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Final Project
Climate Change
Part One: pg. 1-4

Dissolved CO2, Acidification, and the Effects on Marine Biomes

Introduction

There are three major drivers of climate change on post industrial revolution Earth. Long-lived greenhouse gases such as carbon dioxide, methane, and nitrous oxide increase surface temperature by absorbing radiant heat energy from the sun and reflect it back to the Earth's surface. Ozone, a short-lived greenhouse gas has decreased in the stratosphere while increasing its amount in the troposphere (as smog). This means that more solar energy can get through the stratosphere and is then held in the troposphere, increasing surface heat. Finally, reflectivity as surface albedo or contrails and aerosols can cause climate change forcing. Specifically, dark aerosols like soot from fires or car exhaust can cause positive forcing while light aerosols like contrails can reflect solar energy and cause a negative forcing. Albedo, or surface reflectivity can cause negative forcing as it reflects solar heat back away from the surface of the Earth.

The interactions between these major drivers are incredibly complex. While higher greenhouse gas levels from burning fossil fuel and deforestation can raise surface temperatures, volcanic eruptions can lower surface temperatures by throwing dust particles (aerosols) into the atmosphere and prevented solar energy from reaching the Earth's surface. Additionally, cloud cover from a volcanic event would also decrease solar energy reaching the Earth's surface and would lower surface temperatures. It's this sort of event that causes short-term empirical data to show occasional temperature drops even though a long-term graph would show a warming trend. These complicated interactions can make climate change a difficult concept for students to grasp. For some students, it may also be difficult to make the case that climate change is a bad thing. If you're running this activity in the middle of a New England winter, a warmer Earth's surface may seem like a good idea!

This lesson, experiment, and activity are intended to focus on a concrete and documented increase in atmospheric CO2 since the industrial revolution. Students will be able to explore the effect that this increase has on our oceans. By focusing on a part of climate change that *a.) is documented*, *b.) is observable*, and *c.) has an immediate negative impact on human lives*, students will be able to set aside any preconceived notions they may have about the validity of climate change and perhaps invest in the importance of changing current practices.

Scientists like Charles Keeling have worked to create ways of documenting the changing CO2 levels and to study the effects that rising CO2 has on our environment. Empirical and statistical observations have shown a global CO2 increase as a result of burning fossil fuels and deforestation. Carbon dioxide is a very effective at absorbing solar energy and causes positive climate forcing. Global Climate Models like the IPCC use billions of data points and take Earth chemistry and physics into account to make predictions regarding future CO2 levels based on current trends.

As the amount of CO_2 in the atmosphere increases we see a change in the acidity of Earth's water. Rain falling through a CO_2 rich atmosphere becomes more acidic and further reactions with sulfur dioxide and nitrogen oxide creates acid rain. Carbon dioxide is also directly absorbed by the ocean and can change the water's pH directly, particularly in small bodies of water or coastal areas with little water mixing such as coastal inlets. Owners of coastal hatcheries for mollusks and crustaceans have observed rising acids levels in their hatchery beds and continually adjust the water's pH to protect the growing marine animals. In areas where the local economy relies on healthy crustacean and mollusk populations (such as Maine) these type of changes could be hugely detrimental. This is the *c.) immediate negative impact to human life* that I mentioned earlier. The effect of acidification on coastal economy is a small, concrete symptom of a much larger problem—the increase of CO_2 in the atmosphere causing ocean acidification and the implication that the problems that coastal hatcheries face could soon be a global ocean problem and affect the entire marine biome.

Our oceans have an incredible ability to absorb atmospheric CO_2. In fact, this ability has prevented noticeable climate change in the past. As the ocean absorbs CO_2, a chemical reaction results in the creation of carbonic acid and causes the ocean to become more acidic. In fact, the ocean is 30% more acidic now than it was in pre-industrial periods. However, the chemical properties of ocean water (as opposed to fresh water) shows a much slower change in pH as more dissolved CO_2 is added. This lab will allow students to compare the pH of distilled water, pond water, and ocean water as dissolved CO_2 is added. As dissolved CO_2 is added (in the form of carbonated distilled water) pH levels will be tracked using a pH meter connected to a computer to track the changes. Students will be able to see that the pH drops immediately in the distilled water and pond water (similar to acid rain as fresh water rain droplets pick up CO_2 as they fall through the atmosphere). Students will also see that ocean water's pH will show little to no change before dropping significantly and quickly once it's ability to absorb the CO_2 has been maxed out.

After students see this illustration of the ability of ocean water to absorb CO_2 before showing a change, they will discuss how this can prevent public response regarding ocean acidification—because the change is not immediately noticeable, it can be viewed as a non-threat. Students will also discuss what will happen to atmospheric CO_2 levels when the absorptive ability of the ocean is maxed out. Finally, students will learn about the dangers associated with ocean acidification and the effects on the marine and global biome and how these dangers are highest in the polar seas.

