

October, 2009

Dear teacher:

Thanks for your interest in teaching about ocean acidification! As you probably know, ocean acidification is a consequence of human emissions of carbon dioxide to the atmosphere. Even though there is increasing media coverage on this topic, many people find ocean acidification difficult to accept or understand because they aren't familiar with the science behind it. We hope that these hands-on experiences will help students in grades 5-12 understand the science behind ocean acidification and help them become well-informed residents of Earth.

We've designed this series of hands-on experiences to support national science education standards yet remain as low-cost and adaptable as possible. Most of the materials required here can be found at grocery stores and pet stores. By themselves, these labs won't entirely explain ocean acidification to your students but will instead complement your own classroom presentation of the issue. In the lab setup notes, we provide hints and ideas about adapting these exercises to match your time and resources. Handouts and general worksheets are provided with each lab, but you can easily change them to support your curriculum or to suit your teaching style. Finally, we provide an answer key and Web links to additional ocean acidification information for yourself or your students. This list is by no means exhaustive because new discoveries and resources are always being published!

We hope you enjoy working through these exercises with your classes. We welcome any questions or comments you may have.

Best wishes,

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Table of Contents

Lab setup notes.....	1
Red cabbage extract recipe.....	2
Artificial seawater recipe.....	3
Student lab 1: Is seawater more like lemons or bleach?	
Teacher’s setup checklist.....	4
Student handout.....	6
Student worksheet.....	9
Research & discussion questions for advanced students.....	11
Student lab 2: Ocean acidification in a cup	
Teacher’s setup checklist.....	12
Student handout.....	13
Student worksheet.....	18
Group demonstration: I’m melting! Seashells in acid	
Teacher’s setup checklist.....	21
Instructions.....	22
National science education standards supported by this kit	23
Teacher’s answer key.....	24
Additional resources for teachers.....	26
Acknowledgments.....	27

Lab setup notes

Equipment needs

Seawater salt mixes and an alkalinity test kit can usually be found at a pet store or ordered online. The smallest size box of sea salt mix (to make 10 gallons of artificial seawater) costs less than \$10, and an alkalinity test kit can be bought for about \$10-20 (for approximately 75-200 analyses). We recommend alkalinity test kits that relate alkalinity to a numerical scale (KH, meq/l, or ppm CaCO₃) rather than just indicating whether it is high/medium/low. A full complement of household acids, bases, and test solutions may add up to \$20-30 at the grocery store. The experiments may be done in small clear plastic cups or in inexpensive student laboratory glassware that can be found from many sources (one of our favorites is www.sciplus.com). Disposable glass test tubes are available in bulk for a relatively low cost from suppliers like Fisher Scientific.

Setup notes

The Natural Resources Defense Council produced an excellent mini-documentary (<http://www.nrdc.org/oceans/acidification/aboutthefilm.asp>) on ocean acidification that may be used as an introduction to the unit. You may also choose to assign students to read one of the background articles listed at the end of this unit in conjunction with the lab activities.

A color pH scale is included in the student handout (p. 6-14) for data interpretation, but if it's difficult to provide color handouts, consider displaying a color copy of the scale at the front of the room or projecting it on a white wall.

If time is limited, you can demonstrate the household liquids analysis or do it ahead of time and reveal the results after students have predicted what color (pH) each acid or base will be. Then the students can do the hands-on analysis of the different waters. The bubbling experiment is quite short, and shouldn't present a problem during most class periods. In any case, the demonstration of ocean acidification on seashells is best prepared 1-2 days ahead to allow the shells enough time to become brittle. Also, you will need to make red cabbage extract (p. 4) and artificial seawater (p. 5) ahead of either lab. Together, both of these steps take only about 30 minutes.

We've provided the approximate pH value of the household acids and bases for your information so you can choose solutions that will span most of the pH scale. However, students might get the most out of some of the questions if the first experiment includes lemon juice, bleach, and lemon-lime soda for testing (see questions 8 and 9 in Lab 1). Also, it might be best if you test the different types of waters ahead, since tap and seltzer water can vary a lot from place to place and may affect the students' findings.

For students with more chemistry background, we recommend that you provide the chemical formula of each of the household liquids. Then, students can also consider acid or base strength when interpreting their results. The third page of the student worksheet in Lab 1 is intended to promote creative thinking and logical problem solving but is best suited for advanced students.

