CO2 COALITION

An Experiment in Ocean Acidification: Why Buffering Matters

Marty Cornell, March 3, 2024

A Deceptive Exercise in Ocean Acidification

Grade 8

HMH | into Science® Texas

Houghton Mifflin Harcourt

This Student Activity Guide belongs to

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8_HMH_Into_Science_TX_Student_Activity_Guide.pdf

EXPLORATION 2

HANDS-ON LAB

Modeling Carbon Absorption in the Ocean – Part 1

In Part 1 of this lab, you will build and observe a physical model of carbon emission and absorption in the ocean.

MATERIALS (PER GROUP)

- antacid tablet (2)
- beaker, 500 mL (3)
- bromothymol blue indicator solution, in dropper
- container, large, sealable lid
- graduated cylinder, plastic, 500 mL
- marker
- tape, masking
- water, distilled or tap

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ADVANCING EARTH AND SPACE SCIENCE

Reviews of Geophysics

REVIEW ARTICLE
10.1029/2019RG000681

Ocean Alkalinity, Buffering and Biogeochemical Processes

Jack J. Middelburg[1], Karline Soetaert[2], and Mathilde Hagens[3]

"Seawater is a solution with multiple weak acids and bases in contact with both the atmosphere and sediments containing minerals that have the potential to react when solution composition or physical conditions change. **Seawater is consequently well buffered**…"

An annual increase in atmospheric CO2 of 2.1 ppm/yr. → a pH decrease of ~ 0.0023 units/yr.

pH of Ocean Water (Alkalinity $2.3X10^{-3}$ M, 25 ^{O}C)

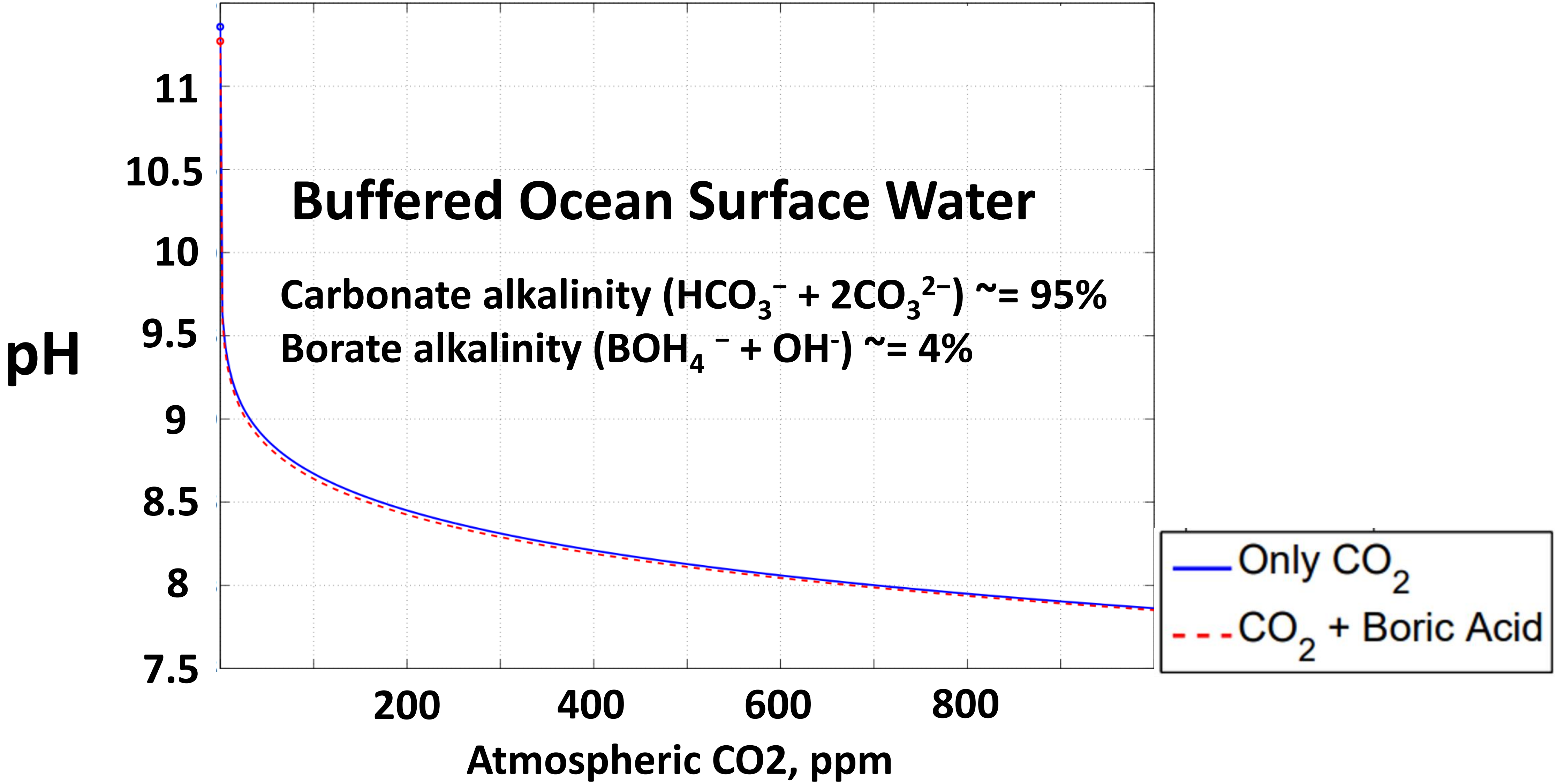
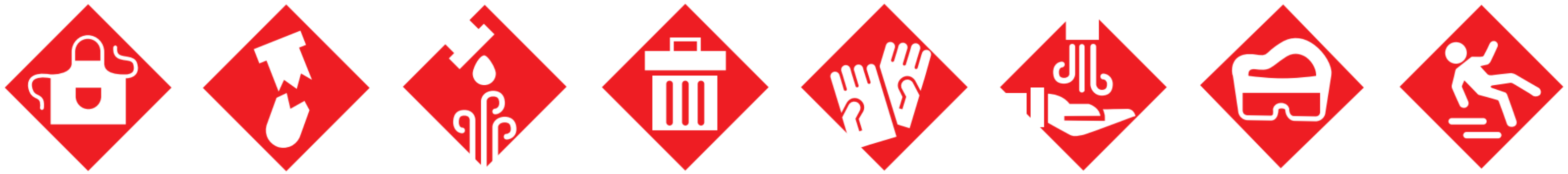