This topic will connect with 7th grade science biome and environmental curriculum and add to student's previous knowledge from 6th grade environment science. I chose to create a lab around this topic because higher atmospheric CO_2 levels as a result of fossil fuel burning and deforestation directly cause the acidification of the ocean. This activity will allow students to understand the ocean's amazing ability to absorb CO_2 and to understand why the acidification doesn't immediately show up in ocean water. This will also be a simple way of showing how the 30% acidification change is a sign of serious CO_2 accumulation/absorption. Additionally, by experiencing this first hand (and seeing the catastrophic fall out from ocean acidification), students may be more willing to make changes to prevent climate change.

Define Learners
The learners for this unit will be junior high age science students, specifically, 7^{th} grade students meeting 4-5 days per week. Class number will range from 20-26 in a public school setting. Class demographic will be a mix of typical learners, students on 504 education plans, and students with IEPs. Students will work in small groups.

Standards-
MS-PS1: Matter and its Interactions
(http://www.nextgenscience.org/msps1-matter-interactions)
MS-LS2: Ecosystems: Interaction, Energy, and Dynamics
(http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics)
MS-ESS2: Earth's Systems
(http://www.nextgenscience.org/msess2-earth-systems)
MS-ESS3: Earth and Human Activity
(http://www.nextgenscience.org/msess3-earth-human-activity)

Topic
In some ways, the direct effect of humans on our environment as drivers of climate change can be imprecise to track. However, studies show an increase in atmospheric CO2 since pre-industrial times. While students have probably been taught that CO2 is connected to climate change, they might not be aware that our oceans and surface water are continually absorbing a huge amount of atmospheric CO2. As the oceans absorb CO2, they act as a sink for atmospheric CO2 and their pH is slowly becoming more acidic. Additionally, polar seas are in the highest danger of acidification due to their salinity and temperature. This project and experiment will allow students to learn about the ability of our oceans to absorb CO2 and see first hand the effect that is caused by adding CO2 to water. Students will be able to see how adding CO2 to any water sample will decrease pH as you add more CO2. They will also be able to see that adding dissolved CO2 to ocean water will show the buffering ability of ocean water before the pH drops. They will also view how water's temperature can influence its ability to absorb CO2. This experiment will show that polar oceans (the cold ocean water in the experiment) can absorb more CO2 than other water samples and is in danger of becoming the most acidic. Students will then learn about the effects on the marine biome and the implications of ocean acidification by soaking eggshells in apple cider vinegar and carbonated water.

Curriculum Links:
7^{th} graders will have completed the following related units* (among other) before completing this activity. Italics indicate direct connection to this activity.
Changes in Ecosystems Over Time
EQ: How have scientists conceptualized the history of Earth based on evidence?
Objective: Students will be able to construct a geologic timeline that describes and illustrates Earth's history, *understand the reactions between different types of biomes, and discuss how human activity can change an ecosystem.*
Evolution and Biodiversity

EQ: What genetic advances are being explored and developed though genetic engineering? How have the interactions between environmental and human factors contributed to genetic variation among species?
Objectives: Students will be able to describe and critically evaluate the Theory of Evolution, compare and contrast natural selection and genetic engineering, *explain how changes in the environment can lead to evolution or extinction of species.*

After this unit/activity students will move on to:
Living Things and their Environment
EQ: How do interactions among organisms affect the balance of ecosystems?
Objectives: Students will be able to provide examples of different interactions among species in an ecosystem, identify biotic and abiotic factors in a given ecosystem.
After this unit they will continue with the science curriculum.
***From Sharon Middle School 7th grade science curriculum.**

Objectives
At the end of this activity, students will know and understand that:

- The burning of fossil fuels has increased the amounts of CO2 in the atmosphere since the Industrial Revolution.
- Higher levels of atmospheric CO2 cause acidification of water in the Earth's water system.
- Rain falling through a CO2 rich atmosphere and ocean CO2 absorption causes or intensifies effects like acid rain and ocean acidification.
- Ocean water has an amazing ability to absorb atmospheric CO2.
- Ocean water's salinity acts as a pH buffer and when pH is tracked in ocean water, there is a period of little to no change after adding CO2. After this buffer is exhausted, the ocean water pH quickly becomes more acidic.
- Polar seas are at the highest risk for extreme acidification due to a combination of its salinity and its cold temperature. The cold temperature allows the polar seas to absorb the highest amount of CO2 and cause the most drastic negative changes to the marine biome.
- A deep understanding of this process and how it will negatively influence human life may help to influence future behavior and inspire students to adopt change to prevent more CO2 emission into the atmosphere.

