Science Unit: Marine Biodiversity: Global Ocean to the Salish Sea
Lesson #6: Shells in Acids

Summary:	Test whether acids affect the weight of marine shells and connect this idea to ocean acidification.
Lesson type:	Data collection
Grade level:	Presented to grade 3; appropriate for grades 3 – 12 with age appropriate modifications
Duration of lesson:	20 min prep 1 week ahead and 90 - 120 min main lesson (to include graphing)
Developed by:	Jonathan Kellogg (Scientist); Andrea Teschner and Gillian Wilson-Haffenden (Teachers)
Developed for:	Lord Kitchener Elementary
School Year:	*2016-2017*
Notes:	Use clam and mussel shells from the dissection lesson, if available. Shells from the beach may also be used. This lesson covers many advanced topics for young ages, judge your class accordingly. Adjust math elements of the lesson to fit your class accordingly.

Connections to BC Curriculum

Living things are diverse, can be grouped, and interact in their ecosystems; Demonstrate curiosity about the natural world; Biodiversity in the local environment; Transfer and apply learning to new situations; Identify questions about familiar objects and events that can be investigated scientifically; Suggest ways to plan and conduct an inquiry to find answers to their questions; Make observations about living and non-living things in the local environment; Observe objects and events in familiar contexts; Make predictions based on prior knowledge; Atoms are building blocks of matter; Observable changes in the local environment caused by erosion and deposition by wind, water, and ice; Collect simple data; Use tables, simple bar graphs, or other formats to represent data and show simple patterns and trends; Compare results with predictions, suggesting possible reasons for findings; Reflect on whether an investigation was a fair test; Demonstrate an understanding and appreciation of evidence; Identify some simple environmental implications of their and others actions;

Objectives

Students will:

a) be introduced to ocean acidification and the underpinning science including: greenhouse effect, carbon cycle, human influence on climate, water as a molecule, pH scale, the effects of acidification on marine organisms, and ways to reduce their carbon footprint.

b) conduct an experiment using various household liquids to assess how acids affect seashells and can do simple graphing to determine which liquid caused the most shell dissolution and thus, which is the most acidic.

Materials

- Clam shells for 1-2 per student group. (chalk can be used in the absence of shells)
- Triple beam balance (or other scale capable of measuring ~3-10 g with 0.1 accuracy)
- pH test strips for the 1-14 range (narrow range 5-9, or 6-8 may also be useful)
- Cups, 1 per student group.
- Paper towels
- Drinking straw
- 1 L each: water, coffee, *Sprite*, white vinegar
- Calculators (depending on class)

Background Information for the Teacher

Ocean acidification is often called the evil twin of climate change, but to understand it, students must first have a basic understanding of climate change in the first place. Much of this background will be unnecessary to cover if you have covered climate change in previous lessons. Skip below if you have already covered atmospheric climate change.

Greenhouse Effect

The greenhouse effect can be thought of as adding additional blankets to the earth's atmosphere. Under preindustrial circumstances solar radiation warmed the earth each day and reflected off the surface. While some of that thermal radiation is reflected from the atmosphere back towards earth, a portion also escapes out to space. The human addition of carbon dioxide (CO_2) to the atmosphere through the burning of fossil fuels has effectively caused there to be additional blankets in the earth's atmosphere, thus trapping more of the sun's radiative energy within the atmosphere and heating the planet.

Carbon Cycle

By grade 3, most students have been exposed to photosynthesis and understand that plants breathe in CO_2 and release oxygen. Most also know that humans and animals breathe in oxygen and release CO_2. Using these two reference points, the carbon cycle can be introduced to the students. Briefly touch on other sources of CO_2 to the atmosphere such as volcanos and air-sea gas exchange. A major long term sink of carbon is accomplished through the geologic cycle as carbon is converted to fossil fuels, a process that takes hundreds of millions of years. However, humans are burning these fuels at a rate much faster than geologic processes can put them back into the ground.

Keeling Curve

Observations of atmospheric CO_2 were first collected by the climate scientist Charles David Keeling from the Mauna Loa Observatory, Hawaii in 1956. Regular measurements have continued since this time and are now the longest record of direct carbon dioxide observations in the atmosphere. Sampling is now automated and data are collected on hourly averages with the latest results reported online.

Looking at a 1 year record of data, the seasonal cycle becomes apparent with CO_2 levels rising between October and May, during fall, winter, and spring in the northern hemisphere when plant matter is decaying and carbon is being released. Between May and October, the prime growing season in the northern hemisphere, the large forests of North America, Asia, and Europe use the CO_2 to grow foliage and, thus, draw it out of the atmosphere. NASA has produced a fantastic video showing the annual evolution of CO_2 in the atmosphere. See references for links to current data and video.

Going further back, a two-year record shows a clear increase in CO_2 over the year before and the signal is made clearer over the entire record from 1956 to present. Scientists know that humans caused modern levels of atmospheric carbon dioxide and are not part of natural cycles in part because of ice core records. Using small bubbles in the ice, and other signals, scientists have been able to recreate the atmospheric composition and create paleoclimate records that go back 800,000 years.

