Sea Grant
NJ Sea Grant Consortium

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Acid in the Ocean: Not a Shell (Building) Game

Overview Students participate in a game that explores how excess carbon dioxide (CO_2) in our atmosphere is changing the chemistry of the ocean and the implications this will have for marine animals.

Objectives In this lesson, students will be able to:

1. Understand how excess CO_2 in our atmosphere diffuses into the ocean and changes the chemistry of seawater making more difficult for some organisms to grow.
2. Make conclusions about the effects of acidity on marine organisms that use calcium carbonate to build their skeletal structures.

Grades 3-12

Standards NGSS: MS-PS1-2, MS-LS2-1, MS-ESS3-5, HS-PS1-2, HS-LS2-6, HS-ESS2-2, HS-ESS3-5, HS-ESS3-6.

Background Carbon dioxide (CO_2) is a trace gas found naturally in the atmosphere that helps keep Earth's climate stable. Many living things on Earth metabolize CO_2, including plants during photosynthesis, however human actions are disrupting the balance of CO_2 in our atmosphere. Excess CO_2 is released into our atmosphere when fossil fuels, such as oil, gas, or coal, are burned for energy. Currently, atmospheric CO_2 levels are at their highest levels in recorded history—about 407 parts per million or ppm. Before the Industrial Revolution in the 19th century, global average CO_2 was about 280 ppm. During the last 800,000 years, CO_2 fluctuated between about 180 ppm during ice ages and 280 ppm during interglacial warm periods. Today's rate of increase is more than 100 times faster than the increase that occurred when the last ice age ended. [1] For daily atmospheric CO_2 concentrations, go to https://www.co2.earth/daily-co2

The ocean absorbs about a quarter of the CO_2 we release into the atmosphere every year, so as atmospheric CO_2 levels increase, so do the levels in the ocean. Initially, many scientists focused on the benefits of the ocean in removing this greenhouse gas from the atmosphere. However, decades of ocean observations now show that there is also a downside: excessive CO_2 absorbed by the ocean is changing the chemistry of seawater through a process called *OCEAN ACIDIFICATION*. [2]

Background

As the ocean absorbs increasingly higher levels of CO_2 from the atmosphere, chemical reactions take place that are decreasing the pH of the ocean. This lowering of pH means that ocean water is becoming more acidic.

Water changes pH as it gains or loses hydrogen ions (H+). As CO_2 is absorbed by the ocean it creates carbonic acid (H_2CO_3). Carbonic acid further breaks down and forms bicarbonate ions (HCO_3) and hydrogen (H+) ions. An increase in hydrogen (H+) ions increases the ocean's acidity, decreasing pH. The ocean's pH has changed from 8.2 to and 8.1 since pre-industrial times. This may not seem like much, but pH is measured on a logarithmic scale, which means a .1 difference in pH indicates that the ocean has become 30% more acidic. With CO_2 continuing to sink into the ocean at extreme rates, scientists predict that the ocean could become 150% more acidic by 2100.

Hydrogen ions (H+) also combine with carbonates ions (CO_3) dissolved in sea water to form bicarbonate ions (HCO_3) that are not useful to organisms. Carbonate ions bond eagerly with hydrogen ions in water; carbonate will even leave calcium behind to bond with hydrogen ions. More hydrogen ions in the ocean interfere with shell or skeleton formation because they reduce the amount of carbonate available for organisms that need calcium and carbonate to bond to grow their shells and skeletons.

Dive Deeper

When carbon dioxide (CO_2) is absorbed by seawater, **chemical reactions** occur that reduce seawater pH, carbonate ion concentration, and saturation states of biologically important calcium carbonate minerals. These **chemical reactions** are termed "**ocean acidification**" or "OA" for short. Listed below are some of the chemical reaction equations associated with ocean acidification.

Ocean Acidification: $H + CO_2 \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3 + H+$ Water + Carbon Dioxide ? Carbonic Acid ? Bicarbonate + Hydrogen - The extra hydrogen ions formed causes acidification, which is a decrease in pH.