Materials

- Glass containers –beakers of various sizes
- Distilled water
- Ocean water
- pH probe (Vernier's probe is used here)
- Connector to link up with a computer (Go!Link used here)
- Computer to run a graphing software such as Logger Pro to track pH change
- A countertop carbonator (such as a Soda Stream and CO2 cartridges)
- Plastic aquarium hosing
- Airline control kit (a series of aquarium tube connectors, available at most pet stores)

- Aquarium air stone
- Stir station and magnetic stir bar (Vernier brand stir station used)
- 9” party balloons
- Rubber bands
- Eggshells (cleaned)
- Apple cider vinegar
- Unflavored seltzer

Time
This activity will take one-week/ five 45 minute classes.

Scope and Sequence
Day One:
Class question: Could a goldfish live in seltzer water? Why? Why not? Have the class discuss the question at their desk groups then share their thoughts with the class. Correct any glaring misconceptions.

Watch the National Resources Defense Council video, Acid Test: The Global Challenge of Ocean Acidification (https://www.youtube.com/watch?v=5cqCvcX7buo) and discuss.

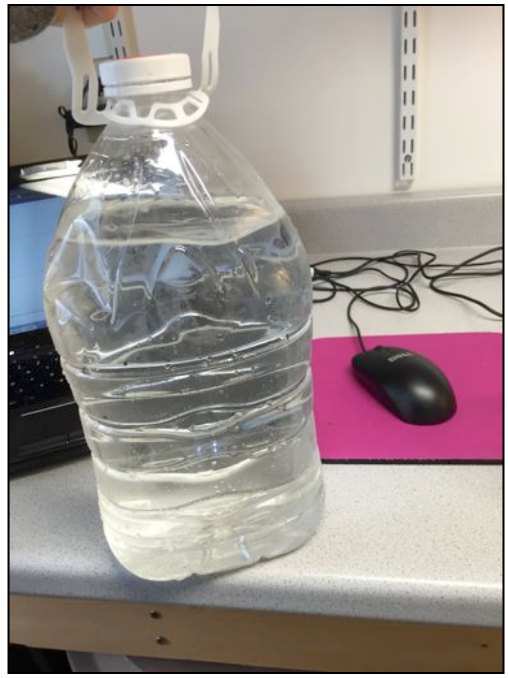
Discussion questions:
- How does atmospheric CO2 affect ocean pH?
- What do you think would happen to the marine biome if the oceans became more acidic?
- Do you think the temperature of the ocean influences its ability to absorb CO2?

Day Two

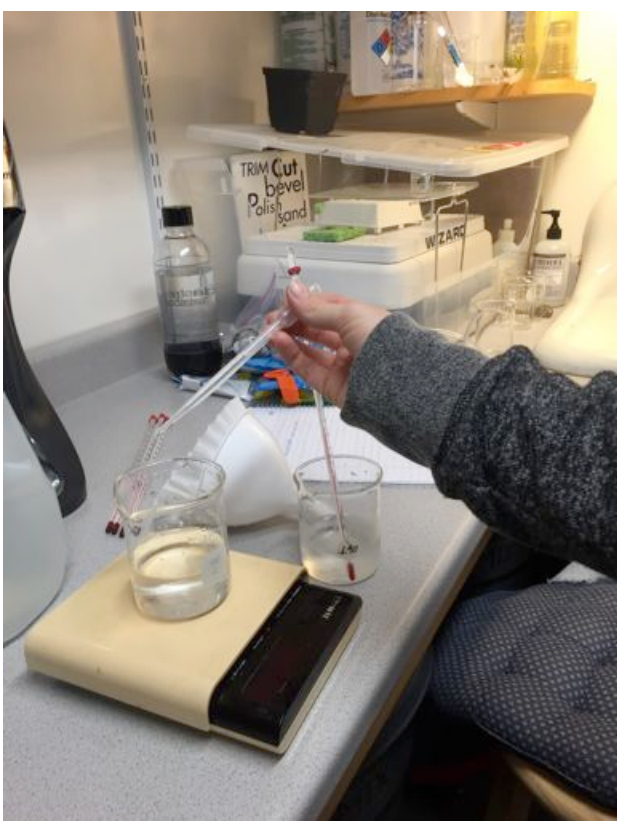
Prepare the materials for the activity.

