Below Basic: Ocean acidification and its impacts on marine organisms

Subject (Focus/Topic): This lesson will address the impacts that ocean acidification has on marine organisms, particularly those with calcium carbonate (CaCO$_3$) shells.

Grade Level: 9-12 (asterisks * indicate higher-order thinking/chemistry concepts that may be added or omitted to fit the needs of a particular classroom)

Average Learning Time: approx. 1 90-minute block of time per section utilized. If all three sections are utilized, the entire unit of study should take about 1.5 weeks to complete on both the standard and block schedules.

Lesson Summary (Overview/Purpose): Students will demonstrate how CaCO$_3$ forms protective shells for marine organisms, how CO$_2$ enters the ocean and impacts pH, why CO$_2$ can remain in solution easily in the ocean, what happens when the balance of CO$_2$ is disrupted in the ocean, how it impacts Calcium Carbonate fixing organisms such as pteropods, and predict how this impacts the global food web.

Overall Concept (Big Idea/Essential Question): How does anthropogenic Carbon Dioxide impact our oceans? What will happen to our ocean in the future as a result?

Specific Concepts (Key concepts):

1. The ocean has a delicate balance in terms of pH that, if disrupted significantly, can have catastrophic effects on marine organisms.
2. Marine organisms rely on a continual supply of Ca$^{+2}$ ions and Bicarbonate ions to produce protective shells for survival.
3. A less basic (more acidic) ocean has two negative impacts: it lowers the amount of available CaCO$_3$ for marine organisms to “fix” into their shells, and the acidity erodes the shells already made by marine organisms.

Objectives/Learning Goals:

Students will be able to demonstrate qualitatively the impacts of an acid environment on hard-shelled organisms by earning a “5” or “6” on 2 of 3 scoring rubrics for each lesson activity. If only one or two lessons are utilized, proficiency will be demonstrated through a score of “5” or “6” on 1 out of 1 scoring rubrics, or 1 out of 2 scoring rubrics.

Background Information:

All background information necessary for students to understand key concepts in the lesson is contained in the submitted PowerPoint presentations that will precede (or follow) each laboratory activity. Key reminders for each lesson are included in the teacher information preceding each daily activity.
Common Misconceptions: Many students may think that the process of Ocean Acidification is making the ocean turn acid by conventional definitions (i.e., ocean water has a pH of 7, so acidifying it makes it a pH of less than 7). The reality is that the pH of the ocean is, on average, about 8.14, a 30% decrease in pH from pre-industrial revolution levels of 8.25 (approx. 1751). Currently, our ocean is still a basic solution. However, the process of ocean acidification refers to this decrease in pH. Projected values into 2100 do indicate a future with a close to neutral ocean.

Materials: Materials will be listed by day in each lesson in case a teacher would like to use part of a daily lesson instead of the entire unit.

Technical requirements: Teachers should have access to a projector in order to run given PowerPoint presentations. However, PowerPoint presentations should be easily transferrable into less-technological media, such as transparencies or even a standard chalk board. Access to standard laboratory equipment and material preparation space (including access to a fume hood) is HIGHLY recommended.

Teacher Preparation: Teacher preparation will be listed by day in each lesson in case a teacher would like to use part of a daily lesson in lieu of an entire unit.

Keywords:

- pH
- equilibrium
- supersaturated
- saturation horizon

Pre-Assessment: N/A

Lesson Procedure: Lesson procedures will be listed by day in each lesson in case a teacher would like to use part of a lesson in lieu of the entire unit of study. Materials, PowerPoint slides, or questions marked with an * indicate an option to omit in order to meet the needs of students. This makes each lesson accessible for ALL types of students.

Assessment and Evaluation: Each assessment will be listed by day in each lesson in case a teacher would like to use part of a daily lesson in lieu of an entire unit of study.

Standards:

NSES STANDARDS:

NSES Category A:

Sub Categories 1, 2

NSES Category B:
Sub Categories 1, 3, 5, 6

NSES Category C:
Sub Category 4

NSES Category D:
Sub Category 2

NSES Category F
Sub Categories 4 & 5

NSES Category G
Sub Category 3

**Ocean Literacy Principles Addressed:**

Principle 1: The Earth has one big ocean with many features.
   Fundamental concepts: e, h

Principle 2: The ocean and life in the ocean shape the features of the Earth
   Fundamental concepts: a, d

Principle 3: The ocean is a major influence on weather and climate
   Fundamental concepts: a, e

Principle 5: The ocean provides a great diversity of life and ecosystems
   Fundamental concepts: a, b, d, f

Principle 6: The ocean and humans are inextricably connected.
   Fundamental concepts: b, e, g

**State Science Standards Addressed (Colorado):**

Physical Science: 1.2, 1.3, 1.4

Earth and Space Science: 3.4, 3.5, 3.6

**Additional Resources:**


*Reference in this document to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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**A very special thank you to Dr. Robert Foy for giving us a tour of the AFSC and alerting us to such an important topic. Your enthusiasm, genuine hospitality, and immense knowledge inspired this series of lessons!
**To Dr. Chris Wilson, who introduced Cat and I to Dr. Foy and transporting us there while we were “stranded on land.”
**To Catherine Fox, my fellow Teacher At Sea partner, who inspired me to continue writing and to create this series of lessons. You are a true friend!

