**Ocean Water Chemistry & Ocean Acidification**

*Exploring the chemical properties of the ocean: pH*

**Summary**

This lesson is part of a series of water quality lessons that will explore the chemical properties of the ocean. Students will learn 3 different methods to test pH including visual color changes (using cabbage juice), pH test stripes and a hand held pH meter.

**Objectives**

Upon completion of this lesson students will be able to:
- Test the pH level of a water sample
- Compare acids and bases
- Understand the effect of pH level(s) on ocean life

**Materials**

<table>
<thead>
<tr>
<th>Plastic cups (or glass jars)</th>
<th>pH test strips</th>
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</thead>
<tbody>
<tr>
<td>Plastic pipettes (or Tablespoons)</td>
<td>Hand held pH meter (optional)</td>
</tr>
<tr>
<td>Stirring sticks (or spoons)</td>
<td>Liquids** (see below)</td>
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<tr>
<td>Marker</td>
<td>Knife and cutting board</td>
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<tr>
<td>Masking tape</td>
<td>Saucepan and stove</td>
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<td>Safety goggles*</td>
<td>Strainer</td>
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<tr>
<td>Gloves*</td>
<td>Paper towels</td>
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<tr>
<td>Apron/lab coats*</td>
<td>Red Cabbage Juice***</td>
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</tbody>
</table>

**Suggested liquids to use:**

<table>
<thead>
<tr>
<th>Acids</th>
<th>Neutral</th>
<th>Bases</th>
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</thead>
<tbody>
<tr>
<td>White Vinegar*</td>
<td>Tap water</td>
<td>Salt water (preferably ocean sample)</td>
</tr>
<tr>
<td>Club Soda</td>
<td></td>
<td>Hand soap</td>
</tr>
<tr>
<td>Apple Juice</td>
<td></td>
<td>Bleach*</td>
</tr>
</tbody>
</table>

**Safety notes:**

* Some of these liquids are harsh on the skin, if you want to use as part of the experiment they should be handled by the teacher only!!! Always wear safety goggles, gloves and lab coat when using harsh acids or bases.

REMINDE THE STUDENTS NOT TO TASTE ANY OF THE LIQUIDS.

**Other solutions that can be used include: lemon, orange juice, tea, coffee, baking soda, etc. remember the lighter or more clear the liquid is the easier it is to see the color reaction in test 2.

***Red cabbage juice can be prepared ahead of time (Instructions below)
Making Connections
This lesson is part of a series of water quality lessons that will explore the chemical properties of the ocean. Students will be able to relate measuring pH levels by using household items. Some test water pH as a job for example: aquaculture technician, marine biologist, swimming pool technician, water quality technician.

Teacher Prep for Activity
Advanced Prep: (Day before)
- Collect local ocean water (or mix your own salt water) and freshwater (you can use tap water)
- Purchase household items to use as tester solutions and materials listed
- Make red cabbage juice:
  ***To prepare the red cabbage juice:
  1. Cut approximately 2 cups of the cabbage
  2. Boil cabbage for about 5 minutes in 2 quarts of water
  3. Strain out the cabbage pieces KEEPING THE JUICE
     (the color may vary from reddish purple to blue- either will work).
  4. Excess juice can be frozen in ice-cube trays for later use.
     This is a good option to prep ahead of time.

Prior to the students arriving for the lab: (30 minutes to 1 hour before lab)
Do the experiment on your own to:
- Test the pH of each with the stripes, and record on an index card with the liquid name.
- Test the freshwater and the saltwater with the pH meter.
- Test the colors of your liquids with cabbage juice and save to display.
Next,
- Display them as a reference in order of most basic to most acidic.
- Place the index cards taped to the table in front of each cup/jar to hide the true solution and pH. (During the experiments let the kids come up and check/compare their colors).
Split the class up into groups of ~5 students. Each group will test the same 5 liquids

- **Label** each cup with a different letter (A, B, C, D, E)
- **Fill** the cups half full (approximately ½ cup of each liquid)
  - o A: Apple juice
  - o B: Soda
  - o C: Fresh water (tap)
  - o D: Salt water
  - o E: Soap
- **Fill a cup** with the cabbage water label INDICATOR

**Background**
See attached reference table with known pH values.

The pH test is one of the most common measurements taken in water quality testing. pH indicates the water quality by measuring the relative amount (or concentration) of hydrogen (H) and hydroxyl (OH) ions in the water sample. Water that has more H+ ions is acidic and water with more OH- ions is basic or alkaline.

