Everblue Education

Seawater Acidification

In this lesson, students will explore the concept of ocean acidification through a series of games, physical activity, and an at-home kitchen chemistry lesson! This lesson is based on the paper "Seawater acidification more than warming presents a challenge for two Antarctic macroalgal-associated amphipods" by Julie B. Schram et al. published in 2016 in the journal *Marine Ecology Progress Series.* This research looked at how amphipods (tiny relatives of shrimp) are affected by changing pH in the ocean environment they live in. Students will get to test their own pH in their kitchen using an organic cabbage chemistry experiment!

Everblue is a 501(c)(3) nonprofit dedicated to encouraging ocean-conscious living by increasing scientific literacy. Our online education resources connect current science to daily life, allowing you to learn about the ocean at your fingertips! Stay in touch by following @oceaneverblue on your prefered social media platform or by visiting our website at www.oceaneverblue.org.

To help us keep the ocean ever blue, please share this program with the teachers and parents you know so we can spread ocean science far and wide. Partnering with marine scientists from around the world who study all parts of the ocean, we've created simple and engaging activities based on recently published papers! These activities connect you and your students to current research while fulfilling education standards for reading, math, science, and writing. Even though the activities are created for grade school, they're fun and informative for parents and siblings, as well! More activities will be available to download for FREE off of our website, with a new activity added every month.

Research Paper:
Seawater acidification more than warming presents a challenge for two Antarctic macroalgal-associated amphipods. *Julie B. Schram et al. 2016.*

Grade Level:	Timing:
Kindergarten through 8th grade	1 hour

Materials:
One red cabbage, a knife, a cutting board, a large heat-safe container, boiling water, three extra top-layers (per student), a writing utensil, at least five small soft objects such as stuffed animals or tiny pillows, at least six small heat-safe containers, a spoon, five household liquids

Next Generation Science Standards

Science & Engineering Practices:	Crosscutting Concepts:	Disciplinary Core Ideas:
Planning & Carrying Out Investigations	Stability & Change Matter & Its Interactions	Earth & Human Activity Energy & Matter

Activity Overview

Title of Activity	Learning Cycle Stage	Time
Cut the Cabbage	Invitation	5 minutes
Move & Molt	Invitation, Exploration	5 minutes
We are Water Molecules	Exploration, Concept Invention	5 minutes
Cabbage Chemistry	Application	40 minutes
Reflection	Reflection	5 minutes

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Activities

Cut the Cabbage

In this activity, you'll be preparing the materials you need for the third activity of the day. You'll need a red cabbage, a knife, a cutting board, a heat-safe container, boiling water, and an adult or guardian at least 16 years old to help. Follow the instructions below to cut your cabbage for chemistry!

1. Grab your adult! Have them use a knife and a cutting board to cut the cabbage into teeny tiny pieces.
2. Put the cabbage pieces in a large heat-safe container or bowl.
3. Pour boiling water in the bowl to completely cover the cabbage and let it sit for at least 10 minutes while you have fun with the next activity!

Move & Molt

While the cabbage is soaking, students will embody different life stages of the **amphipods** discussed in this research paper. Each student needs three additional top-layers. These layers could be shirts, jackets, or anything else that covers their upper body. Set up a space in your learning area that is clear of all obstacles. The student(s) will cross this area a total of five times. Use a timer to record the amount of time needed to cross this area in each life cycle round.