Shell Building: $Ca + CO_3 \Leftrightarrow CaCO_3$ Calcium + Carbonate = Calcium Carbonate. Calcium dissolved in the ocean combines with carbonates in the ocean to form calcium carbonate, needed by organisms who build their own shell and/or skeleton.

Ocean Acidification + Shell Building = Less Shell Building: $H+ + Ca + CO_3 \Leftrightarrow HCO_3 + Ca$

With ocean acidification, the extra hydrogen ions (H+) created bond with the carbonates (CO_3) and form bicarbonates (HCO_3). The carbonates prefer to bond with hydrogen over calcium, but extra bicarbonates are of no use for organisms. This means the carbonates needed to bond with calcium to form calcium carbonate ($CaCO_3$) are no longer available for organisms and calcium (Ca) is left on its own. As a result, animals that need calcium carbonate to build shells or skeletons struggle to grow.

ACTIVITY: ***ACID IN THE OCEAN: NOT A SHELL (BUILDING) GAME***

Introduction

To further the understanding of the chemistry behind ocean acidification and its effect on organisms that need calcium carbonate to build shells and skeletons, students will play a game using Lego blocks (or other interlocking blocks). Each different color Lego block used in the game represents chemicals found in the ocean which support the growth of animals that build shells and skeletons. The game goes through different scenarios which will demonstrate to players the impact ocean acidification will have on many species of animals in our ocean.

Students will play three (3) rounds. The first round is based on pre-industrial ocean water conditions, the second is based on current seawater conditions, and the third is based on future predicted ocean water conditions.

Materials

- 12 Pink Legos (or other type of interlocking block)
- 12 Blue Legos (or other type of interlocking block)
- 8 Red Legos (or other type of interlocking block)
- Or any different color Legos in same amounts
- A small reusable bag
- A stopwatch or timer
- Chart paper and markers

Before Play

Ask students if they have heard of ocean acidification and ask them to share what they know. If they are unfamiliar with the term, ask them what they think it could mean. Ask if they know what an acid is. A review of pH might be necessary to complete the activities. For lessons on pH see:

http://njseagrant.org/wp-content/uploads/2014/03/ph.pdf>

http://njseagrant.org/wp-content/uploads/2014/03/ph_booklet.pdf

http://www.abc.net.au/science/surfingscientist/pdf/lesson_plan16.pdf

www.earthref.org/SCC/lessons/2013/seawaterchemistry/

Explain that in the ocean many organisms build shells or skeletons made up of calcium carbonate which is available in sea water. Ask students if they can name some animals that have shells. If possible, show the students a few seashells (clams, scallops, snails) and/or pieces of coral or pictures of seashells and/or corals. Ask students to brainstorm how these animals are important to our oceans and to humankind. Be sure that students know that these organisms are an important food source for other ocean organisms and also can provide a source of food and income for humans. Be sure students understand that a decrease in organisms in the ocean impacts food webs, decreases biodiversity, reduces the health of the ocean, and can even result in the loss of jobs and income for people. The oyster is a great example of an organism that is important to the ocean food web that also offers other benefits including helping filter water of pollutants and providing a food source for humans that is also economically important in many places, including New Jersey. Coral reefs are another great example since they are simultaneously important habitats and essential to ocean health.

Explain how these organisms take in calcium and carbonate dissolved in seawater and combine them to make calcium carbonate, which forms their shell and/or skeleton. In a healthy ocean organisms can form and grow their shell fairly easily, extracting all the calcium and carbonate they need from seawater. However, the amount of carbonate in the ocean is decreasing. This is because humans are releasing excess CO_2 into our atmosphere. Have students brainstorm some of the sources of excess carbon dioxide. For older students review the carbon cycle. Provide a brief explanation of how carbon dioxide in our atmosphere has increased dramatically since the start of the Industrial Revolution from the burning of fossil fuels (coal, oil, natural gas) for energy. Explain that approximately one third of the excess carbon dioxide in our atmosphere is being absorbed by the ocean and is changing ocean chemistry faster than ever before. When carbon dioxide mixes with water a series of chemical reactions occur that decrease the pH of the ocean (ocean acidification). One outcome is that as the ocean becomes more acidic, the amount of carbonate available to organisms that need carbonate to grow a healthy shell or skeleton decreases.