Red cabbage pH indicator

Materials

- 1 head red/purple cabbage (not green)
- Water
- Stovetop/Bunsen burner/electric kettle
- Pot or stovetop-safe beaker
- Sieve or strainer
- 1 pair of oven mitts
- Storage bottle or jar with tight-fitting lid, about 500-1000 mL (~1-2 pints)
- Isopropyl alcohol
- Dropper bottle(s), one per lab group (contact lens solution bottles, eyedroppers, etc.)

Method

Roughly chop 1 head red/purple (not green) cabbage and put in beaker or pot with enough water to cover the cabbage. Bring the water to a full rolling boil, then turn off the heat and allow the cabbage and water to sit for about 10 minutes until the water is dark purple. (Alternatively, pour boiling water over red cabbage in a beaker and let sit until water is dark.) Fill the clean storage bottle about 10% full with isopropyl alcohol¹, and then fill it the rest of the way with cabbage extract. Use a strainer or sieve to filter out the cabbage pieces. Be careful to avoid spilling the cabbage juice, because it stains counters and clothing. Cap the bottle and shake up the solution to mix it. (The alcohol prevents the extract from spoiling). Extra cabbage juice can be flushed down the drain. Cool the solution. Label the bottle. Then, fill and label the dropper bottles with cabbage extract. 1 head of cabbage provides about 1L of solution; scale up as needed.

(http://www.chemistryland.com/CHM107Lab/Exp10_pHindicator/Lab/PreparingCabbageExtract.htm provides a nice photo-essay about making and using cabbage-based pH indicator.)

¹ **Safety note:** If you are concerned that your students may disregard class instructions not to ingest any seawater/pH indicator mixture when doing the ocean acidification experiment, you may omit the isopropyl alcohol, refrigerate the indicator when not in use, and use it up within 2-3 days, or you may substitute food-grade ethanol (vodka is best) for the isopropyl alcohol.

Artificial seawater

Materials

- Instant Ocean brand aquarium salt
- Water*
- Large jug or clean bucket

Method

Mix up artificial seawater according to the directions on the Instant Ocean salt package. Make enough that each student will have about 250 mL (1 cup) of artificial seawater.

*If you live in an area where the water is very hard, you may wish to use distilled water instead of tap water; using extremely hard water to make artificial seawater could keep the salts from dissolving correctly.

Setup checklist

Lab 1--Is seawater more like lemons or bleach?

Setup time: 30 minutes if artificial seawater and red cabbage pH indicator are already made. If not, 45 minutes.

Materials for a class of ~24-36 students working in groups of 3-4

- Artificial seawater ~100 ml
- Tap water ~100 ml
- Dropper bottles with ~100 mL red cabbage pH indicator (1 bottle per group of 3-4; refill as needed)
- Unflavored seltzer water ~100 ml
- Distilled water ~100 ml
- White paper (10 sheets)
- Label tape & marker (10 sets)
- Small test tubes & rack (140 tubes and 10 racks)
- Aquarium water hardness test kit
- Labeled disposable pipettes (to transfer acids and bases into test tubes) – 1 for each type of solution
- A wide selection of 7-10 of the following household acids and bases² (~100 ml of each)

Acidic substance	Chemical name	Formula	Approximate pH
Muriatic acid*	Hydrochloric acid	HCl	1
Lemon or lime juice	Citric acid	C ₆ H ₈ O ₇	2
White vinegar	Acetic acid	CH ₃ COOH	3
Vitamin C tablets dissolved in water	Ascorbic acid	C ₆ H ₈ O ₆	3
Lemon-lime soft drink	Carbonic acid and citric acid	H ₂ CO ₃ + C ₆ H ₈ O ₇	3-4
Cream of tartar dissolved in water	Potassium bitartrate	KHC ₄ H ₄ O ₆	3-4
Seltzer water	Carbonic acid	H ₂ CO ₃	4-5
Unbuffered, uncoated aspirin tablet dissolved in water	Acetylsalicylic acid	C ₉ H ₈ O ₄	5
Milk	Lactic acid	C ₃ H ₆ O ₃	6.7
Tap or distilled water	Water	H ₂ O	7

² **Safety note:** All solutions listed, but especially the starred solutions, should NEVER be mixed. The starred solutions should only be used by older students who have a thorough understanding of lab safety procedures. The students should wear safety glasses and lab coats/smocks if they use the starred solutions.