Sea Water

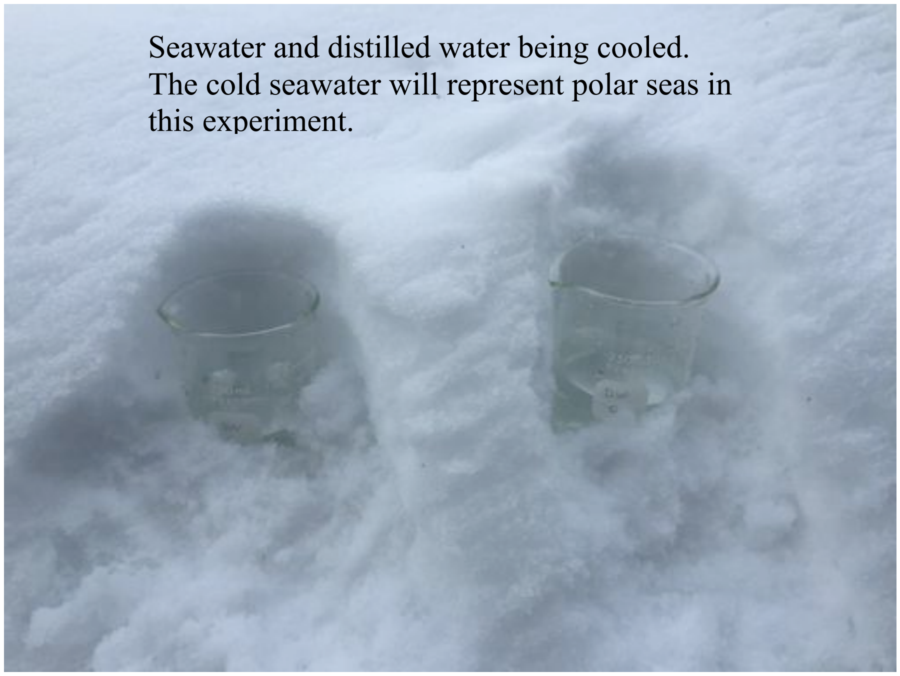
Distilled Water



Using a scale, measure 100 grams of distilled water and pour it into a beaker.

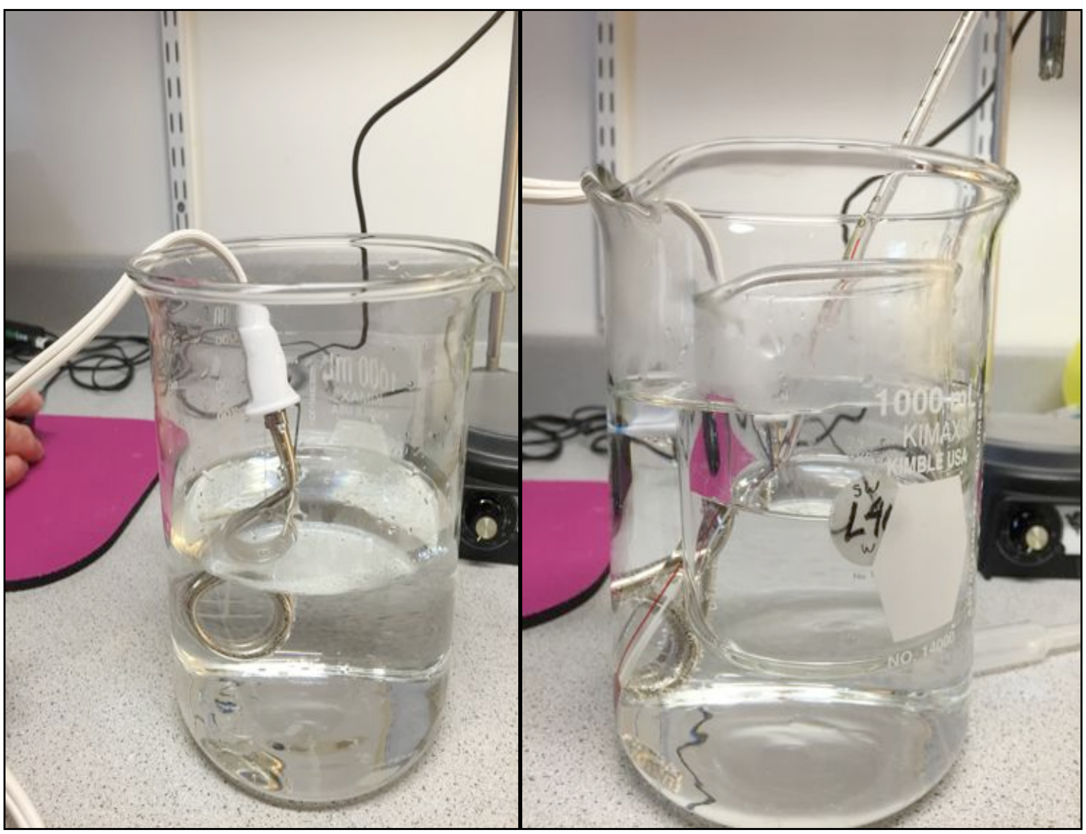


Set this beaker (test 1) in a container full of ice, being sure to prevent any ice from getting inside the beaker. Alternatively, set this beaker in a snow bank.
Repeat this process with the seawater, measuring 101 grams of seawater (to account to dissolved salts and minerals) after filtering out any solids*.
Set this beaker (test 2) in the ice/snow (don't forget to label all beakers!). This seawater will represent polar seas. Repeat this process with the distilled water (test 3) and the seawater (test 4) and set aside for warming.



Seawater and distilled water being cooled.
The cold seawater will represent polar seas in
this experiment.