About the Game

Pink Legos represent carbonate ions and the blue Legos represent calcium ions dissolved in ocean water. Explain that in a healthy ocean most carbonate ions combine with calcium to form calcium carbonate, which are the building blocks of many shelled species such as clams, oysters, scallops, species such as coral and even types of phytoplankton. The red Legos represent the hydrogen ions in sea water, and they determine the pH of the water, or the acidity or alkalinity of the water. The more hydrogen ions, the more acidic ocean water becomes. The carbonate ions (pink Legos) are very attracted to and bond eagerly with the hydrogen ions (red Legos). The carbonate ions (pink Legos) will not bond with calcium (blue Legos) when there are hydrogen ions (red Legos) available to bond with. When the carbonate ions (pink legos) connect or bond with hydrogen ions (red Legos) they form bicarbonate, which is not useful for many forms of sea life. The blue (calcium Legos are left on their own. While playing the game, students will see what happens when excess hydrogen enters the ocean (ocean acidification).

Playing the Game

Explain to students that they will have one (1) minute to reach into the bag and take just one (1) Lego out at a time. Players may not look into the bag to choose Legos. As Legos are taken out, players must combine pink Legos, representing carbonate ions (Co_3), to the blue Legos representing calcium ($Ca+$), as fast as possible to form a calcium carbonate which is used by organisms to build shells or skeleton, such as an oyster shell or a coral. If a red ($H+$) Lego and pink (Co_3) Lego are chosen, you must combine the red ($H+$) and pink (Co_3) to form bicarbonates (HCo_3). If possible, students must connect the Legos to form calcium carbonates or bicarbonates before choosing another Lego out of the bag. If two of the same colors are chosen, players must set them aside and wait to connect them to the correct color on the next grab.

Example- Player pulls out 2 pink Legos but not any blue or red blocks. Player must set the pink blocks aside and wait until blue or red blocks are grabbed.) As pink and blue Legos are connected, each set should be connected together into one large structure, just as an animal building a shell would do. When a red Lego, representing a hydrogen ion, is pulled out of the bag, it must be connected to any pink carbonate Lego that is not already paired with blue calcium Lego. This forms bicarbonate that is not useful for shell or skeleton building, and players must set it aside. Carbonates are much more strongly attracted to hydrogen ions. Therefore a pink carbonate block must connect to a red hydrogen block if a red block is available. Players are not to have any red blocks unconnected, unless a pink block has not yet been pulled out of the bag. Blue calcium blocks never connect to red hydrogen blocks. After one (1) minute, players should count how many blue and pink Lego pairs they were able to connect, and have the students record their results. Be sure players only count the pairs of pink and blue!

Round One

1. Disconnect and place 12 pink, 12 blue and 2 red Legos in a bag. The amount of red Legos (representing hydrogen ions) in this round reflects the amount of hydrogen found in seawater before industrial times.
2. Set the timer for 1 minute.
3. Have players reach into the bag and grab one (1) Lego at a time. They may not look in the bag to choose their blocks. If a blue and a pink block are picked, they need to be connected to represent calcium carbonate. If a red and a pink block are picked, those need to be connected to represent bicarbonate. Red and blue blocks never connect and neither do two (2) blocks of the same color. If blocks are picked out of the bag that cannot connect such as two blocks of the same color, or red and blue, players must set them aside until another red, blue, or pink block is picked out of bag that can connect together.

NOTE: Anytime a red block is pulled out of the bag, it must be connected to a pink block to form bicarbonate. A blue block can be connected to a pink block only when no red blocks have been selected out of the bag.

4. All sets of pink and blue Legos, representing calcium carbonate, should be connected to represent the formation of one animal shell, such as an oyster shell, or a coral.

5. Any red and pink blocks that were connected represent bicarbonates, and cannot be used by an animal. They should be put aside. Any blue blocks left unconnected should also be put aside.

5. Students should quantify how many pairs of calcium carbonate they formed and record the number. This represents the growth in their animal.

6. After completing this round students should be directed to disconnect all the blocks and place back into bag to prepare for Round 2.