Basic substance	Chemical name	Formula	Approximate pH
Tap or distilled water	Water	H ₂ O	7
Baking soda dissolved in water	Sodium bicarbonate	NaHCO ₃	8
Antacid dissolved in water	Calcium carbonate + calcium hydroxide + magnesium hydroxide	CaCO ₃ +CaOH+ MgOH	10
Clorox/liquid bleach*	Sodium hypochlorite bleach	NaClO	11
Soap/washing soda	Sodium carbonate	Na ₂ CO ₃	11
Oxiclean	Sodium percarbonate + sodium carbonate	2(Na ₂ CO ₃ ·1.5H ₂ O ₂)	11
Household ammonia*	Ammonium hydroxide	NH ₃ + H ₂ O	11.6
Lye/drain cleaner*	Potassium hydroxide or sodium hydroxide	KOH or NaOH	12-14

Lab 1 – Student handout

Is seawater more like lemons or bleach?

Goal

In this experiment you will research the pH of different types of water, and you will compare your findings to the pH values of common household acids and bases.

Background

All liquids can be described by their *acidity*. Liquids with high acidity and many free hydrogen ions (H^+) are called *acids*. Acids are used for a wide range of purposes, such as catalyzing reactions, preserving foods, and conducting energy in batteries. Liquids with low acidity and very few free hydrogen ions, or many free hydroxide ions (OH^-), are called *bases*. These substances are very useful as soaps and other cleaning agents.

Foods that are acidic (like lemons) taste sour, and things that are basic (like soap or some medicines) taste bitter and feel slippery. It's dangerous to taste and touch many liquids, though, so we need a better way to judge the acidity of different liquids.

Scientists safely measure acidity by measuring *pH* values. The pH scale measures how many free hydrogen ions are present in a liquid, but the measurement is somewhat counterintuitive: the lower the pH, the greater the concentration of free hydrogen ions, and the higher the pH, the lower the concentration. Acids have low pH measurements, from 0 to less than 7. Neutral liquids have pH measurements of 7. Bases have high pH measurements, from more than 7 to 14.

The pH scale helps researchers measure both very large and very small acidity differences between fluids. Battery acid and drain cleaner have very different pH values. On the other hand, oceans, rivers, and lakes have small pH differences. Earth scientists measure these small pH differences to learn about aquatic organisms and their environments.

Develop hypotheses

After reading the goal and the background for this lab, write down your predictions (hypotheses) about how the pH values of tap water, distilled water, seawater, and seltzer water will compare to pH values of household acids and bases you will test. Use complete sentences. For example, write things like “The pH value of tap water will be lower than the value of ...”

Materials and methods

For each lab group of 3-4 students:

12-14 test tubes	Labeled samples of acids and bases
1 test tube rack	Distilled water
Label tape & marker	Seawater
Dropper bottle of pH indicator	Tap water
White paper	Seltzer water

- 1) Label your test tubes with the names of the household acids and bases that your teacher has provided for this experiment. There should be a different tube for each fluid.
- 2) Label four more test tubes: distilled water, seawater, tap water, seltzer water. Place all the labeled tubes in the rack.
- 3) On your worksheet, write down the date of the experiment, the time of day, and your lab partners' names. Fill in the data table with the names of the solutions you will test. It will look something like this:

<u>Liquid</u>	<u>Predicted acidity</u>	<u>Color</u>	<u>Actual acidity</u>	<u>pH</u>
Lemon juice				
Ammonia				
Distilled water				

Under “liquid”, list all of the acids and bases you will be testing. Also list the four types of water you plan to test.

Under “predicted acidity”, rank the fluids based on how acidic you think they will be. Use 1 for the fluid you think will be most acidic, use 2 for the next most acidic fluid, and so on. The last number should be for the least acidic fluid (which is the same as the most basic fluid).

You’ll fill in the next three columns during data collection and interpretation.

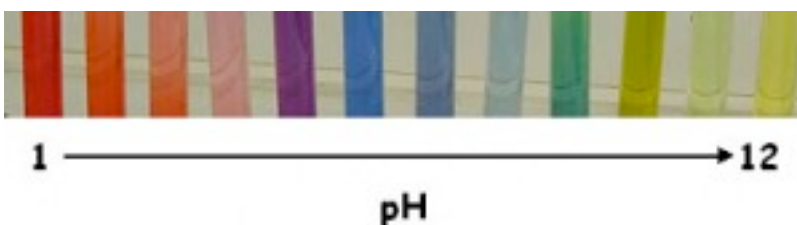
- 4) Use the appropriate pipette to transfer a few milliliters of each of the household acids and bases into their respective test tubes (enough to fill a tube halfway). Add your water types to their labeled tubes. Be sure to follow the labels. Don’t add more than one type of fluid to any test tube. Be sure not to share pipettes among different solutions – only use a pipette for the solution indicated on its label.
- 5) At your lab bench, add a few drops of pH indicator to the fluids in each test tube. Gently swirl the tube to mix it if necessary. You should see each fluid turn a color. (The pH indicator will stain your clothes and notebooks, so be careful!)
- 6) Write down the color of each solution in the “color” column of your data table. Compare the test tubes in front of the white paper if you have trouble telling different colors apart.