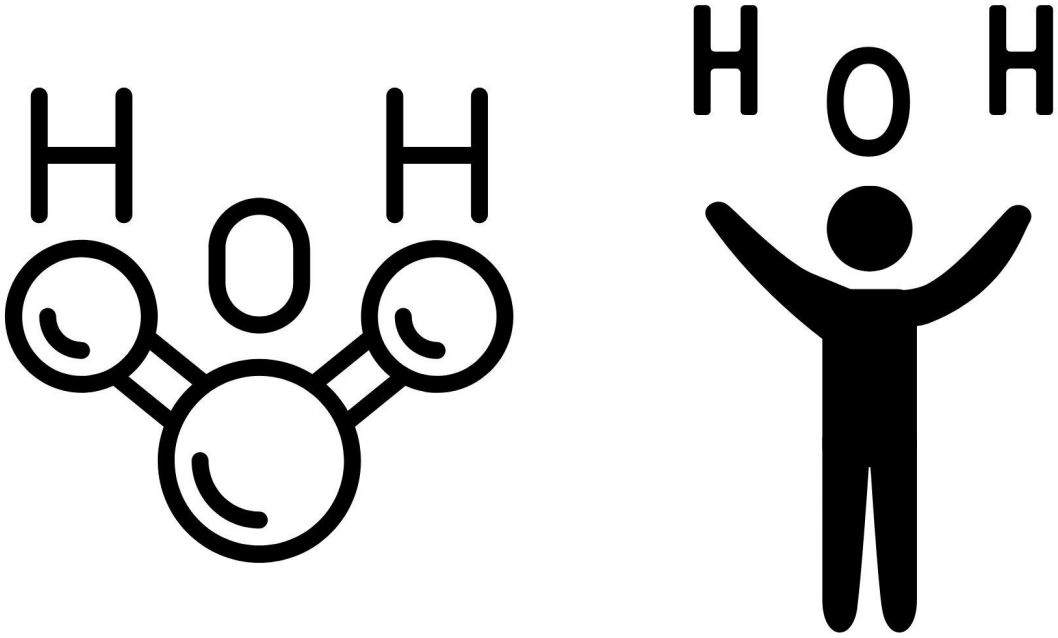
Round 1: Egg // All layers
Roll across the designated area while holding arms around legs.
Round 2: Juvenile I // All layers
Army crawl across the designated area.
Round 3: Juvenile II // Remove a layer
Crawl on hands and knees across the designated area.
Round 4: Juvenile III // Remove a layer
Walk on knees across the designated area.
Round 5: Adult // Remove final layer
Speed walk across the designated area.

We are Water Molecules

This research paper explores what happens to different animals living in the ocean when the ocean water they live in becomes more **acidic.** The ocean becomes more acidic when carbon dioxide (CO_2) reacts with the ocean water (H_2O) and the water atoms let go of hydrogen atoms (H) into the water. Let's play a quick game to see how this happens! *For this game, you'll need*

at least 5 small soft objects such as stuffed animals or tiny pillows. (For the remainder of this activity, we'll refer to these objects as stuffed animals.) Have the instructor or adult hold the stuffed animals and have the students stand in the middle of a large open space, such as a cleared-out living room or backyard. Then, read the students the following information.

Water molecules are made up of one oxygen atom (O) and two hydrogen atoms (H). The image on the left below shows what a water molecule looks like. Now, let's pretend to be water molecules! Hold your arms up in the air like the image on the right below, and hold your hands in fists. You are now a water molecule in the ocean - your head is the oxygen atom, and your fists are the hydrogen atoms!



Begin to slowly turn around and move around the "ocean" (the room) as a water molecule. But oh no - humans on land are using gas in their cars and burning fossil fuels for energy, which adds more carbon dioxide (CO2) to the air! The ocean is going to pick up, or **absorb**, this extra CO2 (*the small stuffed animals are the "CO2 molecules," so explain to the students that you're going to toss the stuffed animals into the "ocean" as CO2 molecules being absorbed by the ocean.*) If you get hit with a CO2 molecule, you have to release one of your hydrogen atoms by releasing one fist and dropping your arm to your side! Ready, set, go!

Once all the CO2 molecules have been tossed into the ocean, the game is over. Have the students sit down and read them the rest of the activity.

More hydrogen atoms in a liquid will make that liquid more acidic. When the CO2 molecules (stuffed animals) entered the ocean, what happened? *Help the students towards the answer that as CO2 molecules entered the ocean, they (as the water molecules) had to let go of a H atom.* And when you water molecules lost a hydrogen atom, did that put more or less hydrogen into the ocean? *Help the students to the answer that as they lost their hydrogen atoms, the ocean gained more hydrogen atoms from the water molecules.* So, with what we know about acidity, when you lost a hydrogen atom after being hit by a CO2 molecule, did that make the ocean more acidic or less acidic? *Help the students to understand that as H atoms are added to a liquid, that liquid becomes more acidic.*

This is why the ocean is becoming more acidic than it used to be; as humans use energy and drive cars and fly planes, we put more carbon dioxide into the air, which gets sucked into the ocean. Move on to the next activity to learn about different liquids that are acidic!

Cabbage Chemistry

By the start of this activity, your cut cabbage should have been soaking for at least 10 minutes and should look a blue-purple-pink-ish color.

