National MagLab
STEM Lesson Plan:

NATIONAL MAGLAB
Research Experiences FOR TEACHERS

The Impact of Rising Carbon Dioxide Levels and Ocean Acidification (High School)

Lesson Objectives: Student will be able to:

- describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
- understand that pH measures acidity on a scale that ranges from 0 – 14.
- determine the pH of household substances using pH test strips.
- predict, observe, and explain expected color changes when adding pH indicators to household substances.
- understand that increasing carbon dioxide levels lower the pH of the ocean, leading to ocean acidification.
- explain the impact of ocean acidification on marine organisms.
- research how they can play a part in reducing ocean and coastal acidification.

Next Generation Science Standard:

- SC.912.N.1.6 Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
- SC.912.E.7.9 Cite evidence that the ocean has had a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water.
- SC.912.E.7.9 Explain how the oceans act as sources/sinks of heat energy, store carbon dioxide mostly as dissolved bicarbonate (HCO_3^-) and calcium carbonate ($CaCO_3$) as precipitate or biogenic carbonate deposits, which have an impact on climate change.

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

STEM RATIONALE FOR LESSON:

Ocean acidification refers to a reduction in the pH of the ocean over an extended period, caused primarily by the rapid absorption of carbon dioxide (CO_2) from the atmosphere. For more than 200 years, or since the industrial revolution, the concentration of CO_2 in the atmosphere has increased due to the burning of fossil fuels and land use change (e.g. deforestation resulting in less photosynthesis).

$$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O \quad \text{(combustion of fossil fuels)}$$

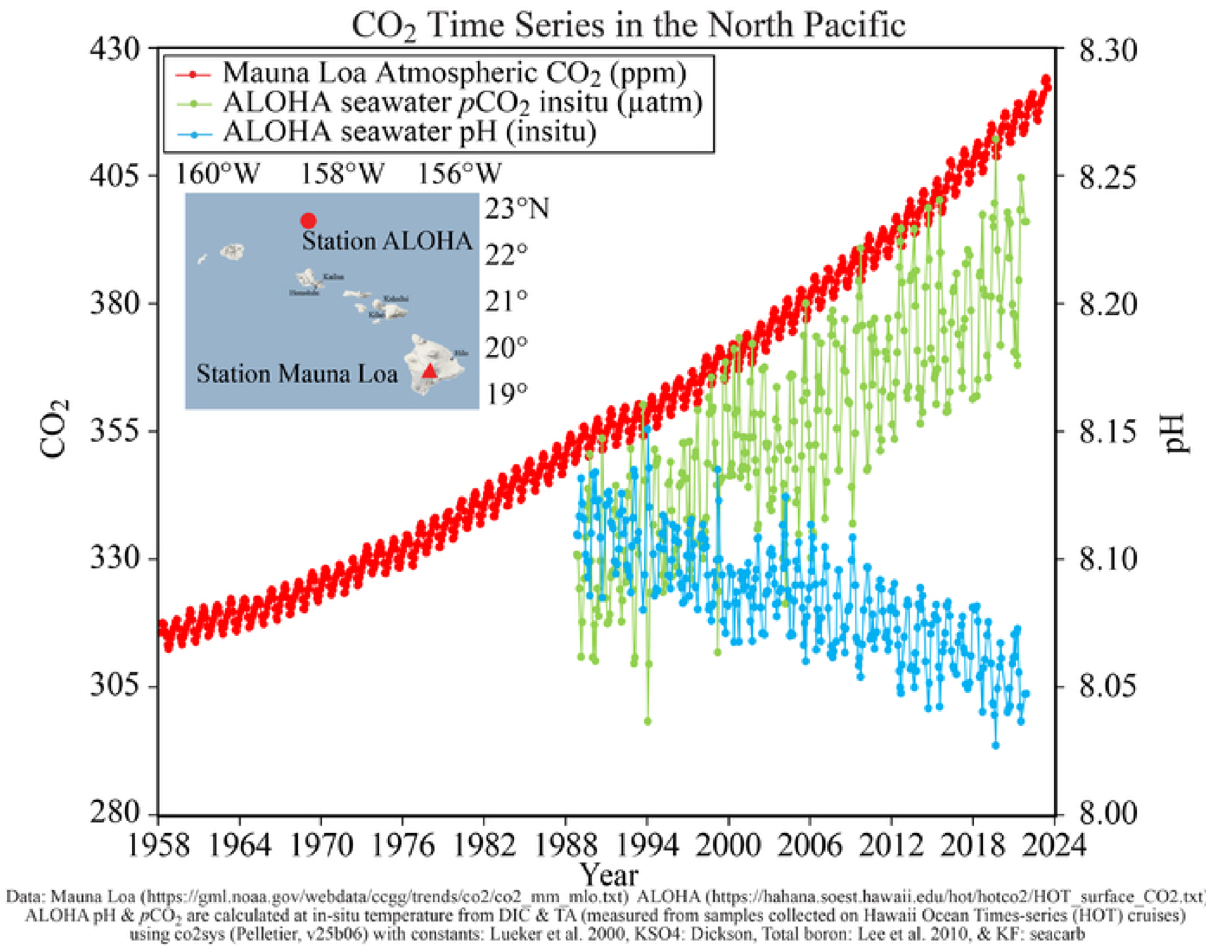
$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2 \quad \text{(photosynthesis)}$$

As levels of atmospheric CO_2 increase, so do the levels in the ocean. The ocean acts as a "carbon sink" and absorbs about 30 percent of the CO_2 released into the atmosphere. Once absorbed, CO_2 reacts with water molecules (H_2O) to form carbonic acid (H_2CO_3). This compound then breaks down (or "dissociates") into a hydrogen (H^+) and bicarbonate (HCO_3^-) ions. These H^+ ions are responsible for the lowered pH of seawater.