The range of pH is from 1-14, with pure water representing the neutral number of 7.0 (meaning the level of H+ and OH – are equal). Values greater than 7 are considered to be alkaline or base, values less than 7 are considered acids. A value of 6.9 is a weak acid. The change from 3 to 2 is a ten-fold change in how acidic the substance has become. A pH of 2 is TEN TIMES more acidic than a pH of 3.

Each organism has adapted to life in water of a specific range in pH. A pH range of 6.5 to 8.5 is optimal for most organisms. Fish can tolerate pH values of about 5.0 to 9.0 depending on the species and the age. Immature fish, shellfish, crustaceans and algae are very sensitive to changes in pH and require a stable pH to survive.

The pH of water can greatly influence the health and growth of marine life. Scientist test pH as an important factor of water quality testing and sample water from different ocean habitats, fishing grounds and fish farms. pH can be used to monitor changes or abnormalities in a fish tank.
or in an ocean area and this is important because fish reproduction is affected around 5 and all fish will die at a pH of 4.2.

The pH levels may be slightly different depending on the site you collect it from. For example a pH of 8.2 might be normal for that site. In order to determine if the pH is normal it must be monitored over a long period of time (some do this daily, weekly) to see if it stays the same or if it changes. Sometimes the changes are more important then the actual measurement values, because it indicates that something is influencing or causing the changes.

Between 1751 and 2004 surface ocean pH is estimated to have decreased from approximately 8.25 to 8.14 (Science daily.com). This process is called ocean acidification. These slight changes can have a big impact on ocean life! The growth of the protective calcium carbonate shells of crustaceans are affected by the pH in the ocean becoming more acidic.

**Vocabulary**

**Acid:** a chemical substance that neutralizes alkalis, dissolves some metals, and turns litmus red; typically, a corrosive or sour-tasting liquid. Acids are compounds that release hydrogen ions (H\(^+\)) when dissolved in water. Any solution with a pH of less than 7 is acidic, strong acids such as sulfuric or hydrochloric acid having a pH as low as 1 or 2.

**Alkaline:** having the properties of an alkali, or containing alkali; having a pH greater than 7. Often contrasted with acid or acidic. Also called a base.

**Base:** a substance capable of reacting with an acid to form a salt and water, or (more broadly) of accepting or neutralizing hydrogen ions.

**Compound:** a substance formed from two or more elements, Example: a compound of hydrogen and oxygen.

**Indicator:** a compound that changes color at a specific pH value or in the presence of a particular substance and can be used to monitor acidity, alkalinity, or the progress of a reaction.

**Neutral:** neither an acid or a base, pH measurement is equal to 7.

**Ocean acidification:** the name given to the ongoing decrease in the pH of the Earth's oceans, caused by their uptake of anthropogenic carbon dioxide from the atmosphere. Between 1751 and 1994 surface ocean pH is estimated to have decreased from approximately 8.179 to 8.104 (wikipedia)

**Periodic table of elements:** a table that displays chemical elements and their properties

**pH:** a figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid, and higher values more alkaline.

**pH indicator:** a visual detection of the pH of a liquid, this can be done by adding an indicator such as cabbage water or by using pH indicator strips
**pH meter:** an electronic instrument used to detect pH

**Reaction:** a chemical process in which two or more substances act mutually on each other and are changed into different substances, or one substance changes into two or more other substances.

**Procedure**

**Display the colored pH range on the board or ELMO:** (2 different ways to display the pH scale)

Draw on the board a sample cup:
A solution with a low pH is full of H ions (cup full with HHHHHHHHHHHHHH)
A solution with a high pH has a low concentration of H ions HHH

There are several ways to test the pH level of a sample, today we will use:
- pH indicator
- pH meter
- pH paper

Tell the students that it is on a scale from 1 to 14 with the number 1 being the most acidic, 7 is neutral and 14 is basic. **Point out the extremes,** strong acids are closest to 1 while strong bases are closer to 14.

**Have the students draw the scale and fill the items** in or give them the blank scale and have them color and fill in the appropriate levels.

**Ask them** where they think the following things would be on the scale & fill them in to match the pH number: (answer in parenthesis)
Stomach acid (1), Acid rain (4), Battery acid (0), Lemon juice (2), Orange juice (3), Saliva (6), Drano (14), “Antacid” – Tums (10), Coffee (5), Baking soda (9), Tomato juice (4).

Ocean water chemistry & acidification
Have the students get into their groups and then tell them to listen and watch closely as you demonstrate what to do.