Figure from *Fundamentals of Ocean pH*, R. Cohen and W. Happer, Sept. 18, 2015



Procedure

STEP 1 Use the masking tape and marker to label the three beakers *Beaker 1*, *Beaker 2*, and *Beaker 3*. Use the graduated cylinder to measure 200 mL of water and fill each of the three beakers with 200 mL of water.

STEP 2 Bromothymol blue is an indicator of pH, which is a scale of how acidic or basic a substance is. Read the package directions on the bromothymol blue. Add drops of bromothymol blue into Beaker 1 and Beaker 2 according to the directions, until a strong color is observed.

STEP 3 Compare the color of the two solutions to the color chart included with the bromothymol blue. Record the pH levels of Beaker 1 and Beaker 2 in the table below.

STEP 4 Place Beaker 1 and Beaker 3 inside a large sealable container. Place Beaker 2 next to, but outside, the sealable container, as shown in the photo. Beaker 2 will serve as a control for the experimental results of Beaker 1.

Chapter 112. Texas Essential Knowledge and Skills for Science Subchapter B. Middle School

The Carbon Cycle (TEKS 8.11.C)

§112.28. Grade 8, Adopted 2021. ; (11) (C) describe the carbon cycle

This is the basis for Houghton Mifflin Harcourt's positioning of "Ocean Acidification"

- water, distilled or tap

STEP 5 Add 2 antacid tablets to Beaker 3 and then immediately seal the large container. The antacid tablets represent a carbon source, such as a living organism, near the ocean. Beaker 1 represents the ocean water that we are monitoring for changes in pH, which will decrease if carbon dioxide is absorbed.

STEP 6 Because it can take several hours for any color change to occur, you will analyze the results of this lab during Exploration 3. Store your materials in a safe place to save them for analysis. After cleaning up your work station, wash your hands, and then remove your goggles and store your safety gear as directed by your teacher.

Beaker 1 represents the ocean water

EXPLORATION 3

HANDS-ON LAB

Modeling Carbon Absorption in the Ocean – Part 2

In Part 1 of this lab, you built a physical model of carbon emission and absorption of carbon dioxide in ocean water. In Part 2, you will analyze the water in the beakers you set up in Part 1.

• water, distilled or tap

MATERIALS (PER GROUP)

- beakers from *Modeling Carbon Absorption in the Ocean – Part 1*

STEP 7 Observe and record the color of the liquid in Beaker 1 and Beaker 2. Then compare the color of the two solutions to the color chart included with the bromothymol blue. Record the pH levels of Beaker 1 and Beaker 2 in the table.

STEP 8 What is the difference in pH between Beaker 1 and Beaker 2? What does this difference represent?

"The ocean acts as a carbon sink in the carbon cycle, absorbing atmospheric carbon and storing it in an aqueous solution in the seawater, which can lead to the effect of ocean acidification. **Ocean acidification has a negative effect on many marine species, especially those that make hard shells**. In more acidic water, it is more difficult for these organisms to build shells, and the water can even cause shells to begin to dissolve. "

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“The ocean ac [illegible] rbon sink in the carbon cycle, absorbing atmospheric [illegible] it in an aqueous solution in the seawater, wh [illegible] f ocean acidification. **Ocean acidification [illegible] y marine species, especially those tha [illegible]** n more acidic water, it is more difficult for these org [illegible] build shells, and the water can even cause shells to begin to d [illegible] solve. ”

False

CO2 COALITION
CO2Coalition.org

Ocean Health – Is there an "Acidification" problem?

Ocean Health White Paper REV 061120.indd (co2coalition.org)

STEP 9 How does this Hands-On Lab serve as a model for the carbon cycle? What are some differences between the model and the actual carbon cycle?

STEP 10 About 25% of carbon dioxide emissions that are released through the burning of fossil fuels end up dissolved in the ocean. Propose a solution to help reduce the effect of carbon emissions on the ocean. Support your solution with observations or data from your model.

