may want your student to create their own graph.*

Student Name_____ Date_____

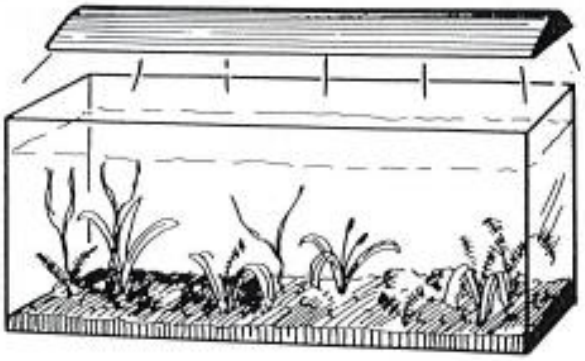
GRAPH TITLE:_____



pH Level

Time Elapsed (minutes)

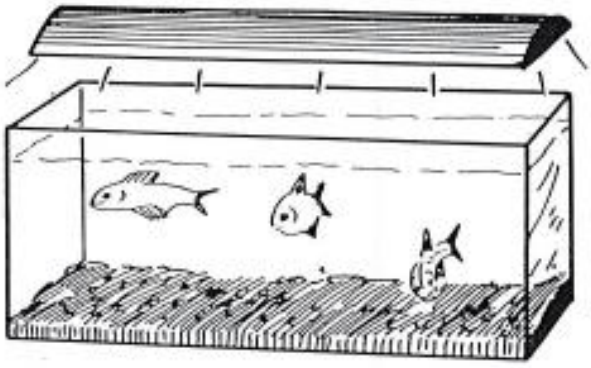
Worksheet Answer Key



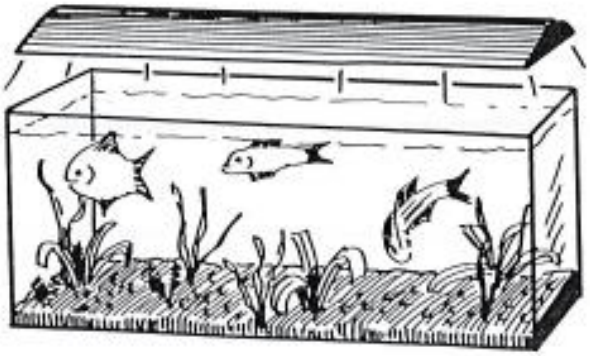
CARBON DIOXIDE - DECREASES
OXYGEN - INCREASES
pH - INCREASES

A. PLANTS ONLY

CARBON DIOXIDE - INCREASES
OXYGEN - DECREASES
pH - DECREASES



B. FISH ONLY



CARBON DIOXIDE - BALANCED
OXYGEN - BALANCED
pH - BALANCED

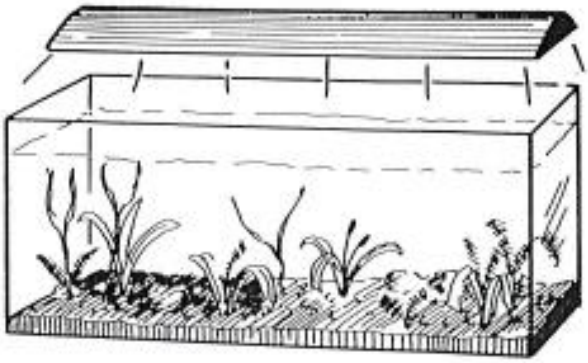
C. PLANTS AND FISH

Fig. 7 Aquarium (A) with plants only will show a decrease in carbon dioxide, an increase in oxygen and an increase in pH. Aquarium (B) with fish only will show an increase in carbon dioxide, a decrease in oxygen and a decrease in pH. Aquarium (C) with both fish and plants shows a proper balance of carbon dioxide and oxygen and the pH value will remain constant.

Source: Charles Renn. A Study of Water Quality. Chestertown, MD: LaMotte Company, 1968.

Name: _____

Circle the best answer for each question.

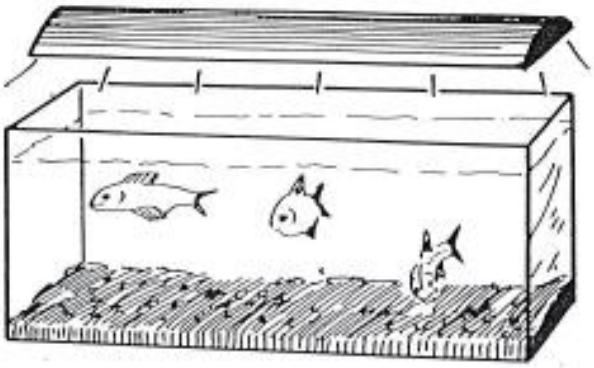


A. PLANTS ONLY

In this aquarium setting, do you think the:
carbon dioxide will **increase, decrease, or remain constant?**

oxygen will **increase, decrease, or remain constant?**

pH levels will **increase, decrease, or remain constant?**

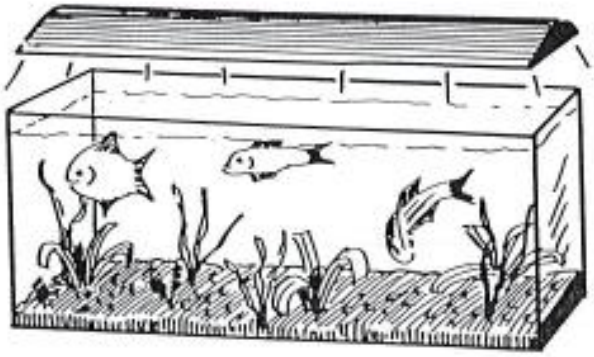


B. FISH ONLY

In this aquarium setting, do you think the:
carbon dioxide will **increase, decrease, or remain constant?**

oxygen will **increase, decrease, or remain constant?**

pH levels will **increase, decrease, or remain constant?**



C. PLANTS AND FISH