Creation Date: October 10th, 2011
Teacher’s Guide

Day 1: How do marine organisms use CaCO$_3$?

Teacher Preparation:

1. Time frame: 90 minutes (or two forty-five minute blocks)
2. Obtain materials listed in lab activity.
   a. Lab activity has two separate set-ups, one for standard level students, and one for advanced students. The standard level lesson provides measurements in standard cooking form (ie, 1 cup, 1 tsp, etc) and the advanced requires students to convert from these standard forms to metric. Each cup of sugar required is 201 grams. Each cup of water is 250 mL, and 1 tsp = 15 mL. I would suggest making lab groups of no more than 4, so be sure you have enough granulated sugar for the labs.
   b. The cleaner the inside of the glass jars is, the more likely the candy will fuse to the string, and not the side of the jar. Keep fingerprints and dust OUT of the insides of the jar!
   c. Make sure all lab equipment you use is safe for use with human consumption – use fresh, out-of-the-box materials that have not been in contact with other chemicals.
   d. Clean-up on this lab can be a beast if you don’t have the students clean out the glassware themselves at the conclusion of the lesson. It’s best to use jars that you can recycle after you are done – they will most likely be caked with sugar crystals.
   e. Make sure you have enough space in your classroom where students can store the jars undisturbed for about a week – jarring the containers makes it harder for crystals to form.
3. Review PowerPoint for lesson objectives, main ideas, etc

Lesson Procedure:

1. Give PowerPoint lecture or brief overview of supersaturated solutions and how this relates to marine organisms utilizing CaCO$_3$ for shells. (Provided)
2. Pass out the lab activity. (Provided).
3. Divide class into manageable lab groups (no more than 4).
4. Have students complete the Pre-Lab questions BEFORE beginning the lab.
5. When ready, lab groups should follow procedure to complete the lab.
6. Have students answer follow-up questions from lab and submit for scoring.
7. After about one week, the candy should be ready for the students to enjoy!
Assessment:
Students should answer post-lab questions to be assessed for accuracy using the rubric provided. A connection should be made between the formation of the sugar crystals and the formation of CaCO$_3$ shell material on marine organisms.
Below Basic: Ocean acidification and its impacts on marine organisms
Part 1: How do marine organisms obtain and use CaCO₃?

Purpose:

The purpose of this lab activity is to demonstrate how a marine organism utilizes a supersaturated solution of Ca^{2+} ions to form a thick, protective shell using everyday materials.

Materials:

- 3 cups Granulated sugar
- 1 cup Water
- CLEAN glass jar
- String
- Pencil
- Life Saver
- Food Coloring
- 1 tsp. Flavoring, extract, or unsweetened drink mix (ie, Kool-Aid)
- Coffee filter
- 1,000 mL beaker (safe for human consumption following use)
- Thermometer (safe for human consumption following use)
- 25 mL graduated cylinder (safe for human consumption following use)
- Stirring rod or spoon (safe for human consumption following use)
- Triple beam balance or electronic balance
- Hot plate
- Dish soap
- Cleaning Sponge
Pre-Lab Questions (Answer on a separate sheet and show work where necessary):

1. * Convert all English measurements to metric units using the factor-label method for the following conversions:
   1c sugar = 201 g sugar
   1c water = 250 mL water
   1tsp = 15 mL
2. What condition is necessary for marine organisms to obtain CaCO\(_3\) to make a shell?
3. Looking at the materials list, based on volume/mass alone, predict what will happen as the sugar solution is made.
4. What role will heating play in the dissolution of the sugar in the water?

Procedure (Recipe credited to chemistry.about.com):

1. Complete the pre-lab questions and submit to your teacher for approval before beginning the lab exercise.
2. Obtain all materials from your instructor.
3. Measure out sugar and water (using triple beam balance and graduated cylinder, if required by your teacher)
4. Plug in hot plate and turn to medium-high.
5. Combine the sugar and the water into the 1,000 mL beaker.
6. Heat the mixture to a boil, stirring constantly, until it boils. It should hit the boiling point, but not cook too long. If you heat it too much, you will not achieve desired results.
7. Stir until ALL sugar has dissolved. The liquid will be clear or straw-colored, without any sparkly sugar.
8. At the end of heating as sugar is completely dissolved, add food coloring and flavoring to solution, if desired.
9. Remove sugar solution from hot plate and place thermometer in solution. Cool until approximately 50°F. **IF your teacher requires, please convert this to Celsius temperature.**
10. Prepare your string by tying a pencil to one end and the lifesaver to the other end. Give your string a quick “dunk” in the solution as it is cooling and hang it to dry. Turn off your hot plate.
11. Once the solution has cooled, pour it into your clean jar – do NOT touch the inside of the jar. Hang string by putting the life-saver end into the jar and hang the pencil end from the outside of the jar. Place the coffee filter on top of the jar to keep the inside clean.
12. Place your jar somewhere will it will not be disturbed.
13. Using the dish soap and sponge, thoroughly clean your materials (beaker, spoon/stirring rod, thermometer) before returning them to your teacher. You want them just as clean as when you received them.
14. Your candy should be crystallized in about one week!
Questions for Discussion:

1. Compare the rock-candy making process to CaCO₃ formation for marine organisms. How are they similar?
2. What role did temperature play in…
   a. The dissolving of the sugar?
   b. The cooling of the supersaturated solution?
3. *Using your answers to #2, describe how the kinetic energy of the molecules allowed for…
   a. Supersaturation of the sugar water
   b. Cooling and formation of the rock candy
4. What would have happened in this experiment if there was only 201 g of sugar compared to 250 mL of water? What if there were 804 g of sugar compared to 250 mL of water?
5. *What are some other ways, other than presence of less sugar, that could have led to the crystals not forming as they should have?
Answer sheet/Assessment for Lab 1: How do Marine Organisms Use CaCO₃?

Pre-Lab:

1. Conversions:
   Sugar:
   
   \[
   3 \text{ c sugar} \times \frac{201 \text{ g sugar}}{1 \text{ c}} = 603 \text{ g sugar}
   \]
   
   \[
   1 \text{ c water} \times \frac{250 \text{ mL water}}{1 \text{ c}} = 250 \text{ mL water}
   \]
   
   \[
   1 \text{ tsp flavoring} \times \frac{15 \text{ mL flavoring}}{1 \text{ tsp}} = 15 \text{ mL flavoring}
   \]

2. The condition necessary for marine organisms to obtain CaCO₃ is an excess of Calcium and Carbonate ions in the water – in effect, a supersaturated solution.

3. Based on the amount of sugar compared to the amount of water, there should be a supersaturated sugar solution as the water heats. As the solution cools, the sugar will begin to form crystals on the string.

Post Lab

1. The rock-candy making process is similar to the shell-forming process because the sugar crystals form out of supersaturated solution as the mixture cools, similar to how the presence of excess Ca and Carbonate ions allows those compounds to form shells for marine organisms.

2. 1. The higher temperature allowed more sugar to remain in solution as the mixture heated.

   2. The cooling of the solution meant that the sugar could no longer remain dissolved, and therefore the sugar crystals attached to the string.

3* 1. A supersaturated solution could be formed by heating the mixture because the faster moving molecules could remain dissolved based on their speed. The warmer (ie faster) the solution, the more sugar could be readily dissolved and remain in that dissolved state.
2. As the solution cooled, the sugar could no longer remain dissolved – it could not move fast enough kinetically to remain in solution and therefore must return to the solid state. The cooler (ie, slower) the solution, the fewer molecules could remain in solution.

4. If less sugar were used, the solution would be undersaturated, meaning that it would be unlikely for large sugar crystals to form on the string. If more sugar were used, then it would be necessary to heat up the solution even more in order to get the sugar to dissolve. Or, there is a chance that no matter how much the solution was heated, the sugar still might not dissolve.

5. Some other ways that might keep the rock candy from forming is the presence of another chemical that reacts with the sugar to make a new compound. Also, if the solution was heated too much or not heated up enough, it may not make rock candy.

Rubric on Following Page
### Scoring Rubric for Lab Activity #1:

<table>
<thead>
<tr>
<th>Element</th>
<th>Lab Procedure</th>
<th>Pre and Post-Lab analysis</th>
<th>Grammar/Usage/Neatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 pts</td>
<td>Measurements made with precision, all directions were followed, and lab station and equipment was cleaned up at the end.</td>
<td>Student connects formation of CaCO₃ to candy-making procedure. Student demonstrates an understanding of supersaturated and undersaturated solutions. Student provides feasible alternatives to why rock candy may NOT form, and cites specifically another chemical present interfering with deposition of sugar crystals.</td>
<td>Student demonstrates proper grammar and usage throughout pre-lab and post lab. Student’s work is legible and clean.</td>
</tr>
<tr>
<td>1 pt</td>
<td>Measurements were made, all directions were followed, and lab station and equipment was cleaned up at the end of the lab.</td>
<td>Student somewhat understands the concept of supersaturated and undersaturated solutions. Student may still lack full understanding of why the process is similar to CaCO₃ formation of marine shells.</td>
<td>Student is missing one element from a “level 2” score. Indicate:</td>
</tr>
<tr>
<td>0 pts</td>
<td>Poor measurements, poor direction following, or poor/improper clean up at the end of the lab.</td>
<td>Student does not demonstrate an understanding of supersaturated and undersaturated solutions. Lacks an understanding of the connection between sugar-making and CaCO₃ formation.</td>
<td>Student is missing more than one element from a “level 2” score.</td>
</tr>
</tbody>
</table>

Score of 5-6 indicates full understanding of concepts  
Score of 3-4 indicates partial understanding of concepts  
Score of 1–2 indicates lack of understanding of concepts.
Teacher’s Guide

Day 2: How does an excess presence of CO₂ impact the ocean? The acidity and solubility of Carbon Dioxide in Ocean Water

Teacher Preparation:

4. Time frame: 60 minutes (or 1 and a half forty-five minute blocks)
5. Obtain materials listed in lab activity.
   a. Lab activity has two separate set-ups, one for standard level students, and one for advanced students, as indicated by asterisks.
   b. Be sure to toss half of the club sodas in the fridge or on ice and leave the other half room temperature – it will make the heating/cooling of the bottles go much more smoothly.
   c. Have the students use caution when opening the warm club soda. It’s won’t (nor should it) be boiling hot, but ensure the students are paying attention to the warm water temperature so they don’t scald themselves in the event the warm seltzer water sprays when it is opened.
   d. The warm seltzer will most likely spray – be prepared for cleanup and make sure that students don’t get any spray on the floor and create a slipping hazard. Aprons are listed as a material in case students worry about getting seltzer on their clothing.
6. Review PowerPoint for lesson objectives, main ideas, etc

Lesson Procedure:

8. Give PowerPoint lecture or brief overview of the interactions between atmospheric carbon dioxide and the ocean. (Provided)
10. Divide class into manageable lab groups (no more than 4).
11. Have students complete the Pre-Lab questions BEFORE beginning the lab.
12. When ready, lab groups should follow procedure to complete the lab.
13. Have students answer follow-up questions from lab and submit for scoring.

Assessment:

Students should answer post-lab questions to be assessed for accuracy using the rubric provided. A connection should be made between the amount of carbon dioxide that can remain in solution and the temperature and pressure of the solution. In this case, a cold and deep ocean (cooler temps/higher pressures) means that more CO₂ can remain dissolved in the ocean water. An advanced student may be able to make the connection to a lack of photosynthesis also contributing to the higher percentage of CO₂ in the deep ocean.
Below Basic: Ocean acidification and its impacts on marine organisms

Part 2: What conditions favor Carbon Dioxide remaining dissolved in ocean water? What impact does the presence of Carbonic Acid have on our Oceans?

Purpose:

The purpose of this lab is to determine the temperature conditions that favor the presence of carbonic acid in ocean water and to determine how the presence of Carbon Dioxide affects the pH of ocean water.

Materials:

- Small ice cubes (about 2 cups)
- Hot plate
- Water
- 1 small, unrefrigerated bottle or can of sealed club soda or seltzer water, (cans of coke or tonic water will work, too, but may be more expensive and produce a less accurate pH result)
- 1 small, refrigerated bottle or can of sealed club soda or seltzer water
- Beaker Tongs
- Rock salt – about a handful
- 2 1000 mL beakers
- 1 thermometer
- 3 strips of Hydrion Papers (pH papers that test in a narrow range)
- Safety goggles and apron

Pre-Lab

1. What are three ways CO₂ gets released into the atmosphere?
2. How does this CO₂ get into our ocean?
3. What chemical is produced as a result of CO₂ being introduced into the ocean?
4. *If the solubility of a gas in water is 0.75 g/L at 3.2 atm of pressure, what is its solubility (in g/L) at 1.0 atm of pressure? Assume a constant temperature. Show all work.*
5. *According to Henry’s Law, Pressure and Solubility of a gas are related. What is the relationship?*
6. *Form a hypothesis about the Solubility of a gas as it relates to temperature.*
7. (omit if you’ve answered question 6) What do you think will happen to the solubility of carbon dioxide as temperature increases? In other words, if the temperature of the carbon dioxide/water solution goes up, will more or fewer bubbles escape when the pressure from the inside of the can is released? Form a hypothesis using an if, then statement.
8. This lab involves both heat and glassware. One critical piece of lab equipment is…
Procedure:

1. Submit your pre-lab answers to your instructor before proceeding.
2. Gather all materials from your lab instructor. Put on your safety goggles!
3. Turn your hot plate on to medium high.
4. Fill one 1000 mL beaker about half full with ice. Add a handful of rock salt to the ice and a bit of water to make a “slurry” of ice, water, and salt.
5. Fill one 1000 mL beaker about half full with water and place it on the hot plate.
6. Place the refrigerated bottle of club soda in the ice/salt bath.
7. Place the room temperature bottle of club soda in the water bath on the hot plate.
8. Using the thermometer as a guide, heat the water until it is about 75-80°C and cool the ice bath until it is about 10°C.
9. Remove the warm water from the hot plate using the beaker tongs.
10. Remove the club soda bottle from the warm water using the beaker tongs.
11. When the bottle has cooled sufficiently enough to touch, hold the bottle over a sink, open the bottle, and observe.
12. Record your observations in the data table.
13. Wait approximately 5 minutes for the bubbles to stabilize (until it looks like no more are rapidly escaping).
14. Using one Hydrion paper, test the pH of the warm soda water. Compare it against the color scheme and record the pH of the warm soda water in your data table.
15. Repeat steps 11 -13 for the cold club soda.
16. Test the pH of regular water as a control.
17. Clean up and return all materials, making sure that any club soda that has spilled to the floor has been wiped up and dried. Recycle the soda water bottles.