Results & discussion

The pictures below show the complete color range of our pH indicator. Red colors indicate more acidic fluids, and blue, green, and yellow colors indicate more basic (less acidic) fluids.



(image from <http://www.greatscience.com/think/projects.php?id=21>)



(image from <http://www.precisionnutrition.com/ie-how-ph-strips-work>)

- 1) Use the color scales above to rank the acidity of your fluids in the “actual acidity” column of your data table. Again, use 1 for the fluid you think will be most acidic, use 2 for the next most acidic fluid, and so on. The last number should be for the least acidic fluid (which is the same as the most basic fluid).
- 2) Use the color scales above to estimate the pH of your fluids, and write down the pH value in the “pH” column of your data table.
- 3) Answer the worksheet questions using complete sentences.

Name:

Date & time:

Lab partners:

Lab 1 – Is seawater more like lemons or bleach?

Hypotheses

1. The pH value of tap water will _____

2. The pH value of distilled water will _____

3. The pH value of seawater will _____

4. The pH value of seltzer water will _____

Data

<u>Liquid</u>	<u>Predicted acidity</u>	<u>Color</u>	<u>Actual acidity</u>	<u>pH</u>

Questions

1. Which fluid was most acidic?
2. Which was least acidic?
3. What was the pH of seawater?
4. What was the pH of tap water?
5. What was the pH of distilled water?
6. What was the pH of seltzer water?
7. Describe the most surprising result you observed during this experiment.
8. What household fluid did you test whose pH was most similar to seltzer water? Describe any other similarities between these two fluids.
9. Is seawater more like lemons or bleach? Explain why you think so.
10. Tap water is usually made from river or underground water. What pH range do you think aquatic organisms living in the sea or in rivers are used to?
11. Do you think a goldfish could live in seltzer water? Why or why not?

Research and discussion questions: answer on a separate sheet

- 1) Considering the chemical formula of each of the substances you tested, discuss why different acids and bases have slightly or widely different pH values.
- 2) The pH indicator we used was made from red cabbage. The purplish color is caused by a natural compound called cyanidin, which is a type of anthocyanin.

A) Research the way that anthocyanins react with acidic and basic fluids. (helpful links for researching this answer: <http://www.webexhibits.org/causesofcolor/7G.html>
<http://science.howstuffworks.com/vegetable/question439.htm>
<http://www.madsci.org/experiments/archive/859332497.Ch.html>
http://www.micro-ox.com/chem_antho.htm
<http://icn2.umeche.maine.edu/genchemlabs/Anthocyanins/fruitjuice2.htm>)

Given what you now know about the chemical structure of anthocyanins, write down a hypothesis predicting how cyanidin can produce the multiple different colors you observed, depending on acidity.

B) In a paragraph, describe an experiment you could use to test this hypothesis if you were a researcher.

(Assume that you could look up how to do anything and that you could build any equipment you needed for the analysis. Use your imagination. The goal is to describe how you would test this hypothesis using the scientific method. Will you need any controls? What test(s) would you perform? How many times should you repeat your test(s)? How would you interpret your results?)

Setup checklist

Lab 2-- Ocean acidification in a cup

Setup time: 30 minutes if artificial seawater and red cabbage pH indicator are already made. If not, 45 minutes.

Part 1: Materials for a class of ~24-36 students working in groups of 3-4

100 mL dropper bottle of pH indicator (10 bottles)

Aquarium alkalinity test kit

Distilled water**

Seawater**

Tap water **

Seltzer water**

**(~100 mL of each)

Part 2: Materials for a class of ~24-36 students working in groups of 1-2

72 test tubes

181 test tube racks

10 sets of label tape & marker

White paper (18 sheets)

72 clear plastic cups

724 straws

Clock with second hand or stopwatch

Distilled water*

Seawater*

Tap water*

Seltzer water*

*(of each liquid, provide ~250 mL + enough to ½ fill a test tube)

Lab 2 – Student handout

Ocean acidification in a cup

Goal

In this experiment you will learn about alkalinity, which helps seawater resist changes in pH, and test the alkalinity of four different types of water. You will then compare the responses of different waters to carbon dioxide gas.

Background

Sea salt gives seawater some unique properties. Sea salt includes a lot of sodium and chloride and gives seawater its salty taste. Sea salt also includes other positively and negatively charged *ions*.