Using an immersion heater, heat a large beaker of tap water and place the warm water samples inside while monitoring temperature with a stick thermometer.



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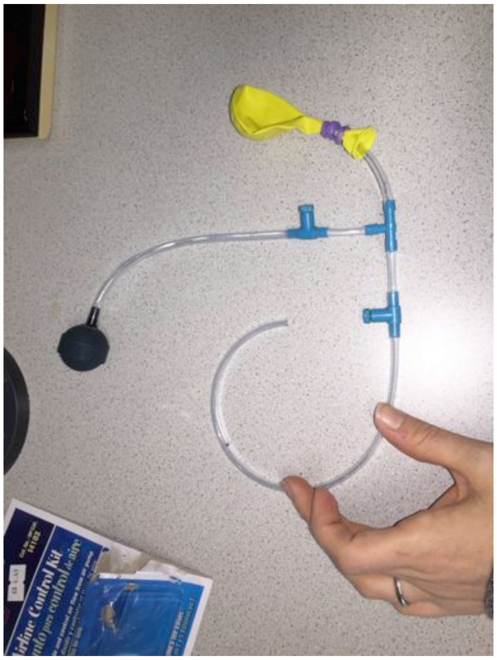
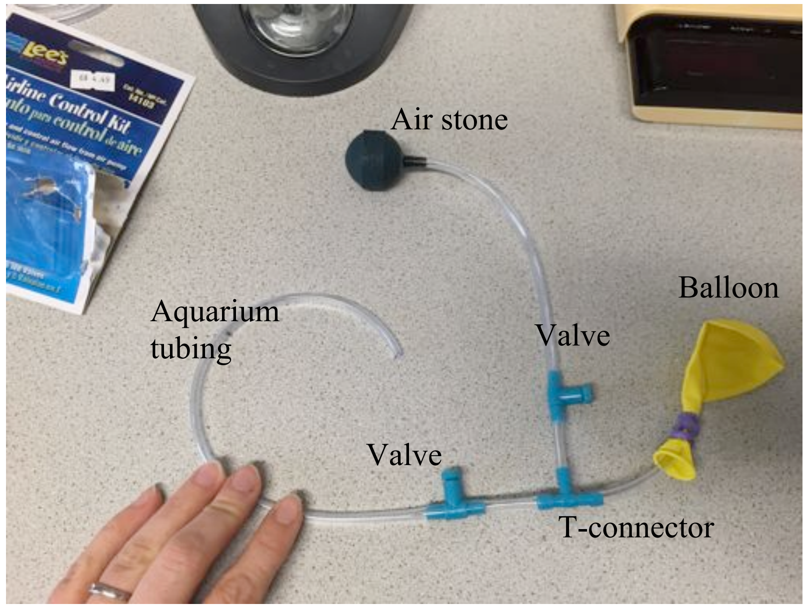
Preparing the CO_2 feed for the water samples.

In order to add CO_2 at a constant rate during this experiment, I created a CO_2 feed using aquarium hosing, an airline control kit, a balloon, rubber band, and an air stone.