= ~8.15 Gt of 293.3 Gt or ~2.8% of CO_2 annually absorbed by oceans

How Added Fossil Fuels Affect the Carbon Cycle

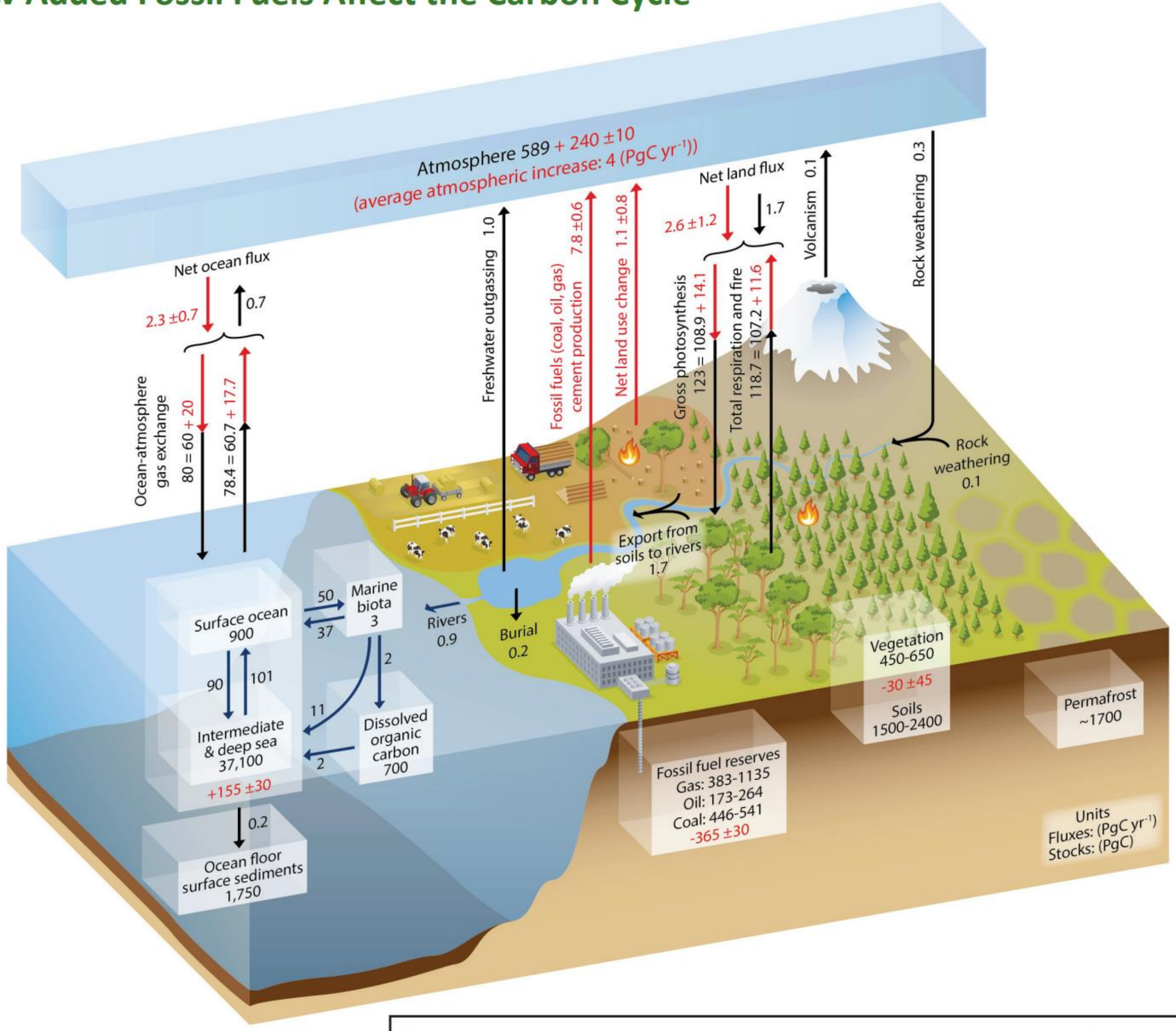


Figure 1 The Global Carbon Cycle from IPCC *CLIMATE CHANGE 2013: The Physical Science Basis - figure 6.1, p. 471*

CO2 Emissions, GT/Year

Oceans	291.1	38.3%
Respiration/Decay	435.2	57.2%
Volcanos/Rock Weathering	1.5	0.2%
Total Natural	**727.8**	**95.7%**
Fossil Fuels & Cement	28.6	3.8%
Land Use Change	4	0.5%
Total Anthropogenic	**32.6**	**4.3%**
Total CO2 Emissions	760.4	100.0%

CO2 Sinks, GT/Year

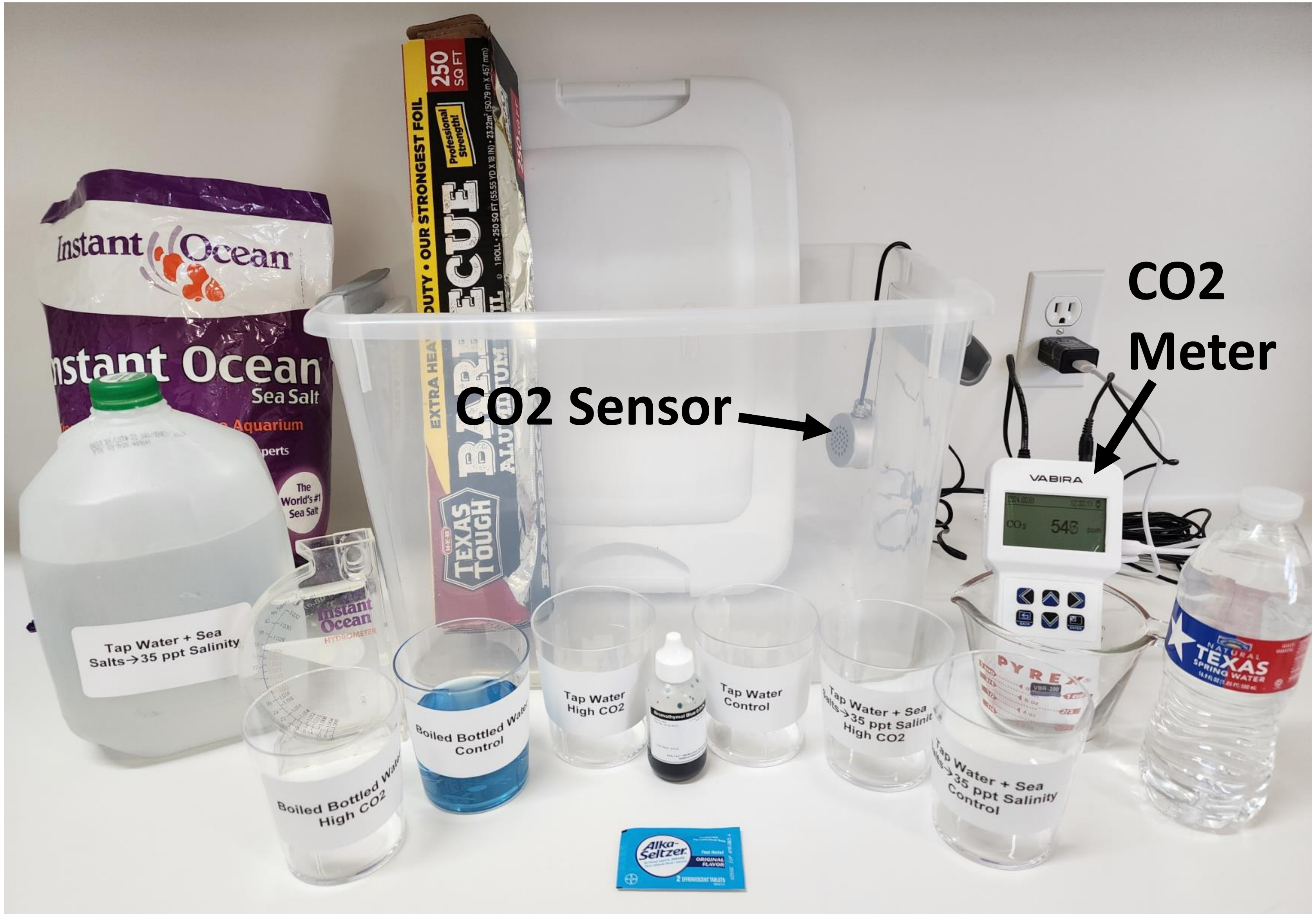
Oceans	293.3	39.4%
Photosynthesis	451.0	60.6%
Total	**744.3**	**100.0%**