**Start the experiment by demonstrating** with the strong acids and bases that you don’t want them to handle (such as the harsh acid and bases, Household cleaners, and vinegar).

For Test 1 you will:
- Put the test strip into the solution, and show them how to match the color to the indicator colors on the bottle.

For Test 2 you will:
- Put approximately 2 Tablespoons of the cabbage juice into the jar and stir. Note color change and compare to the fresh water as this has a neutral pH of 7.

“Now that I have demonstrated the procedure using the two most extreme solutions for you, follow the directions on the **instructions handout** to find the pH of the other solutions that fall within the range of the two extremes.” Tell them to read the instructions carefully!

**REMEMBER THE STUDENTS NOT TO TASTE ANY OF THE LIQUIDS.**

Have the students get their own materials. Tell them once they have completed test 1 then they can come up and get directions for test 2, once they are done with test 2 come up and see you.

**For Test 1 each group will need:**
- 5 samples (pre-labeled A-E), 5 strips of testing paper

**For Test 2 each group will need:**
- Each group needs: 5 pipettes or spoons, 5 stirring sticks, same 5 samples (pre-labeled A-E), one cup of INDICATOR reagent (Cabbage juice).

For Test 3 they will come up to test the pH with the hand held meter.

Show the students a hand held pH meter (if available) use the saltwater and freshwater to demonstrate how to read the digital reading.

It’s even more accurate!!! With decimals to what place? 0.00?

**Assessments**
- Completed lab worksheet
- pH predictions made and worksheet completed (you may also chose to have them write their findings on the board).

Questions to ask the kids throughout the experiment (Formative assessment):

- Ocean water chemistry & acidification
Can you think of anything in the ocean that might break down when the pH becomes more acidic?

**Resources**


Wikipedia - pH tables

**Extension Activities**

Ocean Acidification experiment:

What do you think will happen to the shell of an egg when it is submersed in a strong acid? This demonstrates the effects of low pH on the carbonate exoskeleton of marine organisms.

Instead of an egg in vinegar you could try to dissolve a sea shell in a stronger acid and measure it before and after to truly represent how ocean species are being affected by more acidic pH levels.

Discuss how increased emissions of CO₂ changes the chemistry of our oceans. What effects will this have on marine life?

Discuss ocean acidification and CO₂ in more detail, watch video and read article as a class: [http://news.bbc.co.uk/2/hi/science/nature/7437862.stm](http://news.bbc.co.uk/2/hi/science/nature/7437862.stm)

How does pH change when you add more CO₂

Make your own pH test stripes:

Use the cabbage water on plain white paper, let it dry and cut into stripes

Hibiscus flowers contain the same natural dye (Anthocyanin found in cabbage)

when crushed on white paper will change red with acid and back to blue with base.

Field Trips:

Visit the beach or local aquaculture center to test the pH and additional water quality parameters.
LAB WORKSHEET: WATER QUALITY: Measuring pH

**Background information:** pH is a type of measurement that can indicate how acidic or how basic a liquid is. The pH is measured on a scale of 0 to 14 with numbers in the range 0-6 are acidic, 7 is neutral, and 8-14 are basic. It is important to measure the pH of water because animals such as fish have a certain range of pH that they can live in. Water is made up of Hydrogen and Oxygen, as the amount of Hydrogen increases the pH of the water becomes more acidic. Scientists monitor changes in pH to predict and understand the possible effects that it may have on animals living in water.

**Vocabulary:**
1. **pH:** a measurement that indicates if a liquid is an acid, a base or neutral, the scale is 0-14
2. **Acid:** pH measurement is less than 7
3. **Base:** pH measurement is more than 7
4. **Neutral:** neither an acid or a base, pH measurement equal to 7
5. **pH indicator:** a chemical compound that can be added to a liquid so that the pH can be determined easily by a change of color. Liquids with a pH that is acidic will turn a red color while basic liquids will turn a blue color
6. **pH test strips:** paper that is used to test if a liquid is acidic or basic
7. **pH meter:** an electronic instrument used to measure the pH of a liquid
8. **Periodic table of elements:** a table that displays chemical elements
9. **Hydrogen (H):** the most common chemical element, important in determining pH, major component of water
10. **Oxygen (O):** the third most common chemical element, important product of photosynthesis, major component of water
11. **Dissolved oxygen (D.O):** measurement of the amount of oxygen dissolved in water
12. **Water:** a chemical substance that’s molecule includes two Hydrogen atoms and one Oxygen atom, it is important to all life
13. **Salt:** a mineral made of Sodium and chloride (NaCl)
14. **Salinity:** measurement of the saltiness or amount of dissolved salt in water
15. **Carbon dioxide:** (CO₂) A chemical compound composed of two oxygen and one carbon atom, used by plants in photosynthesis, also a major waste product of burning fossil fuels (like gas)
16. **Calcium Carbonate:** (CaCO₃) a chemical compound composed of calcium and carbonate, it makes up most shells and coral.
17. **Ocean acidification:** the ongoing process of the pH of the Earth’s oceans becoming more acidic because of atmospheric carbon dioxide (CO₂).
LAB #1
Question: What is the pH of the ocean?