When the ocean becomes more acidic, it is a problem for a lot of little animals with shells like the **amphipods** discussed in this research paper, because they need some carbon atoms mixed in the surrounding seawater to make their shells. When the ocean becomes more acidic, these carbon atoms get used up and there aren't enough left for shell-making. Amphipods kind of look like little roly-poly bugs in the water. What are some other animals you can think of that have shells that live in the ocean? (*Conchs, snails, oysters, clams, sea urchins, scallops, and whelks are all examples.)*

Lots of scientists, like the ones who wrote the research paper that this lesson is based on, study how acidic the ocean is. This type of science is called **ocean chemistry**. Today, we're going to do a little chemistry of our own in our kitchens! What liquids can you think of around your kitchen or home that are acidic? (*Lemon, oranges, lime, and vinegar are a few examples.)* The opposite of acidic is something that is **basic.** Can you think of anything around your house that is basic? (*Baking soda, toothpaste, and laundry soap are a few examples.)* "Acidic" and "basic" are two words we use to describe the pH of a substance - the lower the pH, the more acidic the substance; the higher the pH, the more basic the substance.

In this activity, we're going to do our own kitchen chemistry! *Help your students go around the house and collect at least five different liquids or substances that you can use to test pH. A scaled list of common household items and their pH distinctions are listed below - try to have your students find at least two substances that are acidic and two that are basic.*

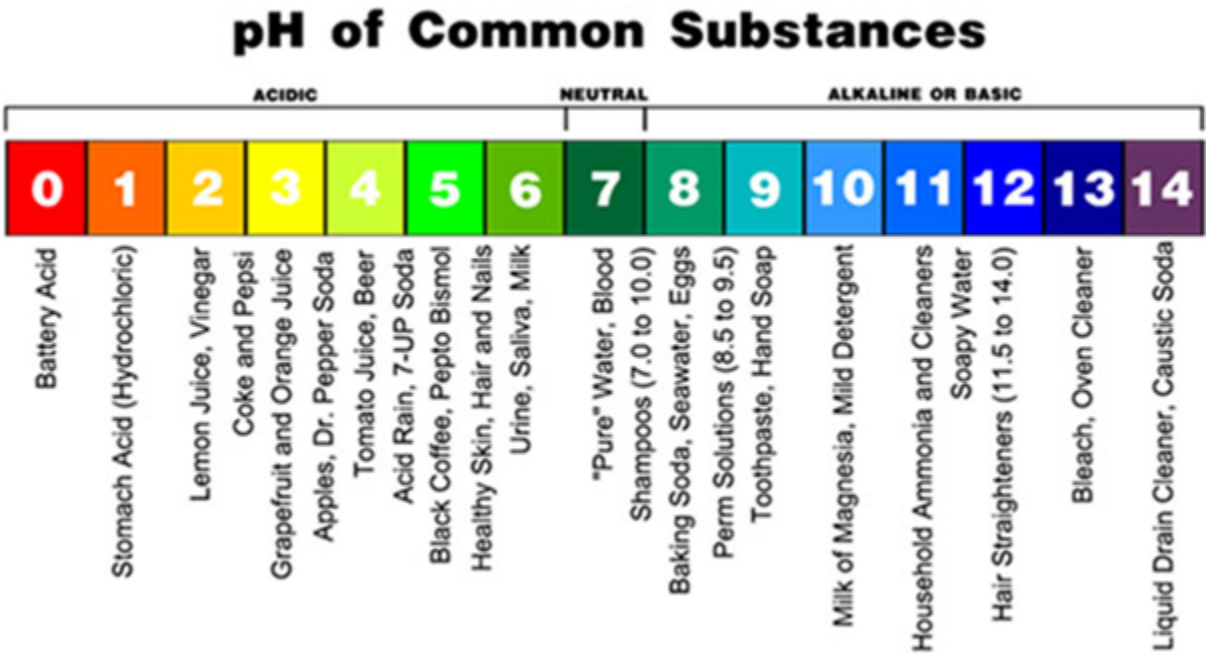


Image credit: epa.gov

Now that we've collected our substances, go ahead and write the name of each substance into the top row of the table printed out from Appendix II, titled "household substance or liquid"! (*If your students collected more than 5 substances, just have them draw another table similar to the one below and fill it out. And, if you do not have access to a printer, simply recreate the table on a blank sheet of paper with a writing utensil.*)

Next, strain the colored water into a jar and set the used cut cabbage to the side (*remember to compost this if you have a home or community composter!*) This colored water from our boiled red cabbage is what we will use as our **pH indicator.** Indicators are colored liquids that scientists use to figure out what the pH of a certain substance is - when you add a substance to the indicator, it will turn different colors to tell you what the pH of the substance is!