STEP 9 How does this Hands-On Lab serve as a model for the carbon cycle? What are some differences between the model and the actual carbon cycle?

STEP 10 About 25% of carbon dioxide emissions that are released through the burning of fossil fuels end up dissolved in the ocean. Propose a solution to help reduce the effect of carbon emissions on the ocean. Support your solution with observations or data from your model.

Solution to a false problem led by a deceptive experiment!

Ocean "Acidification" of Buffered Sea Water



Materials

- ✓ Sea salts
- ✓ Bottled water
- ✓ Tap water
- ✓ Hydrometer
- ✓ Six 8-oz clear cups
- ✓ Measuring cup
- ✓ Antacid tablets
- ✓ Bromothymol blue
- ✓ CO2 meter
- ✓ Labels
- ✓ Gallon jug
- ✓ Translucent container with sealable lid
- ✓ Aluminum foil*

* Placing a sheet of foil between the container and lid will better seal and preserve high CO2 level

Experimental Procedure

Step 1 Prepare a solution of sea water by adding ~$^{1}/_{2}$ cup of aquarium sea salts to a gallon jug, then fill the jug with bottled water. Using a hydrometer, adjust the salt content to 35 ppt salinity.

Step 2 Label each cup:

- Tap Water Control
- Tap Water High CO2
- Boiled Bottled Water Control
- Boiled Bottled Water High CO2
- Tap Water + Sea Salts → 34 ppt Salinity Control
- Tap Water + Sea Salts → 34 ppt Salinity High CO2

Step 3 Boil and cool bottled water to remove residual carbonization

Step 4 Add 200 ml of the appropriate water to each cup

Step 5 Add 30 drops of bromothymol blue to each cup and stir to mix.

Experimental Procedure

Step 3

Bottled spring water is likely to have some degree of natural carbonization, and must be stabilized by degassing under open air as shown here, or by boiling and then cooling (next slide)

0 Hrs. **48 Hrs.** **60 Hrs.**

Time after adding bromothymol blue to bottled water (before exposure to elevated CO_2.)
Hill Country Fair Texas Spring Water pH 6.9, alkalinity 53 in $CaCO_3$ units.