If acid is added to seawater, the negatively charged ions in sea salt [including mostly carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), and borate ($\text{B}(\text{OH})_4^-$)] react with the free hydrogen ions (H^+) from the acid and help *buffer* (resist changes in) seawater pH. The ability of seawater's negative ions to neutralize added acid is called alkalinity. In nature, the buffering provided by alkalinity helps keep seawater pH in a fairly small range.

Every year, humans are releasing more carbon dioxide into the atmosphere, and the gas mixes into the ocean as well. When atmospheric carbon dioxide gas mixes with seawater, it creates carbonic acid and allows seawater to dissolve calcium carbonate minerals. This process is called ocean acidification.

The hard shells and skeletons of marine creatures like scallops, oysters, and corals are made of calcium carbonate minerals. As more carbon dioxide from the atmosphere enters the ocean in the next 100 years, ocean chemistry will change in ways that marine creatures have not experienced in hundreds of thousands of years. The hard shells of marine creatures may become damaged from ocean acidification. Scientists are currently researching what this will do to populations of marine organisms.

Develop hypotheses

After reading the goal and background for this lab, write down predictions (hypotheses) about 1) how the alkalinities of tap water, distilled water, seawater, and seltzer water will compare to each other and 2) their ability to resist pH changes. Use complete sentences. Your hypotheses for Parts 1 and 2 should be something like “I predict that the order from lowest to highest alkalinity will be tap water, distilled water, seawater, and seltzer water,” and “I predict that the order from most resistant to least resistant to pH change will be tap water, distilled water, seawater, and seltzer water.”

Materials and methods

For each 1 or 2 students:

- 4 test tubes
- 1 test tube rack
- Label tape & marker
- White paper
- 4 clear plastic cups
- 4 straws
- Clock with second hand or stopwatch
- Notebook and pencil or pen

For each group of 3-4 students:

- Dropper bottle of pH indicator
 - Aquarium alkalinity test kit
 - Distilled water*
 - Seawater*
 - Tap water*
 - Seltzer water*
- *(of each liquid, you need ~250 mL + enough to ½ fill a test tube)

Part 1: alkalinity (do in groups of 3 or 4)

1) On your worksheet, write down the date of the experiment, the time of day, and your lab partners' names. Fill in the data table with the names of the solutions you will test. It will look something like this:

<u>Liquid</u>	<u>Predicted Alkalinity</u>	<u>Actual Alkalinity</u>	<u>Rank</u>
Seawater			
Tap water			
Distilled water			
Seltzer water			

Under “predicted alkalinity”, rank the fluids based on how much alkalinity you think they will have. Use 1 for the fluid you think will have most alkalinity and 4 for the fluid that you think will have the least alkalinity.

2) Follow the instructions on the alkalinity test kits to test the alkalinity of distilled water, seawater, tap water, and seltzer water.

3) Write down the alkalinity value (in dKH, meq/l, or ppm CaCO₃ depending on your test kit) under “actual alkalinity”.

4) Rank the fluids based on your alkalinity test results. Use 1 for the fluid with highest alkalinity and 4 for the fluid with lowest alkalinity.

Part 2: ocean acidification (do in groups of 1 or 2)

- 1) Label your control test tubes with the four types of water: distilled water, seawater, tap water, and seltzer water. Fill them and place them in the rack.
- 2) Label your plastic cups with the four types of water. Fill them each with about 250 mL (1 cup) of fluid, following the labels. These are your experimental samples.
- 3) In your notebook, write down your lab partner's name for this part of the experiment. Draw a data table that looks something like this:

<u>Liquid</u>	<u>Control/start color</u>	<u>Start pH</u>	<u>Bubbling time (seconds)</u>	<u>End color</u>	<u>End pH</u>
Tap water					
Seawater					
Distilled water					
Seltzer water					

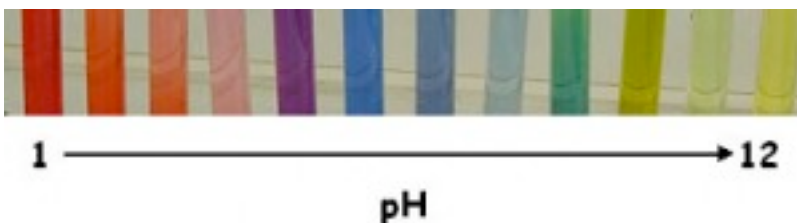
- 3) Add a few drops of pH indicator to the fluids in each test tube and about 10 drops to the fluids in each cup. Under “control/start color”, write the colors of the controls (fluids in the test tubes). Check that the control colors match the sample colors. Again, hold the tubes or cups in front of the white paper if you need help telling apart the colors. Place a straw in each cup.
- 4) Without sucking up any colored water into your mouth, blow through the straw into the tap water sample so that bubbles come up through the water. Keep blowing for 45 seconds and move the bottom of the straw around to make sure bubbles flow through all the liquid. It's ok to take quick breaks to breathe in, like you would if you were playing a flute. At the end of 45 seconds of bubbling, write down the color of the water under “end color”.
- 5) Repeat step 4 for the other three water samples.