Our cabbage indicator starts out as a bluish-purple color. This color comes from a natural **pigment** found in red cabbage called **flavin**, which changes color when mixed with different pHs. When you add something acidic, it will turn red. When you add something basic, it will turn green. Refer to the photo on the next page to see what the colors should look like.

An acidic substance will turn our cabbage indicator from bluish-purple to red. A basic substance will turn our cabbage indicator from bluish-purple to green.

Image credit: Clive Streeter, Thought Co.

Pour the cabbage indicator water into separate small jars or glasses for pH testing. (*Your number of jars should equal the number of substances your student found to test plus one - so if your student found five substances to test, you should have six jars of cabbage indicator.)* Set one of the jars of cabbage indicator to the side - this will be your **control** indicator, which will stay the normal bluish-purple color and will have nothing else added to it.

Before adding any substances to the cabbage indicator, let's make a guess, or **hypothesis**, of what we think will happen! Use the "pH of Common Substances" colored scale on page 6 to find your household substances and see if they are on the acidic or basic side of the scale. Write your guess for what color the indicator will turn (red for acidic or green for basic) into the second row of the table from Appendix II, titled "what color do you think the indicator will turn?" (*If your student wants to test a liquid or substance that is not on the scale on page 6, have them make an educated guess based on what they know about the substance of whether it will be basic or acidic. Is it similar to any substances on the scale? Is it edible, and if so, what does it taste like? Is it used for cleaning? These are some questions that could help students hypothesize about the pH of the substance.)*

After making your hypotheses, one by one, add your collected household substances to the **experimental** jars (*remembering to keep the control jar set aside)* and stir them with a spoon! **Observe** what colors they turn into and make a note in your table in the row titled "pH color from cabbage indicator." (*For making notes in the second row of the table, you can either write in the words of the colors "red" and "green" OR you can have the students color in the blank square on the table with red or green colored writing utensils.)*

Once you've tested all your substances and used all your experimental indicators, it's time to make some **conclusions**! In the last row on your table, titled "is the substance more acidic or basic," use the color that you observed the indicator turn to decide whether each of your substances is an acid or a base. Write the word "acidic" or "basic" into each square on the table below your substances.

Congratulations - you've made it to the end of a fully formed scientific experiment! You gathered materials, made some hypotheses, followed methods, observed some results, and drew your own conclusions, just like the researchers who wrote this paper on amphipods and ocean acidification! Give yourself a science high-five, then move on to some final reflection questions.

Reflection

As you and your student are cleaning up, talk to your student about what you just did together. Here are some guiding questions to help shape your conversation.

- What was your favorite part of our activity today?
- What is something that you learned about acidity?
- Did you notice any patterns during our activity today?
- What is something you wonder about ocean chemistry?
- What surprised you the most during our activity today?

Appendix I - Instructor Support

Ocean Vocabulary

- absorb - to take in or soak up another substance by chemical or physical interaction
- acidic - a substance with a pH below 7 due to an excess of hydrogen (H) ions
- amphipods - tiny marine crustaceans related to shrimp that look like roly-poly bugs in the ocean
- basic - a substance with a pH above 7 due to a lack of hydrogen (H) ions
- conclusions - a scientific claim made after testing and experimentation that answers the initial research question
- control - a variable or trial in an experiment that remains unchanged
- experimental - a variable or trial in an experiment that is changed or manipulated
- flavin - a type of anthocyanin (a blue, red, or purple pigment commonly found in plants that can be used as a pH indicator)
- hypothesis - a scientific guess or claim based on previous knowledge, made before testing and experimentation
- observe/observation - perception and recording of data during scientific experimentation
- ocean chemistry - study of the chemical nature of the ocean
- pH indicator - chemical compound used to visually determine the pH of a solution
- pigment - natural coloring matter

Appendix II - Attached Lesson Materials

Move & Molt Time Sheet

Life Stage Movement	Number of extra Layers	Time needed to cross space
Round 1: Egg Roll holding arms around legs	3 Layers	
Round 2: Juvenile I Army crawl on belly	3 Layers	
Round 3: Juvenile II Crawl on hands & knees	2 Layers	
Round 4: Juvenile III Walk on knees	1 Layer	
Round 5: Adult Speed walk	0 Layers	

Cabbage Chemistry Activity Table

household substance or liquid					
what color do you think the indicator will turn?					
pH color from cabbage indicator					
is the substance more acidic or basic?					