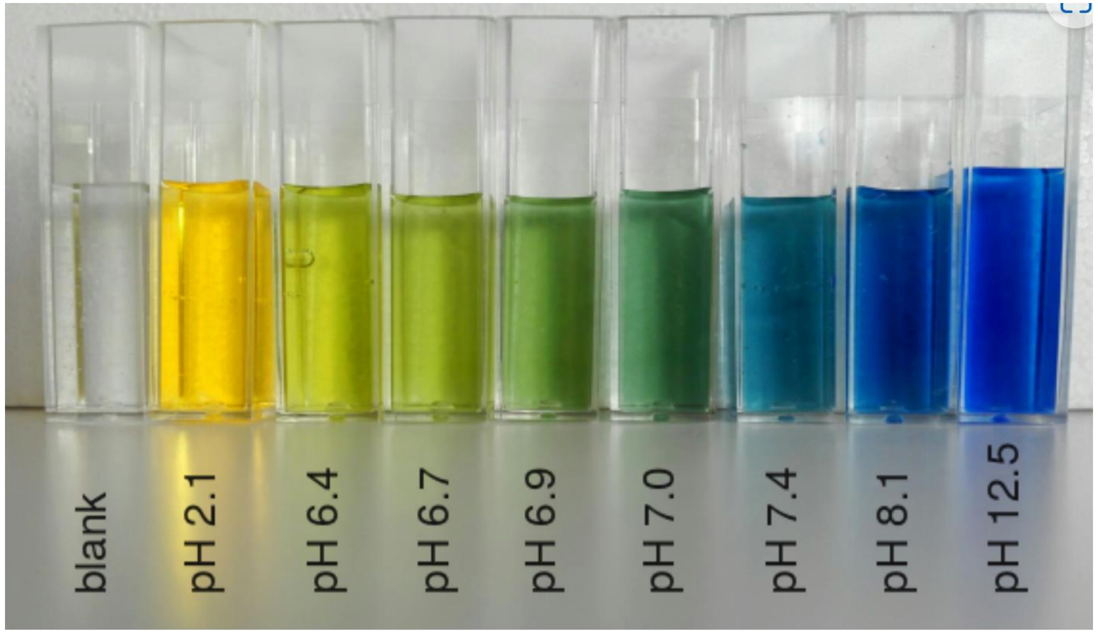
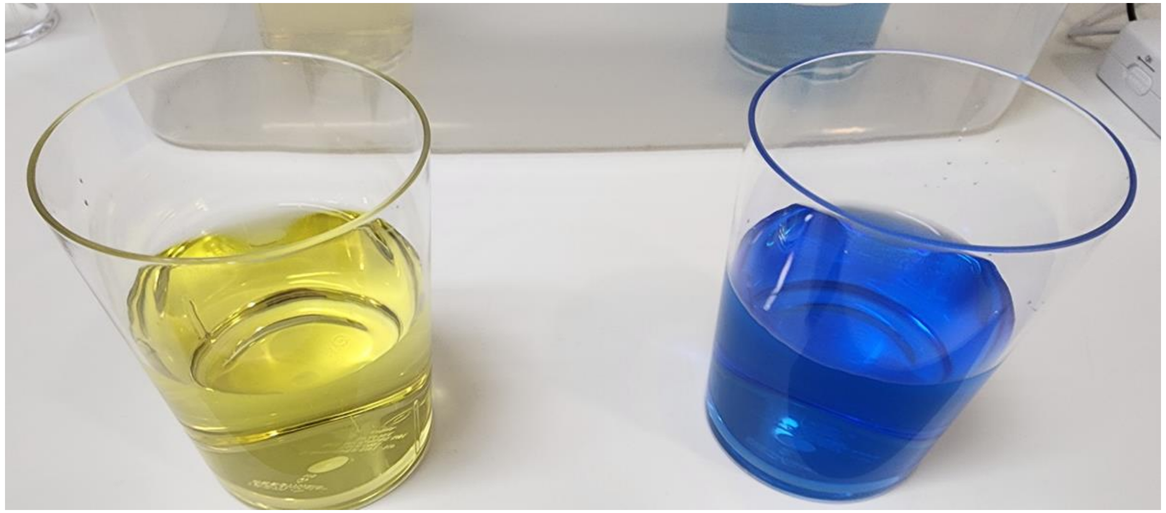


Photo from [Bromothymol blue colors at different pH - Bromothymol blue - Wikipedia]

Experimental Procedure

Step 3

Boil bottled spring water to remove residual carbonization, and cool to room temperature.



From bottle **After boiling**

Initial color of 200 ml Bottled Water with 30 drops bromothymol blue

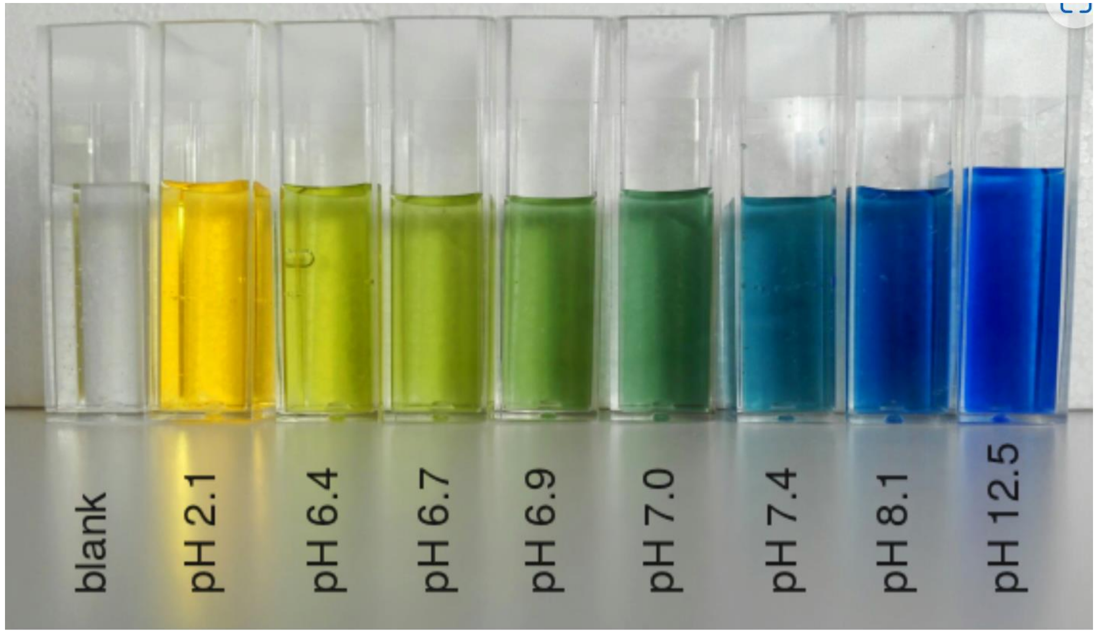


Photo from Bromothymol blue colors at different pH - Bromothymol blue - Wikipedia

Experimental Procedure

Step 6

Record the color of the three solutions at the start of the experiment with the bromothymol blue color chart

Water Quality Analysis (2021)