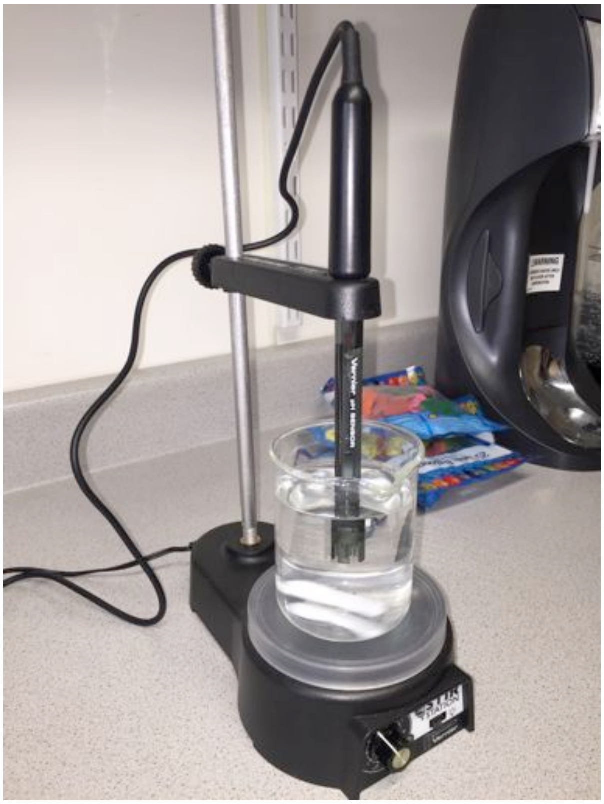




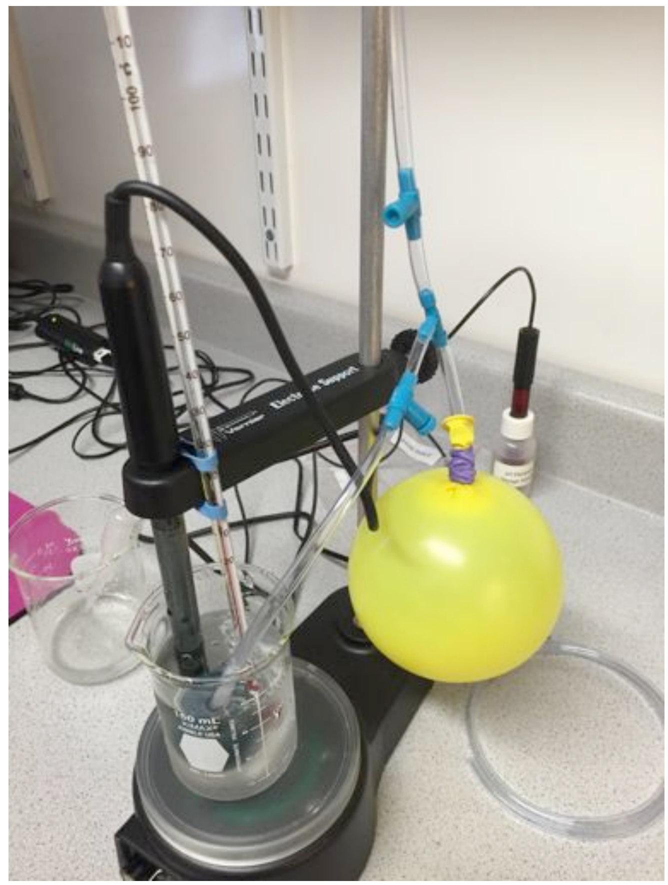
Attach the end of the aquarium tubing to the countertop carbonator and open the valve leading to the balloon. Fill the balloon with CO_2.

Ocean Acidification Experiment

1. Get an initial pH reading on the water sample before adding CO2.

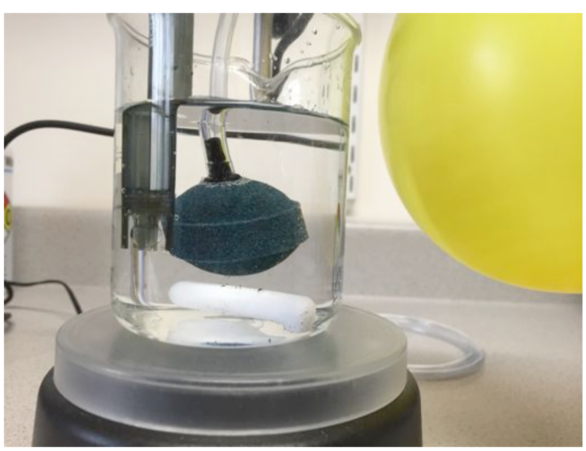


Record the starting pH of every water sample before adding CO2 and running the pH tracking computer program. Compare to expected pH levels for the sample (sea water should be between 7.5-8 and distilled water should be between 5.6-7) and make sure your pH probe is working properly.



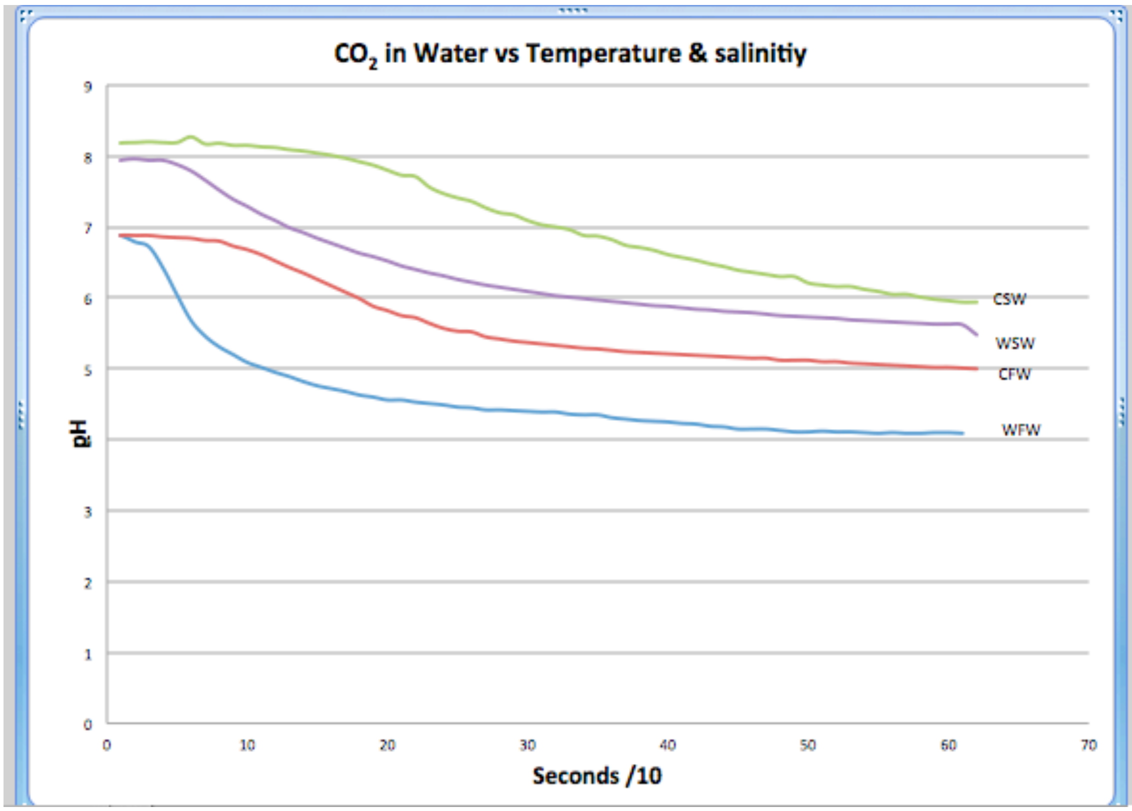
2. Start the pH-tracking program and wait until the pH stabilizes before adding the air stone and opening the valve from the balloon until the air stone starts to bubble. Track the pH changes during the next 10 minutes.
Repeat this process for each of the samples: the warm distilled, the cold distilled, the warm seawater, and the cold seawater.