Results & discussion

The pictures below show the complete color range of our pH indicator. Red colors indicate more acidic fluids, and blue, green, and yellow colors indicate more basic (less acidic) fluids.



(image from <http://www.greatscience.com/think/projects.php?id=21>)



(image from <http://www.precisionnutrition.com/ie-how-ph-strips-work>)

- 1) Use the color scales above to estimate the pH of your fluids at the start and end of your experiment, and write down the pH value in the “Start pH” and “End pH” columns of your data table.
- 2) Answer the worksheet questions in complete sentences.

Alkalinity units conversion table*

Boldface numbers indicate the recommended alkalinity range for a saltwater aquarium.

dKH	meq/l	ppm CO ₃ ²⁻
0	0	0
0.5	0.18	8.9
1.0	0.36	17.9
1.5	0.54	26.8
2.0	0.71	35.7
2.5	0.89	44.6
3.0	1.07	53.6
3.5	1.25	62.5
4.0	1.43	71.4
4.5	1.61	80.4
5.0	1.79	89.3
5.5	1.96	98.2
6.0	2.14	107.1
6.5	2.32	116.1
7.0	2.50	125.0
7.5	2.68	133.9
8.0	2.86	142.9
8.5	3.04	151.8
9.0	3.21	160.7
9.5	3.39	169.6
10.0	3.57	178.6
10.5	3.75	187.5
11.0	3.93	196.4
11.5	4.11	205.4
12.0	4.29	214.3
12.5	4.46	223.3
13.0	4.64	232.1
13.5	4.82	241.1
14.0	5.00	250.0
14.5	5.18	258.9
15.0	5.36	267.9
15.5	5.54	276.8
16.0	5.71	285.7
16.5	5.89	294.6
17.0	6.07	303.6
17.5	6.25	312.5
18.0	6.43	321.4
18.5	6.61	330.4
19.0	6.79	339.3
19.5	6.96	348.2
20.0	7.14	357.1
20.5	7.32	366.1
21.0	7.50	375.0
21.5	7.68	383.9
22.0	7.86	392.9
22.5	8.04	401.8
23.0	8.21	410.7
23.5	8.39	419.6

Possible aquarium pH ranges

pH	Best for freshwater tanks	Best for saltwater tanks	Best for saltwater tanks with coral reefs
6.0			
6.1			
6.2			
6.3			
6.4			
6.5			
6.6			
6.7			
6.8			
6.9			
7.0			
7.1			
7.2			
7.3			
7.4			
7.5			
7.6			
7.7			
7.8			
7.9			
8.0			
8.1			
8.2			
8.3			
8.4			
8.5			
8.6			
8.7			
8.8			
8.9			
9.0			

*From http://ozreef.org/library/tables/alkalinity_conversion.html. dKH = degrees of carbonate hardness; ppm = parts per million; meq/l = milliequivalents per liter.

Name:

Date & time:

Lab partners:

Lab 2 – Ocean acidification in a cup

Part 1

Hypothesis (about how the alkalinities of 4 waters will compare to each other)

I predict that: _____

Data

<u>Liquid</u>	<u>Predicted Alkalinity</u>	<u>Actual Alkalinity</u>	<u>Rank</u>

Part 2

Hypothesis (about how the 4 waters will resist pH changes)

I predict that: _____

Data

<u>Liquid</u>	<u>Control/start color</u>	<u>Start pH</u>	<u>Bubbling time (seconds)</u>	<u>End color</u>	<u>End pH</u>

Questions

1. Which sample had the highest pH before bubbling? The lowest before bubbling?
2. Which sample had the highest alkalinity? The lowest alkalinity?
3. Your breath contains CO₂ gas in it. After bubbling the samples with your breath, describe what happened in the samples compared to the controls.
4. Which sample had the highest pH after bubbling?
5. Which sample had the lowest pH after bubbling?
6. Which sample showed the greatest change in pH from bubbling? Looking at all the results from Parts 1 and 2, why do you think this happened?
7. The bubbles in seltzer water come from CO₂ that has been added at the factory. Did you see a significant pH difference between your seltzer sample after you bubbled it and your seltzer control? Explain why you think this is true.
8. What might happen to the pH of seltzer water if you allowed it to go flat?
9. How low was the seawater pH at the end of the experiment? Could you make it go any lower? Explain why you think seawater behaves this way.
10. Look at the tables on the next page. Would you want to use any of these water types if you were setting up a saltwater aquarium? Why or why not?