Hypothesis: I think the pH of the ocean is ____________.
(Pick a number between 0-14 with 7 = neutral, less than 7 is acidic, greater than 7 is basic).

Experiment: In this experiment we will use 3 different methods to measure the pH of the ocean and common household liquids. The three methods used to measure pH are 1.) Indicator liquid 2.) pH test strips 3.) pH meter

Materials:
- 1ml Pipette or spoon
- Gloves
- Jars with lid
- Indicator solution (cabbage water)
- Safety goggles
- pH meter
- Common household liquids
- Paper towels
- pH test strips
- Ocean water sample

Steps:
1. Put on gloves and safety goggles
2. Tell your teacher if you spill any liquids during the lab
3. Observe the liquids and record the initial color in the data table below
4. Put about 2 ml (or about two spoonfuls) of indicator solution into each liquid
5. Note the color change and record in data table
6. If the color changed to a red/pink/lavender then it is acidic, if the color changed green, yellow or dark blue then it is basic, if the color is light blue then it is neutral.
7. This method doesn’t give you a specific pH number it only tells you if it is an acid, base or neutral
8. Now use the pH strips to determine a number
9. Take out one strip for each liquid
10. Dip it in for about 5 seconds
11. Hold and let dry
12. Compare the color to the color indicator on the pH strip jar to determine the closest #
13. Record the # in the pH strip # column of your data table
14. This method is also determined by a change in color and is not as specific as the pH meter
15. Lastly take out the original ocean water sample
16. Record the location, date and time the water sample was collected in the second data table
17. Place the pH meter inside until the numbers are settled
18. Record the pH # in the second data table under the pH meter reading column
19. Analyze your results and report if your hypothesis was correct or not and why
Lab #1 (continued)

Data:

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Initial color</th>
<th>Color after cabbage indicator added</th>
<th>Is it an Acid, Base or Neutral?</th>
<th>pH strip #</th>
</tr>
</thead>
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<table>
<thead>
<tr>
<th>Sample site of ocean water</th>
<th>Date and time collected</th>
<th>pH meter reading</th>
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<tbody>
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Analysis of data:
The pH of the ocean water sample is ______________.

Report your results:
Was your hypothesis correct? ____________________________________________

What are your conclusions? (What did you learn)
________________________________________________________________________
________________________________________________________________________
LAB #2

**Question:** What effect do you think a strong acid will have on a shell?

**Background information:** The pH of the ocean is becoming slightly more acidic with an increase in Carbon dioxide in the atmosphere and this may have an effect on ocean animals. Shells and coral are sensitive to slight changes in pH.

**Name 3 animals that live in the ocean that have shells:**
1. __________________________ 2. __________________________ 3. __________________________

**Why is the shell important?**

**Hypothesis:** I think the vinegar (strong acid) will make the shell ___________________.
*pick one: dissolve, grow, change color*

**Materials:**
- Jar with lid
- Vinegar
- Forceps (tweezers)
- Shells
- Egg
- Ruler

**Steps of experiment:**
1. Fill the jar half full with vinegar
2. Select no more than 2 items
3. Measure each item and record length in data table
4. Draw an outline around each item (on the back of this paper)
5. Pick up one item at a time with the forceps and place them gently in the jar
6. Close the lid on the jar
7. Record any observations that you noticed once the items were placed in the jar
8. Set the jars aside in an area marked off by your teacher and look at them everyday
9. Wait two days and then measure again
10. Take each item out of the jar carefully the your forceps (dry them off with a paper towel)
11. Measure the length of each item and record observations

**Data Table:**

<table>
<thead>
<tr>
<th>Item name</th>
<th>Initial length</th>
<th>Observations</th>
<th>Length after 2 days</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
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**Results and Discussion:**
What did you notice when you added the shell to the vinegar?

What happened to the items after 2 days in the vinegar?

What do you think will happen to an animal’s shell if the pH of the ocean becomes more acidic?