Close-up of air stone in the water sample (before adding the CO2). →



**To filter seawater, pour through a coffee filter set in a funnel.* →

3. Repeat this experiment for each of the water samples. The warm and cold distilled water will be the control and comparison experiment and the warm and cold seawater will show the effects of CO2 absorption on the oceans (ocean acidification). The warm seawater will show how ocean acidification affects tropical oceans and the cold water will show how ocean acidification affects polar seas. Compare the four graphs and have students record their initial reactions to the data. Ask students: Which seas will be at higher risk for acidification, warm seas or polar seas?

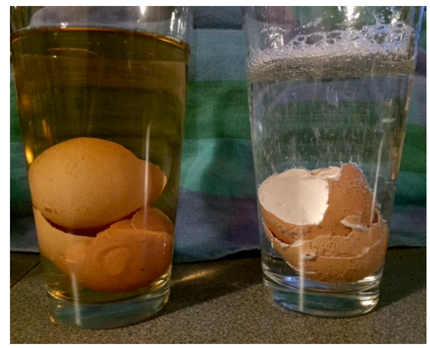


(Example graph done in Excel.
Notice the difference in CO2 absorption and pH change in the 4 different samples (Cold Sea Water @2 C, Warm Sea Water @ 33 C, Cold Fresh Water @ 2 C, Warm Fresh Water @ 33 C.)

Carbon dioxide addition to seawater does not cause as obvious a change in pH as it does in fresh water. Carbon dioxide added to fresh water shows up almost immediately as a change in pH while seawater has a slight buffer due to its salinity. This means that even though the ocean is absorbing CO2 in huge amounts, it isn't immediately noticeable on a global scale.

Share this quote from, "Threatening Ocean Life from the Inside Out," by M. Hardt and C. Safina and discuss: "Ocean acidification also changes the rules for the planet's entire carbon cycle. Although the oceans now absorb a vast quantity of human emissions, the absorption rate slows as the sea-water CO_2concentration increases, and CO_2 "backs up" at the sea surface. As a result, atmospheric CO_2 concentration will rise even faster, accelerating global weather changes."

Day Three:
1. At the beginning of today's class students will set up the materials for the "How ocean acidification affects marine life " follow-up activity before beginning the Day Three discussion.
Each student group will receive two beakers or glasses—one filled with apple cider vinegar and one filled with carbonated water (from the countertop carbonator). Each group will record the pH of each beaker. Give each group two clean eggshells and have them describe and record the appearance. Each group will drop a clean eggshell into each of their beakers. We will return to this activity on Day Four. *



*You will need to empty and refill the carbonated water beakers periodically to recreate the circulation of seawater to get the best result for this activity.

2. Write the quote from the previous class on the board and have student groups discuss the results from the lab the previous day.
Discussion Questions:
- What happened to the water samples as we added CO2?
- How did the H change differ in the distilled water samples and the seawater samples?
- How did temperature affect the pH change?
- Imagine these samples as tiny polar and tropical seas. How much CO2 can polar seas absorb compared to tropical seas?
- Do you think higher atmospheric CO2 levels will affect the seas equally?
- Which seas may be more drastically affected by CO2 levels, CO2 absorption, and ocean acidification?
- Consider the quote on the board—are there other negative impacts of ocean acidification?
- What will happen to the climate and atmospheric CO2 levels as we exhaust the ocean's ability to absorb CO2?
- How will an increase in atmospheric CO2 impact human life?