				Water Type		
				Hill Country Fare Distilled Water	Hill Country Fare Purified Drinking Water	Hill Country Fare Texas Spring Water
Substance	Units	MRL*	MCL**	Level Found***	Level Found***	Level Found***
Physical Quality						
Alkalinity in CaCO3 units	mg/L	2	NR	30	9	53
Apparent Color	ACU	3	15	ND	ND	ND
Specific Conductance, 25 C	umho/cm	2	1600	ND	46	137
Total Hardness	mg/L CaCO3	3	NR	ND	8	54
Odor at 60 C	TON	1	3	1	1	1
Total Dissolved Solids (TDS) ◊	mg/L	10	500	ND	33	95
Turbidity	NTU	0.1	5	ND	0.1	0.1
PH ◊	Units	0.1	NR	5.8	6.7	6.9
Bicarb.Alkalinity	mg/L HCO3	2	NR	36	11	63

Experimental Procedure

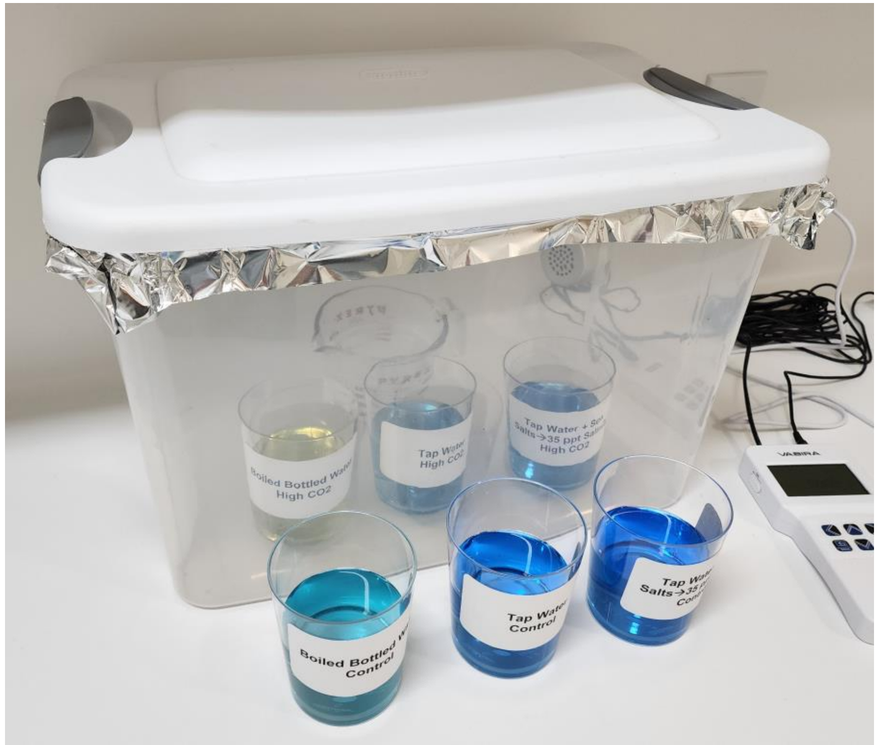
Step 7 Record the ambient air CO_2 content in the room. Because human breath will increase the CO_2 reading, this is best done before the room is filled with students.

Step 8 Position the sensor of the CO_2 meter on an inside wall of the container

Step 9 Place the three cups labeled “High CO_2 and the measuring cup filled with ~200 ml of tap water inside the container. Add two antacid tablets to the water-filled measuring cup.

Step 10 Place a sheet of aluminum foil over the container, then cover with the lid and lock in place; this will provide a tighter seal and preserve elevated CO_2 at >5,000 ppm for at least ten hours

Experimental Procedure



Step 10

Placing a sheet of aluminum foil over the container before adding the lid will provide a tighter seal and preserve elevated CO_2 at >5,000 ppm for at least ten hours.

Start of Experiment

2 Alka-Seltzer Tablets Pegged the Meter at > 11.9 times Ambient

Ambient Room Air

Container (2 antacid tablets)

