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
1 test tube rack
Label tape & marker
Dropper bottle of pH indicator
White paper

Labeled samples of acids and bases
Distilled water
Seawater
Tap water
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:

Liquid	Predicted acidity	Color	Actual acidity	pH
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.

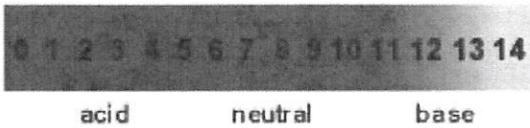
4) Use the appropriate pipette to transfer a few milliliters of each of the household acids and bases into their respective test tubes (enough to fill a tube halfway). Add your water types to their labeled tubes. Be sure to follow the labels. Don't add more than one type of fluid to any test tube. Be 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!)

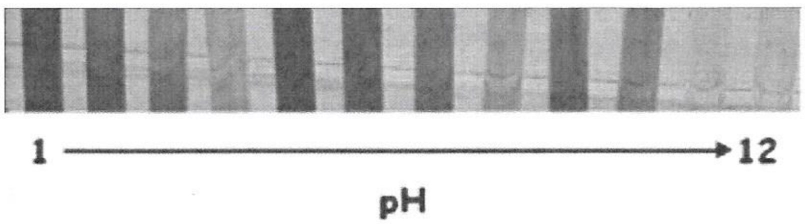
6) Write down the color of each solution in the "color" column of your data table. Compare the test tubes in front of the white paper if you have trouble telling different colors apart.

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

Liquid	Predicted acidity	Color	Actual acidity	pH

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?)

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 ($B(OH)_4^-$)] 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:

Liquid	Predicted Alkalinity	Actual Alkalinity	Rank
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 $CaCO_3$ 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:

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

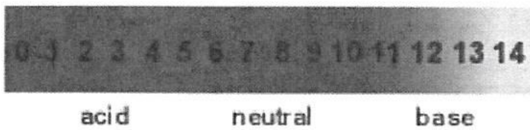
3) Add a few drops of pH indicator to the fluids in each test tube and about 10 drops to the fluids in each cup. Under "control/start color", write the colors of the controls (fluids in the test tubes). Check that the control colors match the sample colors. Again, hold the tubes or cups in front of the white paper if you need help telling apart the colors. Place a straw in each cup.

4) <u>Without sucking up any colored water into your mouth</u>, 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.



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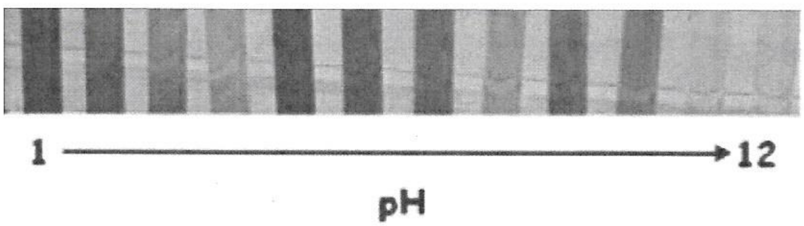

(image from http://www.precisionnutrition.com/ie-how-ph-strips-work)

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

Liquid	Predicted Alkalinity	Actual Alkalinity	Rank

Part 2

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

I predict that:____

____

Data

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

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 CO_2 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 CO_2 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?