Setup checklist
Demonstration--I'm melting! Seashells in acid

Setup time: 10 minutes. Begin soaking the shells a day or two in advance.

Materials required for an entire class

White vinegar (500 mL)

Water (1500 mL)

2 large glass beakers (1000 mL)

Enough seashells (1-2" across and fairly thin; see specific recommendations in protocol)
to give a few each of digested and control shells to groups of 3-4 students

Heavy books

Demonstration*

I'm melting! Seashells in acid

Goal

Simulate ocean acidification's effects on the shells of mollusks.

Background

Ocean acidification is the term used to describe the ongoing decrease in pH and carbonate ion availability in the world's oceans that is an inevitable consequence of rising atmospheric carbon dioxide levels. Ocean acidification is receiving a great deal of attention in the media, but the chemistry involved is not especially intuitive. (See some of the resource articles listed in this packet for a good overview of how OA works.) In short, the decrease in carbonate ion availability that results from a decrease in seawater pH makes calcium carbonate minerals, the primary component of mollusk shells and skeletons

Damage to the shells and skeletons of mollusks and corals has been observed as a result of ocean acidification, and this damage is similar to the examples we will generate here.

Materials and methods

White vinegar

Non-reactive containers (glass beakers)

Small, thin seashells (1 or 2 inches across; try slipper, scallop, ark, or small clam shells) – try to have two similar shells of each type, to provide a control and an experimental shell. Buy at a craft store or collect yourself, but make sure they're not occupied by any living creatures!

Water

Heavy books

- 1) Dilute 1 part vinegar in at least 1 part fresh water. If you have multiple types of seashells, place one of each type in this mixture. Place one of each type in fresh water.
- 2) Check on the shells every few hours. When the vinegar-digested shells are visibly degraded (a day or two, depending on vinegar mixture strength), drain all the shells and rinse off the vinegar-digested shells. Degraded shells will be dull, pitted, translucent, or even cracked.
- 3) Have students pile books on top of the shells to compare the strength of digested shells and undigested shells. Digested shells should break more easily than undigested shells.
- 4) If desired, show students the shells while they are in acid. Have them discuss why bubbles are generated and what the bubbles are composed of.

*Note: this demonstration requires 1-2 days of advance preparation

National science education standards supported by this kit

Levels 5-8

Unifying concepts and processes	Science as Inquiry Standards	Physical Science Standards	Life Science Standards
Evidence, models, and explanation	Abilities necessary to do scientific inquiry	Properties and changes of properties in matter	Populations and ecosystems
Change, constancy, and measurement	Understanding about scientific inquiry		Diversity and adaptations of organisms

Earth & Space Science Standards	Science & Technology Standards	Science in personal and social perspectives	History and Nature of Science Standards
Structure of the earth system	Understanding about science and technology	Populations, resources, and environments	Science as a human endeavor
		Natural hazards	Nature of science
		Science and technology in society	

Levels 9-12

Unifying concepts and processes	Science as Inquiry Standards	Physical Science Standards	Life Science Standards
Evidence, models, and explanation	Abilities necessary to do scientific inquiry	Structure and properties of matter	Interdependence of organisms
Change, constancy, and measurement	Understanding about scientific inquiry	Chemical reactions	

Earth & Space Science Standards	Science & Technology Standards	Science in personal and social perspectives	History and Nature of Science Standards
Geochemical cycles	Understanding about science and technology	Natural resources	Science as a human endeavor
		Environmental quality	Nature of science
		Natural and human-induced hazards	
		Science and technology in local, national, and global challenges	

National Committee on Science Education Standards and Assessment, and National Research Council. 1996. *National Science Education Standards*.

Teacher's answer key

Lab 1

Hypotheses

Students' answers will vary. Check that they made predictions relating the pH value of the 4 waters and the pH values of the solutions they tested.

Data

Students' tables will vary based on the substances tested and based on their predictions.