In this long record, periods where CO_2 are high are between ice ages (interglacials), while periods where CO_2 are low are ice ages. These cycles represent the natural variability on the planet due to all known natural phenomenon. Given the current levels of CO_2 at over 400 ppm (when the natural variability does not go over 300 ppm), this is a clear departure from nature and is evidence of human changes to our environment.

The majority (87%) of the carbon being added to the atmosphere comes from the burning of fossil fuels with the balance resulting from deforestation. About half (~47%) ends up in the atmosphere with the rest being absorbed by land (27%) and ocean (26%) sinks. For the ocean this means that there is ~2.3 Gton of carbon per year of extra carbon being absorbed by the ocean each year. For perspective, it would take 25 million railroad hopper cars of coal to contain this amount of carbon. This train would stretch around the Earth's equator 14 times!

Water and pH

Water is a special molecule. Its structure makes the molecule become polarized with a positive charge on the side of the hydrogen and a negative charge on the side of the oxygen. This polar nature of water means that water can bind to many different substances and helps water become such a great solution for dissolving. When something dissolves in solution, it may become an acid or a base, simply where there is more H^+ or OH^- available, respectively.

The pH scale is a measure of this type of ion activity and students are familiar with many substances along the spectrum. It can easily be shown that CO_2 dissolves in water and changes the acidity of the water by simply taking tap, or distilled, water and testing its pH with pH test strips before and after exhaling into the water through a straw (blowing bubbles) for about a minute.

Note: With pH test strips it is important to look at the colour right at the interface between dry and wet and also to make the observation quickly (within seconds) after dipping.
For the lesson, the liquids water (7), coffee (4.5), Sprite (3.3 - 3.5), and vinegar (2.5) are chosen for their differences in pH. Other liquids may be used.

Ocean Acidification

The polar nature of water allows it to bind to CO_2 and to make the weak carbonic acid. This can be easily demonstrated in class and using records from the Hawaii Ocean Timeseries. Observations show that dissolved CO_2 concentrations in the ocean have been increasing at the same rate as concentrations have been increasing in the atmosphere and have documented the corresponding decrease in pH.

Observations show that the preindustrial global ocean averaged a pH of 8.2 and is currently measuring around 8.1. This doesn't sound like much but since pH is a logarithmic scale (not necessary to include for the students) this represents a 30% increase in the hydrogen ion concentration in the seawater. If current trends continue, oceanic pH is expected to decline to 7.6 by 2300, and therefore increasing acidity much further.

A more acidic ocean dissolves the shells of many marine organisms from shell making phytoplankton (coccolithophores) and zooplankton (pteropods) to corals and commercially important shellfish like clams, oysters, and mussels. In all cases, the organism isn't able to form the necessary bodily structures out of calcium carbonate and the deformations get more severe and increase mortality as the pH decreases.

In some cases, fish and squid have been found to lose their sense of smell, direction, or self-preservation where they become "brave" when encountering a predator. On the bright side, as with on land, marine sea grasses and non-shell building algae may benefit from increased CO_2 concentrations that are necessary for photosynthesis.

Reducing Carbon Footprint

While students may not have control over the temperature of their house or how they make transit options, they can still reduce their carbon footprint in significant ways. Since it was the combined efforts of humans that led to the increases in carbon dioxide emissions, it will also take the combined efforts of everyone to reduce emissions as well.

Some ideas include:

- Learn 1 more thing that can be recycled….and then recycle it!
- Pick up a piece of trash a day (then wash your hands)
- Participate in a shoreline cleanup!
- Turn off the lights in all rooms you aren't using
- Use a reusable water bottle
- Ask your parents to turn down the heat in your house just 1 degree
- Eat one less meal of meat a week
- Reuse paper
- Reuse everything you can
- Compost food scraps
- Pick up after your pet even in your own yard
- Plant a rain garden
- Unplug items you aren't using
- Eat locally grown food
- Shop Made in Canada/USA

Vocabulary

- **Element** – the simplest form a chemical can take
- **Carbon** – a common element that is in all living things
- **Carbon dioxide** – a heavy colourless gas that does not support combustion, dissolves in water to form carbonic acid, is formed through animal respiration and the decay of organic material, is absorbed from the air by plants during photosynthesis
- **Fossil Fuel** – a fuel (as coal, oil, or natural gas) formed in the earth from plant or animal remains
- **Greenhouse effect** – a warming of the surface and lower atmosphere of a planet that is caused by the conversion of solar radiation into heat in a process involving selective transmission of short wave solar radiation by the atmosphere, its absorption by the planet's surface, and re-radiation as infrared which is absorbed and partly reradiated back to the surface by atmospheric gases
- **pH** – a measure of acidity and alkalinity of a solution
- **Ocean acidification** – term used to describe significant changes in ocean chemistry caused by oceanic absorption of increasing levels of carbon dioxide gas present in the atmosphere
- **Calcium** – an important element in shells constructed by marine animals.