Experimental Procedure

4 Hrs. at >5,000 ppm CO_2

Step 11 Note change of color of specimen exposed to high CO_2 level with time

Experimental Procedure

24 Hrs. at >5,000 ppm CO2

Step 11

Note change of color of specimen exposed to high CO2 level with time

Experimental Procedure

48 Hrs. at >5,000 ppm CO2

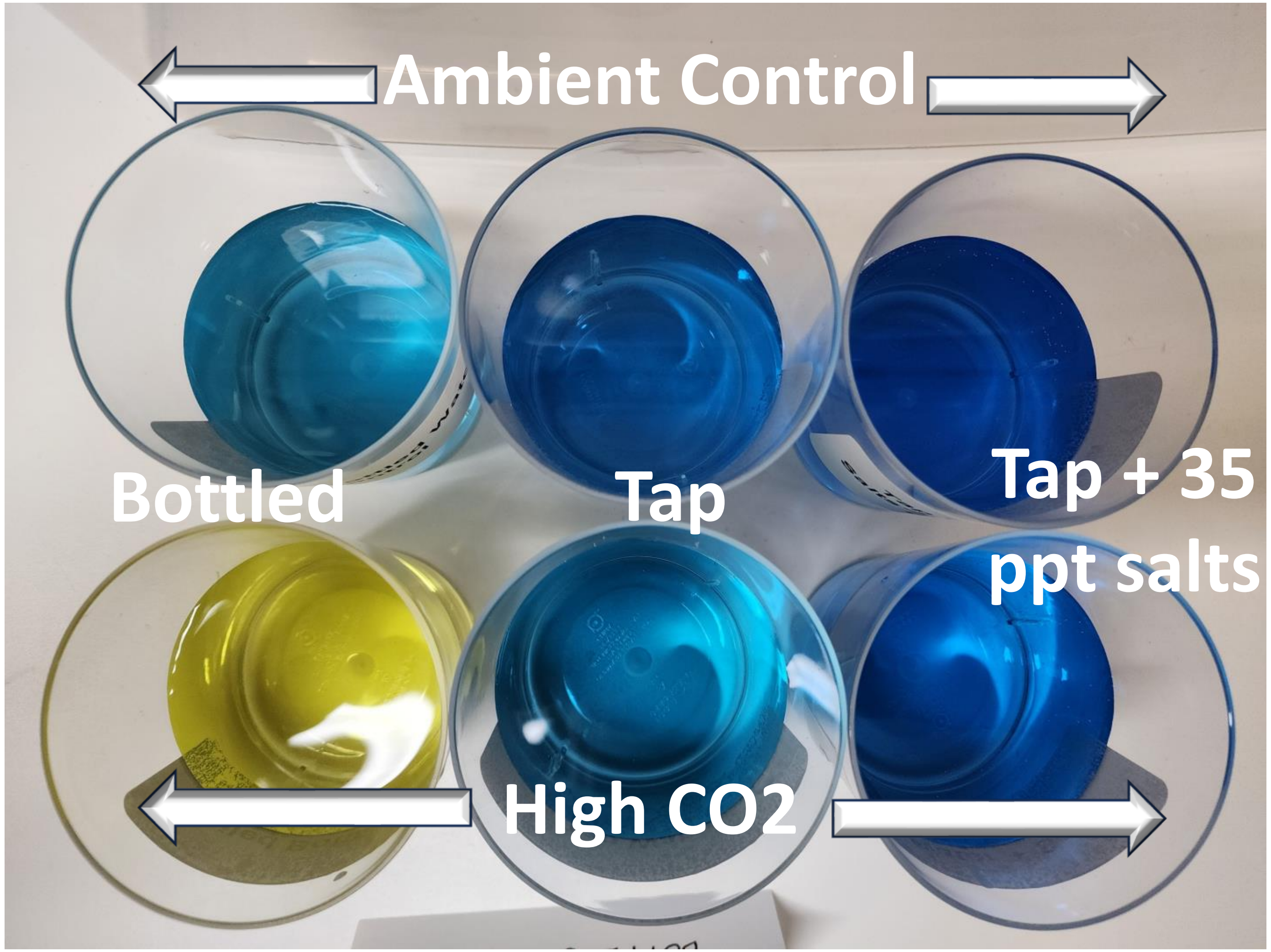
Step 11

Note change of color of specimen exposed to high CO2 level with time

Experimental Procedure

4 Hrs. at >5,000 ppm CO_2

Step 11 Note change of color of specimen exposed to high CO_2 level with time



Experimental Procedure

24 Hrs. at >5,000 ppm CO2

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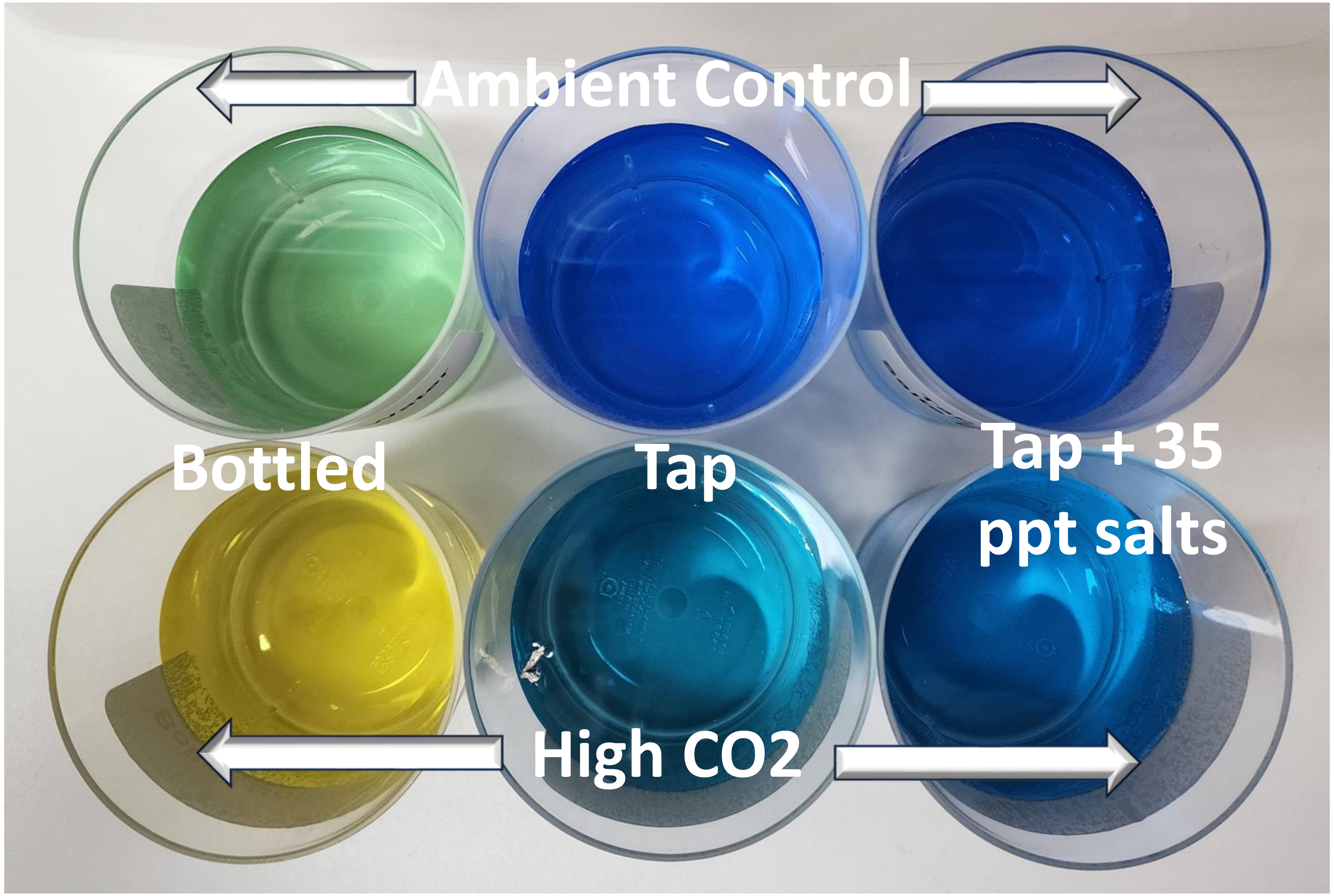
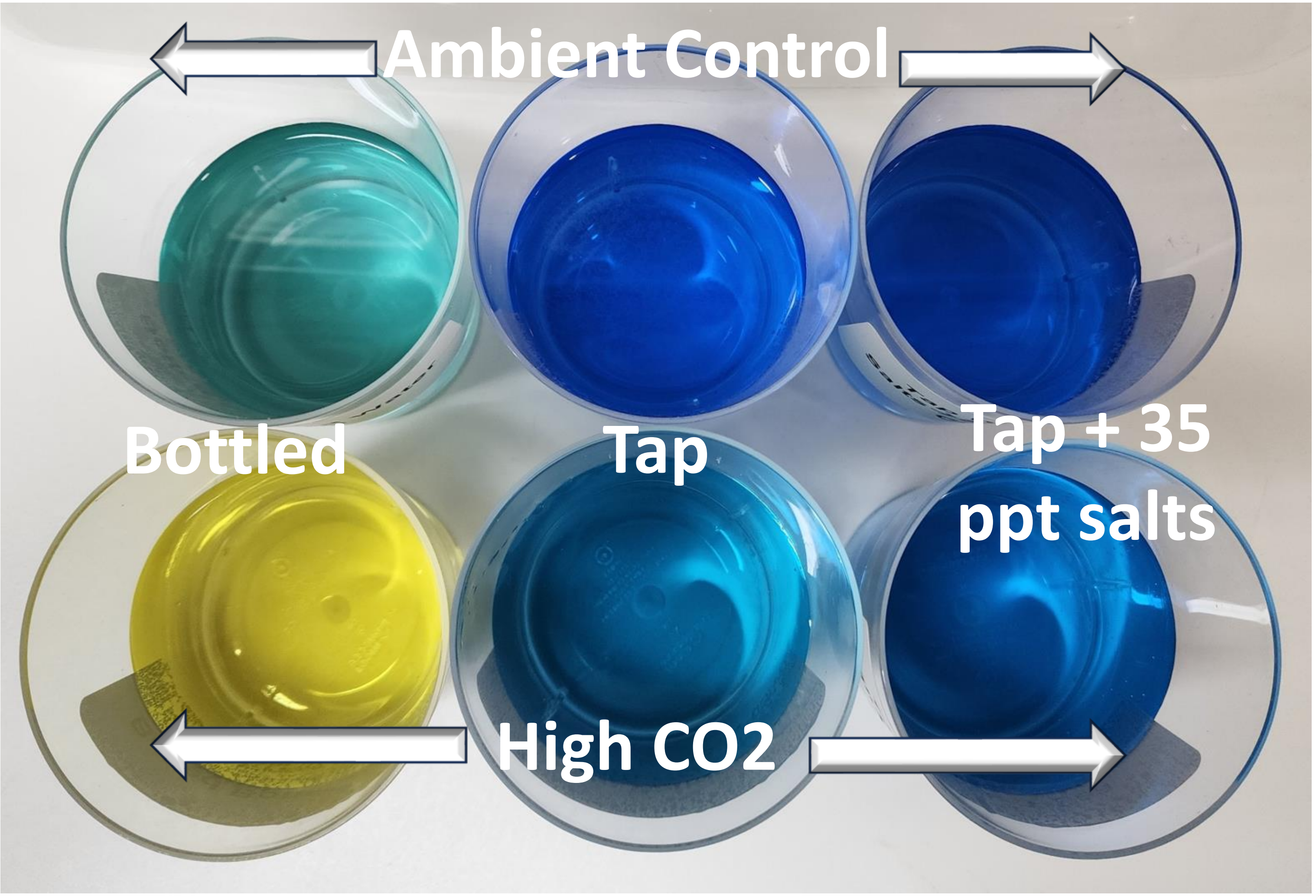


Experimental Procedure

48 Hrs. at >5,000 ppm CO2

Step 11 Note change of color of specimen exposed to high CO2 level with time



Experimental Procedure

24 Hrs. at >5,000 ppm CO2

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Experimental Procedure

48 Hrs. at >5,000 ppm CO2

Step 11

Note change of color of specimen exposed to high CO2 level with time

Experimental Procedure

Step 11 Note change of color of specimen exposed to high CO_2 level

Step 12 After two days, observe the color shift of specimen removed from a high CO_2 environment

24 hrs exposure to > 5,000 ppm CO_2 + 34 hrs ambient

Conclusions

- The HMH experiment falsely equates tap and distilled water to buffered ocean water
- After 48 hours, >Ten times atmospheric CO2
  - did not noticeably shift the pH of tap water buffered with sea salts
  - slightly decreased the basic pH of tap water
  - shifted the pH of unbuffered bottled water from slightly basic to acid.
- The pH of bottled water exposed to >5,000 ppt CO2 shifted to slightly basic after return to ambient air.

Conclusions

- The concept of buffering is ignored by HMH
- HMH avoids mention of the CO_2 level generated by antacid tablets, which is beyond the possible amount from burning all fossil fuel reserves.
- HMH is misdirecting students on ocean acidification potential and harm to aquatic life.

Conclusions

Buffering Matters