Round Two

1. Place 12 pink, 12 blue and 3 red Legos in a bag. The amount of red Legos represents the amount of hydrogen found in seawater in 2018. This represents the increase in ocean acidity since the pre-industrial times. This increase in acidity is caused by an increase in carbon dioxide absorbed by the ocean from the burning of fossil fuels (coal, oil, gas.) When the ocean absorbs excess carbon dioxide chemical changes increase the amount of hydrogen in the ocean, increasing ocean acidity.

2. Repeat the game following the steps listed above. Students should count and record the pairs of pink and blue blocks, or calcium carbonate they formed and compare results to their results from the first round. Students might see a small difference in the amount of calcium carbonate formed. In today's ocean, some sea animals do have a slightly more difficult time finding carbonate to form with calcium but most species are able to still do so.

3. After completing this round students should be directed to disconnect all the blocks and place back into bag to prepare for Round 3.

Round Three

1. With a continued rise of carbon dioxide released in the atmosphere, it is predicted the ocean will become nearly 150% more acidic by the end of the century. This will cause more hydrogen to be released into the ocean. For round three, place six (6) red Legos into the bag.

2. Again, time students for 1 minute. Remember, pink carbonate blocks are much more attracted to the hydrogen red blocks; therefore red blocks always connect over blue blocks! If players have a free pink block and then choose a red and blue block, the red block must be connected to the pink block, and not the blue calcium block. Players may set the blue block aside until the next two blocks are grabbed out of the bag.

The End of the Game

Have students look at each chart they completed from the three rounds of play and compare the results. As a class or group, share and compare results. Students should notice a small difference, between rounds 1 and 2, and a larger difference between rounds 1 and 3 and 2 and 3. Review the chemistry and be sure students understand that excess carbon dioxide released in our atmosphere is the root cause of ocean acidification.

Be sure to talk about SOLUTIONS after playing the game. Be sure that not only do the students understand the chemical reaction and what is causing it, but also what can be done to stop or slow ocean acidification from affecting our oceans. It is important that students are given hope that not all is lost and they do not walk away thinking nothing can be done to solve this important issue concerning the health of our oceans. As an extension have students research how we can lower the amount of carbon dioxide entering the atmosphere. For instance, they could compare and contrast solutions such as solar farms versus off- shore wind turbines. Students could also research what their school or community is doing, or could do to lower carbon dioxide emissions and increase sustainability. Have students pledge to get involved with a group already taking action or create a group of their own. If students are younger ask them to look at their carbon foot print and individually or as a group/class to pledge to take action that could help lower carbon dioxide emissions (i.e. carpooling, walking to school, less time playing video games and more time playing outside). Be sure to encourage students to educate others as well. Ask them to keep learning and share information about what ocean acidification is, how it is affecting sea life, and what can be done with friends and family too.

Below is a list of websites that discuss solutions to climate issues and ocean acidification:

http://www.eschooltoday.com/ocean-acidification/solutions-to-ocean-acidification.html

https://climateinterpreter.org/content/humans-can-take-action-slow-process-ocean-acidification

https://www.nature.org/greenliving/carboncalculator/?redirect=https-301 https://www.c2es.org/content/what-we-can-do/

http://www.c2es.org/category/climate-solutions/reducing-your-carbon-footprint/

http://www.drawdown.org/solutions

https://climatekids.nasa.gov/how-to-help/

http://www.sustainablejersey.com/

https://e360.yale.edu/features/kelp_seagrass_slow_ocean_acidification_netarts

http://oceanandclimatedefender.com/

An additional NJSGC lesson plan on Ocean Acidification can be found at:
http://njseagrant.org/wp-content/uploads/2014/02/Ocean-Acidification.pdf

Citations

1. NOAA. Earth System Research Laboratory. NOAA Global Monitoring Division. May 10, 2013. http://www.esrl.noaa.gov/gmd/news/7074.htm> Web. 4, May 2016

2. NOAA. PMEL Carbon Program. NOAA. http://www.pmel.noaa.gov/co2/story/Ocean+Acidification**>** Web.4, May 2016