Classroom Set-up

- Arrange students into groups of 1-2 or as many as four at their desks

Lesson Detail

Introduction

Engage students in a discussion about what they already know about climate change and the processes / scientific foundation behind the current state of knowledge. In its initial presentation, this lesson addressed the background information above from the *Greenhouse Effect* to *Water and pH*. You may wish to adjust the content covered in the introduction to accommodate the background knowledge that your students have gained through prior lessons.

Activity

1. To set up the lesson, students should be broken into groups. Each group will get a shell (or shell pair if using shells from the clam dissection lesson). Weigh and record the mass of each shell using a triple beam balance, or other available scale.

2. Distribute cups and have students place one shell in the cups. If using a shell pair, mark the other shell with identification and set aside. Assign liquids to groups such that there are even numbers of each liquid represented. Pour enough liquid in each cup to cover the shell and allow for some evaporation over the course of the week (about an extra 1 cm, or so).

Before setting aside, have students make initial observations. Do they notice any changes? Specifically look at the shells with the vinegar, which should start bubbling immediately. What are the bubbles? (*carbon dioxide*) Place all the cups in a safe location where they can sit undisturbed for approximately 1 week.

Note: For the lesson, the liquids water (7), coffee (4.5), Sprite (3.3 - 3.5), and vinegar (2.5) are chosen for their differences in pH. Other liquids may be used.

3. As described in the background, you can prove to students that carbon dioxide dissolves in water and makes it more acidic simply by having them blow through a straw into tap water. Have them measure the pH using test strips before and after they blow into the water for 1 minute. Note: when using pH strips look at the wet/dry border for clearest change in colour and make the observation quickly. Narrow range (5 – 9 or 6 – 8) strips are available and will make the difference more clear to students than wide range strips.

4. After shells have sat in liquids for 7-10 days, have students make observations. Those with the vinegar may notice a white substance has formed around the surface of the vinegar, like a bathtub ring. This is shell that precipitated out of solution. If the vinegar is left to completely evaporate, shell would precipitate out of solution and coat the surface of the container.

5. Remove shells from the liquid and pat them dry with paper towel. Weigh shells using the triple beam balance and record the final mass. How does the final mass compare to the initial mass? Where did the additional shell material go? If students used a shell pair from one animal, can they see or feel a difference between the shell that wasn't in the liquid for a week? For those with shell pairs, try to break both shells. Does one break easier than the other? Have students qualitatively compare the physical characteristics of shells placed in water, coffee, Sprite, and vinegar for the week. Are there differences between the liquids?

6. Quantitatively, have the students calculate how much mass was dissolved from the shell. What percent of the shell dissolved away? Compare the percent dissolved across treatments. Identify the scientific reasoning behind having a water treatment and having replicate experiments in the same class. Calculate the average percent lost for each treatment and create a bar graph of the results, if desired.

7. Based on their results, which liquid was the most acidic? How do they know? Use the pH test strips (1-14 range) to validate their results (preferred in a sample of liquid that hasn't reacted with a shell, the chemical reaction with the shell neutralizes the liquid over the experimental period).

Closure Discussion

Use the experiment as a basis to demonstrate what will happen to marine organisms with ocean acidification, acknowledging that while organisms will not be dissolving in a week, there will be considerable changes. Some of these changes are described in the background, and many more can be found online and in the references below.

End the class with a discussion about what students can do to help reduce their carbon footprint and help the oceans. After all, it took the collective actions of all humans to put the planet on its current path. Therefore, it will take changes in all humans' lives to change that path towards one that is more sustainable.

Extensions of Lesson

1. Quantitatively, the lesson can be extended to talk about error and standard deviation.
2. Increase the depth to which any of the climate related topics are addressed.
3. Discuss timescales of change in the deep ocean addressing ocean circulation
4. Have students calculate their carbon footprint

References

A primer on pH *NOAA Pacific Marine Environmental Laboratory* https://www.pmel.noaa.gov/co2/story/A+primer+on+pH

Effects of Ocean Acidification on Marine Ecosystems *National Acadamies of Sciences Engineering and Medicine* https://www.nap.edu/read/12904/chapter/6

Hawaii Carbon Dioxide Time-Series *NOAA Pacific Marine Environmental Laboratory* https://www.pmel.noaa.gov/co2/file/Hawaii+Carbon+Dioxide+Time-Series

NASA | A year in the life of Earth's CO2 https://www.youtube.com/watch?v=x1SgmFa0r04

Ocean Acidification *Smithsonian* http://ocean.si.edu/ocean-acidification

Paleoclimatology *NASA Earth Observatory* https://earthobservatory.nasa.gov/Features/Paleoclimatology/

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The Carbon Cycle *NASA Earth Observatory* https://earthobservatory.nasa.gov/Features/CarbonCycle/

The Keeling Curve – Scripps Institution of Oceanography https://scripps.ucsd.edu/programs/keelingcurve/

The Ocean's Carbon Balance *NASA Earth Observatory* https://earthobservatory.nasa.gov/Features/OceanCarbon/

USGS Carbon Cycle Image: https://www.wpclipart.com/geography/diagrams/carbon_cycle_USGS.jpg