Day Four:

1. Starting discussion (before students are able to view their beakers and the eggshells):
    - What do you think the acidic solution has done to the eggshells?
    - Do you have any predictions?
2. Have each student group observe their beakers and the eggshells within.

Discussion:

- How have the eggshells changed since you first observed them? (The apple cider vinegar eggshells should be significantly dissolved, the carbonated water eggshells should be damaged and weakened.)
- Which beaker shows the most change? What's the difference in pH of apple cider vinegar compared to carbonated water?
- Eggshells are made of calcium carbonate, similar to marine life exoskeletons and shells. How do you think ocean acidification will affect marine life?
- Using our expertise on acidification of tropical versus polar seas—which seas will show the most damage to marine life, tropical or polar?

Reference the chart from the Catlin Arctic Survey and share with students to add to the discussion: http://www.catlinarcticsurvey.com/science/ocean-acidification-2010/

If there is extra time: Have students explore the virtual urchin lab at the following URL: http://virtualurchin.stanford.edu/AcidOcean/co2lab.swf

Day Five:

Flex-time and Reflection.

1. Finish up any parts of the experiment that might have needed more time and continue and complete class discussions from previous days.

    Supplementary Discussion:

    - What can we do to prevent ocean acidification? Brainstorm ideas.
    - How can we lower our CO2 production? Brainstorm ideas.
    - How can we influence others regarding the importance of lowering CO2 emissions and preventing ocean acidification?

Supplementary Materials

- See the imbedded photographs of the CO2 feed, pH monitoring station, and eggshell activity.
- In my research to create this lab I found a similar lab that may be more feasible to run in a larger classroom: http://www.carboeurope.org/education/CS_Materials/CO2solubility.pdf
  This lab uses fizz tablets, cold and warm water, and graduated cylinders to show how cold water can absorb more CO2 than warm water and supports the connection that ocean acidification is more dangerous in polar seas due to the CO2 absorptive properties of cold water.
- Virtual Urchin: A virtual lab that shows ocean acidification in action and how it affects ocean life: http://virtualurchin.stanford.edu/AcidOcean/co2lab.swf
- The Catlin Arctic Survey chart addressing ocean acidification: http://www.catlinarcticsurvey.com/science/ocean-acidification-2010/

Assessment of Students

Students will show proficiency by being able to complete the labs and participate actively in class discussions. Additionally, students will meet each of their objectives. Lab grades will be given according to the classroom rubric for lab work and discussions will be graded according to the classroom rubric for discussions.

If additional assessment is needed, each student could complete a check-in quiz before they leave the classroom each day. The check-in quiz will be a handout with the discussion questions written down; in order to leave the classroom, students will write down their answers to the discussion questions. This will allow the teacher to track understanding in all of the students and will allow shyer students to illustrate comprehension without having to speak in front of the class.

Evaluation of Lesson

At the beginning of the lesson (or the day before) students will be given a brief pre-test to gauge student's understanding of pH, carbon dioxide, the term acidification, etc. It can be a simple fill-in-the-blank, true/false, or short answer pre-test to get an idea of what students know and what they don't. It will also give the teacher an idea if any unit specific vocabulary needs to be learned or clarified. Pre-test questions could include, "Carbon dioxide dissolves more in cold water than in warm water, T or F?" or Fill-in-the-blank, "CO2 means ______." The teacher will know her students and what their strengths and weaknesses are so can design the most effective pre-test for her classroom.

At the end of the lesson a more substantial concrete assessment will be given to students in the form of a test based on the student objectives. This will give concrete evidence that students know and understand the lesson's objectives.

Conclusion

Scientists and science teachers run into many challenges when discussing and teaching climate change. The scope of a global issue that spans hundreds of years with multiple influences is difficult to present concretely in the classroom. Additionally, some students may have previous misconceptions regarding the validity of climate change and climate change research. The main purpose of this lesson, experiment, and activity is to allow students to focus on one factor of climate change (the burning of fossil fuels has added more CO2 to the atmosphere in post industrial-revolution Earth) and one result of this change (higher levels of atmospheric CO2 leads to more oceanic CO2 absorption). Ocean acidification is one part of the much larger climate change conversation. This project allows students to experience the concrete chemical change that is occurring in the world's oceans as a result of higher levels of atmospheric CO2. They will make the connection that polar seas are at the highest risk of acidification due to their ability to absorb more CO2 than warmer tropical oceans and therefore become more acidic. Finally, they will experience what a more acidic ocean will mean to the marine biome and how this will affect humans in the future.

This unit will fit best into the "Living Things and Their Environment" unit in the curriculum but may run into conflict if the teacher is at all behind or if the class has trouble with transitioning or comprehension. Ideally, this lesson would be part of a supplementary science lab class or science elective where the teacher would have more control over their curriculum and assessment. On a personal note, I am working to develop a science elective (a STEAM class) for my middle school and I feel activities such as this one would be ideal for such a class.

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