Questions

1. Depends on the solutions tested.
2. Depends on the solutions tested.
3. Approximately 8
4. Approximately 7.
5. Approximately 7.
6. Approximately 2-5. (Varies by brand of seltzer used.)
7. Answers will vary.
8. Answers will vary, but should refer to a weak acid like soda, aspirin, or even vinegar.
9. Seawater is more like bleach ; seawater's pH is around 8 and the pH of bleach is around 11, while the pH of lemon juice is low, around 2.
10. River organisms are accustomed to pH values of about 6-8, similar to fresh water values.
11. Probably not. Seltzer water is about pH 5 and goldfish live in fresh water, which is about pH 7.

Research questions

1. Answers should invoke the concept of strong and weak acids.
- 2 A. Hypotheses should focus on the ability of multiple sites on the molecule to gain or lose a proton and change the molecule's characteristics.
- 2B. Answers will vary. Students should consider ways to examine the molecule's absorbance and compare its different states (achieved by gaining or losing protons) to its appearance.

Lab 2

Part 1

Hypothesis

Students' answers will vary. Check that they predicted how the 4 waters will compare to each other.

Data

Students' tables will vary depending on the substances tested and their predictions.

Part 2

Hypothesis

Students' answers will vary. Check that they predicted how the 4 waters will resist pH change, either by ranking them or by some other method.

Data

Students' tables will vary depending on the substances tested and their predictions.

Questions

1. Depends on the solutions tested.
2. Depends on the solutions tested.
3. The pH decreased in most solutions after bubbling, but not the seltzer water.
4. Likely seawater, but answers may vary.
5. Likely seltzer water.
6. Either tap water or distilled water will likely show the greatest change in pH from bubbling. These waters have low alkalinity and low CO₂, so putting CO₂ into them via bubbling creates carbonic acid and lowers the pH. Other waters with alkalinity (like seawater) can resist pH change.
7. Students' answers may vary, but probably not. Seltzer water already contains a great deal of CO₂ and is unlikely to gain more, since it is actually losing CO₂ by fizzing.
8. The pH of seltzer might rise as CO₂ leaves the water.
9. Answers may vary. Seawater pH will not likely get below 7. Again, this is because it contains alkalinity.
10. Answers may vary, depending on the alkalinity of the artificial seawater. Artificial seawater is likely to be closest to the correct conditions for a saltwater aquarium – not only does it contain alkalinity but it also contains salts that marine animals need.

Additional resources for teachers

Overview documents

“Ocean Acidification - From Ecological Impacts to Policy Opportunities”.

Special issue of *Current: The Journal of Marine Education*, 29(1) 2009.

<http://www.mcibi.org/what/current2.htm>

Doney, S.C., V.J. Fabry, R.A. Feely, and J.A. Kleypas. 2009. Ocean acidification: the other CO₂ problem. *Annual Reviews of Marine Science*. 1:169-192.

<http://arjournals.annualreviews.org/eprint/QwPqRGcRzQM5ffhPjAdT/full/10.1146/annurev.marine.010908.163834>

Doney, S.C. 2006. The dangers of ocean acidification. *Scientific American*. 294: 58-65.

[http://loer.tamug.edu/Loup/MARS281/Ocean-Acidification\(SciAmer-2006\).pdf](http://loer.tamug.edu/Loup/MARS281/Ocean-Acidification(SciAmer-2006).pdf)

Kleypas, J.A., et al. 2006. Impacts of ocean acidification on coral reefs and other marine calcifiers: a guide for future research. Report of a workshop sponsored by NSF, NOAA, and USGS. 96 pp.

http://www.ucar.edu/communications/Final_acidification.pdf

Raven, J. et al. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. The Royal Society.

<http://royalsociety.org/document.asp?id=3249>

Teaching tools

Interactive tutorial about ocean acidification's effects on marine organisms, with a virtual biology lab about ocean acidification and sea urchins.

<http://i2i.stanford.edu/carbonlab/co2lab.swf>

Short video (21 min) about ocean acidification produced by the Natural Resources Defense Council: “Acid Test: The global challenge of ocean acidification”

<http://www.nrdc.org/oceans/acidification/aboutthefilm.asp>

Another ocean acidification teaching kit, with all necessary materials included, is available for loan from select locations. You can get more information about this kit and other marine science educational kits from the Center for Microbial Oceanography:

Research and Education website :

http://cmore.soest.hawaii.edu/education/teachers/science_kits/ocean_acid_kit.htm

Short video (8 min) about ocean acidification produced by students in the UK:

“The Other CO₂ Problem” <http://www.youtube.com/watch?v=kvUsSMa0nQU>

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