<table>
<thead>
<tr>
<th></th>
<th>Observation (How “bubbly” was the soda?)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Club Soda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold Club Soda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Post-Lab Discussion Questions:

1. Which club soda water released more gas? The warm club soda? Or the cold club soda? Which temperature favors more gas remaining in the solution?
2. Was your hypothesis supported or refuted? Defend your answer, citing specific observations from your data table.
3. Compare the pH of the cold seltzer water to the pH of the warm seltzer water after the CO₂ was released from both containers. Which one was more acidic?
4. Is a colder ocean more acid, or more basic?
5. At what depth (shallow, medium, or deep water) do you think that the ocean is the most acid (or least basic)? Defend your answer using your results from the lab.
6. Predict: What might the presence of more acid do to pteropods, the animals that make their shells from Calcium Carbonate?
7. *Consider living creatures in the ocean, both photosynthesizing and respirating. What role do these living creatures play in the presence or absence of carbon dioxide? Predict the contribution or removal of carbon dioxide at shallow and deep waters as it relates to living organisms.
Lab 2: The Acidity and Solubility of Carbon Dioxide in Water.

Pre-Lab

1. What are three ways CO\textsubscript{2} gets released into the atmosphere?
   a. Volcanic outgassing
   b. Respiration
   c. Burning of organic materials
   d. Fossil fuels

2. How does this CO\textsubscript{2} get into our ocean?
   a. Carbon dioxide dissolves readily in our oceans after it is released into the atmosphere – the ocean is a good “trap” for carbon dioxide.

3. What chemical is produced as a result of CO\textsubscript{2} being introduced into the ocean?
   a. Carbonic acid is produced when Carbon dioxide dissolves into the ocean.

4. *If the solubility of a gas in water is 0.75 g/L at 3.2 atm of pressure, what is its solubility (in g/L) at 1.0 atm of pressure? Assume a constant temperature. Show all work.
   0.23 g/L

5. *According to Henry’s Law, Pressure and Solubility of a gas are related. What is the relationship?
   a. The relationship is directly proportional. As pressure increases, so does solubility.

6. *Form a hypothesis about the Solubility of a gas as it relates to temperature.
   a. Any hypothesis will do as long as it is in an “if, then” format as it relates to independent and dependent variables. Here is an example:
      i. If temperature is related to solubility, then an increase in temperature will lead to a decrease in solubility.

7. (omit if you’ve answered question 6) What do you think will happen to the solubility of carbon dioxide as temperature increases? In other words, if the temperature of the carbon dioxide/water solution goes up, will more or fewer bubbles escape when the pressure from the inside of the can is released? Form a hypothesis using an if, then statement.
   a. Same as above, but it may be related directly to the experiment or to bubbles released, ie “If the temperature of the carbon dioxide and water solution increases, then more bubbles will escape when the can is opened.

8. This lab involves both heat and glassware. One critical piece of lab equipment is…
   a. SAFETY GOGGLES!
Post-Lab:

8. Which club soda water released more gas? The warm club soda? Or the cold club soda? Which temperature favors more gas remaining in the solution?
   a. The warm club soda released more gas. Therefore, the colder temperatures favor more gas remaining in solution.

9. Was your hypothesis supported or refuted? Defend your answer, citing specific observations from your data table.
   a. Answers will vary, but make sure they relate directly to the individual student’s hypothesis.

10. Compare the pH of the cold seltzer water to the pH of the warm seltzer water after the CO_2 was released from both containers. Which one was more acidic?
    a. The cold seltzer water should be slightly more acidic than the warm water. Answers will vary based on the temperatures the seltzer was initially heated or cooled to.

11. Is a colder ocean more acid, or more basic?
    a. A colder ocean is a more acidic ocean.

12. At what depth (shallow, medium, or deep water) do you think that the ocean is the most acid (or least basic)? Defend your answer using your results from the lab.
    a. The ocean is the most acid in the deep water because it is both the coldest and under the greatest pressure.

13. Predict: What might the presence of more acid do to pteropods, the animals that make their shells from Calcium Carbonate?
    a. Answers will vary because the lesson hasn’t tied the two labs together yet, but the presence of acid will wear away at the shells of pteropods and make it harder for the pteropods to make shells from CaCO_3 in the water.

14. *Consider living creatures in the ocean, both photosynthesizing and respiring. What role do these living creatures play in the presence or absence of carbon dioxide? Predict the contribution or removal of carbon dioxide at shallow and deep waters as it relates to living organisms.
    a. Photosynthesizing organisms will remove CO2 from the water, and respiring organisms will add CO2 to the water. At shallower depths, light will penetrate enough for photosynthesizing organisms to live and thrive, therefore there may be less carbon dioxide. At greater depths, however, photosynthesis does not occur. Therefore, there will be more carbon dioxide based on the presence of respiring organisms, the colder temperatures, and the greater pressure.
## Scoring Rubric For Lab Activity # 2:

<table>
<thead>
<tr>
<th></th>
<th>Data and Lab Procedures</th>
<th>Pre and Post Lab Analysis</th>
<th>Grammar, Usage, and Spelling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2</strong></td>
<td>Measurements made with precision, all directions were followed, and lab station and equipment was cleaned up at the end.</td>
<td>Student understands the relationship between pressure, temperature, and solubility demonstrated through clear, concise and thoughtful answers. Student provides specific backup evidence from lab data and observations to support this learning target. Student can predict with some accuracy the effects of carbonic acid on a pteropod, and can determine the impacts that photosynthesizing organisms have on carbon dioxide levels, where applicable.</td>
<td>Fewer than 5 grammar, usage, or spelling errors. All complete sentences.</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td>Measurements were made, all directions were followed, and lab station and equipment was cleaned up at the end of the lab.</td>
<td>Student understands the relationship between pressure, temperature, and solubility, but some answers are unclear or incorrect. Student does not use lab data to back up or support claims made in pre-and post-lab analysis.</td>
<td>More than 5 grammar, spelling or usage errors, but it does not interfere with understanding of topic.</td>
</tr>
<tr>
<td><strong>0</strong></td>
<td>Poor measurements, poor direction following, or poor/improper clean up at the end of the lab.</td>
<td>Student does not demonstrate an understanding of the relationship between temperature, pressure, and carbon dioxide levels and how this impacts oceanic pH levels.</td>
<td>Grammar, spelling or usage interferes with student understanding of topic or incomplete sentences.</td>
</tr>
</tbody>
</table>

**Total**

5-6: Student indicates proficient understanding of concepts
3-4: Student indicates partially proficient understanding of concepts.
0-2: Student lacks proficiency in this topic.
Teacher’s Guide

Day 3: How does an excess presence of CO₂ impact marine organisms?

Teacher Preparation:

1. Time frame: 90 minutes (or 2 forty-five minute blocks)
2. Obtain materials listed in lab activity.
   a. Lab activity has two separate set-ups, one for standard level students, and one for advanced students, as indicated by asterisks.
   b. Be sure the chalk is completely dry before re-massing, otherwise students will get a catastrophically incorrect result! Wait about 24 hours for the chalk to completely dry.
3. Review PowerPoint for lesson objectives, main ideas, etc

Lesson Procedure:

1. Give PowerPoint lecture or brief overview of the interactions between atmospheric carbon dioxide and the ocean. (Provided)
2. Pass out the lab activity. (Provided).
3. Divide class into manageable lab groups (no more than 4).
4. Have students complete the Pre-Lab questions BEFORE beginning the lab.
5. When ready, lab groups should follow procedure to complete the lab.
6. Have students answer follow-up questions from lab and submit for scoring.

Assessment:

Students should answer post-lab questions to be assessed for accuracy using the rubric provided. A connection should be made between the presence of carbonic acid and the amount of dissolved chalk and the thinning of pteropod shells which can lead to poor overall health of pteropod populations. Advanced students will be able to predict that the dissolved solution of chalk may increase the pH of the acid solution and act as a buffer, but will also predict that the rate at which carbonic acid enters the atmosphere is so drastic that the buffer effect cannot “keep up” with the rate of dissolution of carbon dioxide.
Below Basic: Ocean acidification and its impacts on marine organisms
Lab Day 3: How Carbon Dioxide interacts with marine organisms

Purpose:

The purpose of this lab is to determine the effects of a less-basic (more acidic) environment on the shells of pteropods.

Materials:

- 5 5.00 g samples of chalk
- 1M HCl
- Pipettes
- Gloves and apron, if needed
- 1000 mL beaker
- Stirring rod
- forceps
- 5 250 mL beakers
- Calculator
- 10 mL graduated cylinder
- Marking tape or labeling system
- Triple beam balance or a quad beam balance
- Paper towels
- Instant ocean Sea Salt Mix

Pre-Lab

1. What conditions are necessary for a pteropod to form a shell?
2. What conditions are necessary for Carbon Dioxide to remain in solution in ocean water?
3. Describe the acidity of our ocean. How has it changed since pre-industrial revolution times? What are the predicted changes for acidity in the future?
4. Predict what will happen to the pteropod shells as the acidity of the ocean increases. Form a hypothesis using an “if, then” statement.
5. This lab involves both acidic materials and glassware. Therefore, it requires that each lab member wears ________________.
6. *Calculate the amount of acid needed in a 1000 mL sample of water for the following concentrations of acid. You will need these numbers to mix your acid solutions for the lab:

<table>
<thead>
<tr>
<th>Year</th>
<th>Concentration (in ppm)</th>
<th>Concentration (in ppt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pre-Industrial Revolution</td>
<td>280 ppm</td>
<td>0</td>
</tr>
<tr>
<td>Current</td>
<td>383 ppm</td>
<td>0</td>
</tr>
<tr>
<td>Year 2100</td>
<td>800 ppm</td>
<td>0</td>
</tr>
<tr>
<td>Year 2300</td>
<td>2100 ppm</td>
<td>0</td>
</tr>
</tbody>
</table>
Procedure:

1. Submit your pre-lab questions to your instructor before proceeding.
2. Obtain all materials from your instructor.
3. Label each beaker according to the table above: Control, Pre-Industrial Revolution, Current, Year 2100, Year 2300.
4. Obtain about 200 mL of Ocean Water from your instructor. Obtain all other solutions from your instructor, if needed. Otherwise go to step 5.
5. **Mix up each remaining solution of acid/water in a 1000mL beaker to the correct ratio using the 2M HCl, pipettes, stirring rod, and the 10mL graduated cylinder. You will only need about 200 mL of each solution, so it may benefit to “share” the work amongst lab groups, if permitted by your instructor. Remember that 2M HCl is a skin irritant. Use caution and proper lab techniques when measuring acid.
6. After you’ve mixed your initial concentrations, take about 200mL of the 280ppm acid solution and pour it into the beaker marked “Pre-Industrial Revolution”. Take about 200 mL of the 380ppm acid solution and pour it into the beaker marked “current.” Take about 200 mL of the 800 ppm acid solution and pour it into the beaker marked “Year 2100”. Take about 200 mL of the 2100 ppm acid solution and pour it into the beaker marked “Year 2300”
7. Mass each individual piece of chalk and record the initial mass in your data table.
8. Place one piece of chalk into each of the five beakers, including the “control” beaker of Ocean Water.
9. Move your lab set up to a location where it will remain undisturbed for about 10 days.

AFTER 10 DAYS

10. Fold 5 pieces of paper towel into quarters.
11. Label each paper towel the same way you labeled the beakers.
12. Using forceps, remove each piece of chalk from the solution and place it on a piece of absorbent paper towel that matches the labeling from the beakers.
13. Clean up your lab equipment according to your instructor’s directions.
14. Place your chalk in a location where it will not be disturbed for 24 hours.

AFTER 24 HOURS

15. Make sure each piece of chalk is completely dry.
16. Using forceps, mass each piece of chalk and record in your data table. *Calculate the percent change in mass for each piece of chalk.
17. Dispose of your chalk and paper towel according to your instructor’s directions.
**Data Table:**

<table>
<thead>
<tr>
<th>ERA/Time Frame</th>
<th>Concentration (ppm)</th>
<th>Mass of Chalk Before</th>
<th>Mass of Chalk After</th>
<th>Percent Change in Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Industrial Revolution</td>
<td>280</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>383</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2100</td>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2300</td>
<td>1200</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Post Lab:**

1. What effect does the presence of an increased amount of acid have on the chalk? What effect does the presence of an increased amount of acid have on a pteropod?
2. Was your hypothesis correct? Use data from your lab to support or refute your hypothesis.
3. This lab represented one way that excess acid can negatively affect pteropod shells. Explain two ways in which Carbon Dioxide impacts organisms with Calcium Carbonate Shells. Which effect did this lab demonstrate?

4. *Infer.* If the Calcium Carbonate reacts with acid, what will happen to the pH of the acid solution as this reaction occurs? Why might this not happen in our oceans?
5. *Infer.* Think about the solubility of both Carbon Dioxide and Calcium Carbonate as ocean depth increases. Why do you think that bottom-dwelling organisms lack hard shells?
6. *Predict.* The boundary (depth) at which Calcium Carbonate is no longer supersaturated (and therefore will not produce pteropod shells) is called a saturation horizon. What impact will a shallowing saturation horizon have on shelled marine organisms? What might be contributing to this shallowing effect?
7. *Calculate.* How many grams of CO2 are produced when 5.00 g of Chalk (CaCO3) reacts with an excess of HCl?
8. *Infer.* Based on these calculations and the chemical reaction, The reaction of the Calcium Carbonate with an acid actually produces (more/less) carbon dioxide in the process.

9. Think about the effects of a “below basic” ocean on a pteropod. What kinds of issues may arise if the population of the pteropod becomes stressed or crashes? Would it impact humans? How so?
Answer Key

Lab 3: How Carbon Dioxide Interacts with Marine Organisms

Pre-Lab

1. What conditions are necessary for a pteropod to form a shell?
   a. In order for a pteropod to form a shell, there must be a supersaturated presence of Calcium Carbonate.

2. What conditions are necessary for Carbon Dioxide to remain in solution in ocean water?
   a. Carbon dioxide remains in solution in ocean water when it is cooler and under greater amounts of pressure. Carbon Dioxide will, however, readily absorb into the ocean.

3. Describe the acidity of our ocean. How has it changed since pre-industrial revolution times? What are the predicted changes for acidity in the future?
   a. Our ocean is not acidic. It is basic. Since pre-industrial revolutionary times, the pH of our ocean has been dropping. If CO2 emissions go unchecked, the ocean’s acidity levels will continue to rise until it is nearly neutral.

4. Predict what will happen to the pteropod shells as the acidity of the ocean increases. Form a hypothesis using an “if, then” statement.
   a. Answers will vary, but here is an example: If ocean acidity is realted to pteropod shell thickness, then an decrease in pH will result in thinner or deteriorating pteropod shells.

5. This lab involves both acidic materials and glassware. Therefore, it requires that each lab member wears ______________.
   a. SAFETY GOGGLES

6. *Calculate the amount of acid needed in a 1000 mL sample of water for the following concentrations of acid. You will need these numbers to mix your acid solutions for the lab:

<table>
<thead>
<tr>
<th></th>
<th>Concentration (in ppm)</th>
<th>Concentration (in ppt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pre-Industrial Revolution</td>
<td>280 ppm</td>
<td>0.28 mL</td>
</tr>
<tr>
<td>Current</td>
<td>383 ppm</td>
<td>0.383 mL</td>
</tr>
<tr>
<td>Year 2100</td>
<td>800 ppm</td>
<td>0.8 mL</td>
</tr>
<tr>
<td>Year 2300</td>
<td>2100 ppm</td>
<td>2.1 mL</td>
</tr>
</tbody>
</table>
Post Lab:

1. What effect does the presence of an increased amount of acid have on the chalk? What effect does the presence of an increased amount of acid have on a pteropod?
   a. As acid concentrations increase, the chalk mass decreases. This means that an increased amount of acid will deteriorate pteropod shells, as well.

2. Was your hypothesis correct? Use data from your lab to support or refute your hypothesis.
   a. Answers will vary, but be sure that the data from the lab supports the hypothesis.

3. Explain two ways in which Carbon Dioxide impacts organisms with Calcium Carbonate Shells.
   a. 1. It keeps Calcium Carbonate in an undersaturated state, so that pteropods can’t form Calcium Carbonate shells.
      2. It dissolves the Calcium Carbonate that is on the shells to begin with because the equilibrium shifts.
      c. This lab demonstrated the second effect – shells that are present deteriorate as a result of the presence of a more acid environment.

4. *Infer. If the Calcium Carbonate reacts with acid, what will happen to the pH of the acid solution as this reaction occurs? Why might this not happen in our oceans?
   a. The pH should increase again because the salt produced acts as a buffer. However, the amount of CO2 that is entering the ocean is so great that the buffering effect gets minimalized. (This is a tough one for students who haven’t learned acid/base chemistry yet).

5. *Infer. Think about the solubility of both Carbon Dioxide and Calcium Carbonate as ocean depth increases. Why do you think that bottom-dwelling organisms lack hard shells?
   a. Bottom-dwelling organisms lack hard shells because of the high presence of Carbonic Acid and the high solubility of Calcium Carbonate. Conditions are not favorable for shell formation.

6. *Predict. The boundary (depth) at which Calcium Carbonate is no longer supersaturated (and therefore will not produce pteropod shells) is called a saturation horizon. What impact will a shallowing saturation horizon have on shelled marine organisms? What might be contributing to this shallowing effect?
   a. If the saturation horizon is shallowing, that means that shells will no longer be able to be formed at shallower and shallower depths. The presence of excess anthropogenic carbon dioxide may be a contributing factor to this shallowing.

7. *Calculate. How many grams of CO2 are produced when 5.00 g of Chalk (CaCO3) reacts with an excess of HCl?
   a. 2.15 g of CO2 are produced in this particular reaction.
8. *Infer.* Based on these calculations and the chemical reaction, the reaction of the Calcium Carbonate with an acid actually produces (more/less) carbon dioxide in the process.

9. Think about the effects of a “below basic” ocean on a pteropod. What kinds of issues may arise if the population of the pteropod becomes stressed or crashes? Would it impact humans? How so?
   a. If pteropods are at the bottom of the food chain, if their population is stressed, then lower trophic levels will have less food, making competition higher for higher trophic levels. This could lead to a population decline of organisms in higher trophic levels (such as fish). If the amount of fish is reduced, then the fishing industries may crash and food supplies from our oceans will decrease.
### Scoring Rubric For Lab Activity #3:

<table>
<thead>
<tr>
<th>Element</th>
<th>Data and Lab Procedures</th>
<th>Pre and Post Lab Analysis</th>
<th>Grammar, Usage, and Spelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Measurements made with precision, all directions were followed, and lab station and equipment was cleaned up at the end.</td>
<td>Student understands the relationship between Carbon Dioxide and Calcium Carbonate. Student can demonstrate with proficiency the impacts of a “less basic” on the environment. Student can infer/predict post-lab answers using clues from both the lab and the PowerPoint to support their claims for each answer. Student ties all three lessons together to create a cohesive and clear statement of the impact of anthropogenic CO₂ on our oceans.</td>
<td>Fewer than 5 grammar, usage, or spelling errors. All complete sentences.</td>
</tr>
<tr>
<td>1</td>
<td>Measurements were made, all directions were followed, and lab station and equipment was cleaned up at the end of the lab.</td>
<td>Student understands the relationship between Carbon Dioxide and Calcium Carbonate. Student can demonstrate with proficiency the impacts of a “less basic” on the environment.</td>
<td>More than 5 grammar, spelling or usage errors, but it does not interfere with understanding of topic.</td>
</tr>
<tr>
<td>0</td>
<td>Poor measurements, poor direction following, or poor/improper clean up at the end of the lab.</td>
<td>Student does not back up claims with evidence from the lab or PowerPoint. Student makes gross conceptual errors with respect to the presence of Carbon Dioxide and its interactions with Calcium Carbonate in the ocean.</td>
<td>Grammar, spelling or usage interferes with student understanding of topic or incomplete sentences.</td>
</tr>
</tbody>
</table>

| Total | | | |

5-6: Student indicates proficient understanding of concepts

3-4: student indicate partially proficient understanding of concepts.

0-2: student lacks proficiency in this topic.