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^- \quad \text{(ocean acidification)}$$

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:



(NOAA PMEL Carbon Program https://www.pmel.noaa.gov/co2/file/Hawaii+Carbon+Dioxide+Time-Series)

This graph shows rising levels of CO_2 in the atmosphere (red), rising CO_2 levels in the ocean (green), and decreasing pH in the water (blue) off the coast of Hawaii.

Ocean acidity has increased by about 25 to 30 percent in the past three centuries, and it is likely to increase another 40 to 50 percent by 2100. Increasing ocean acidity can result in damage to corals, as well as shellfish and other marine species. As the ocean becomes more acidic, corals are less able to remove minerals from the water to build their skeletons.

Coral skeletons are made of the mineral, calcium carbonate ($CaCO_3$). Ocean acidification causes the amount of available $CaCO_3$ to decrease. This is because some of the carbonate ions (CO_3^{2-}) that normally pair with calcium ions (Ca^{2+}) to form calcium carbonate instead pair with H^+ to form bicarbonate (HCO_3^-).

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3 \quad \text{(biomineralization)}$$
$$H^{+} + CO_3^{2-} \rightarrow HCO_3^{-} \quad \text{(competing reaction)}$$

With less $CaCO_3$ around, corals find it more difficult to build and regrow their skeletons, increasing the chance of coral death. Shellfish, like clams, oysters, and other marine organisms, also depend on these minerals, and acidity interferes with their ability to build their shells. Coral reefs provide critical habitat for one in four ocean animal species, and small shell-producing animals are important sources of food for larger animals. Therefore, ocean acidification threatens the foundation of the entire ocean food chain.

Culturally Responsive Connection:

Florida is surrounded by the Atlantic Ocean and the Gulf of Mexico. Ocean acidification is, therefore, a real concern as this process harms Florida's marine ecosystems, fisheries, and tourism. Florida is also home to the only nearshore coral reef in the continental United States. Consequently, the Florida Reef Tract (FRT) has been one of the most studied ecosystems regarding the negative impacts of ocean acidification. A 2016 study of the FRT confirmed the vulnerability of Florida's corals to ocean acidification. Northern portions of the coral reef tract are now "net erosional," which means that in these areas more $CaCO_3$ is being dissolved than is being created by biological activity each year. This suggests that the FRT is no longer a functioning, healthy coral reef (Muehllehner et al. 2016).

Furthermore, a 2016 study of two Caribbean species examined the idea that corals that occur in relatively shallow water may be resilient to the effects of acidification. Despite experiencing daily fluctuations in pH, the results suggested that even corals acclimatized to areas with high natural variability in pH were harmed or killed by the pH levels predicted for the year 2100 (Camp et al. 2016).

Students who attend my school, and by extension, my classes are multicultural. I have students who are Floridians by birth, including those of Hispanic or Caribbean heritage. Other students are originally from Caribbean countries (Haiti, Puerto Rico, Jamaica, Bahamas) and Central American countries (Honduras and Guatemala). All are familiar with beaches, the ocean, and marine organisms. Many of these economies are dependent on marine activities including fishing and tourism.

STEM Lesson Plan:

NATIONAL MAGLAB
Research Experiences FOR TEACHERS

Globally, ocean acidification threatens the food security of one in seven people that rely on food from the ocean as their primary source of protein. The only way to stop ocean acidification is to stop emissions of CO_2. Even if we stop, the CO_2 that we have emitted in the last 200 years will still be absorbed by the oceans in the future, and the damage will take thousands of years to reverse. To secure a healthy planet, public awareness of the effects of ocean acidification at regional and national levels is of critical importance.

Time: Each part can take 30-40 minutes.

Materials:

- Personal protective equipment – safety googles, aprons, gloves
- pH test strips
- red cabbage
- ziplock bags (optional)
- beakers
- plastic spoons (for mixing solutions)
- sharpie markers (for labeling solutions)
- Household items to test, such as: vinegar, lemon or apple juice, milk, solutions of liquid cleaning products (no bleach), baking soda, detergent, antacid tablets, etc.
- clear soda
- bottled or tap water
- straws
- clear plastic cups
- saran wrap
- white chalk broken into 2-inch pieces

Previous Knowledge:

- pH is a measure of the activity of hydrogen ions (H^+) in solution, and is calculated by $pH = -\log([H^+])$; $[H^+]$ = molar (mol/L) concentration of H^+
- The pH scale ranges from 0 - 14
- Acidic solutions contain higher concentrations of H^+ and have pH < 7
- A pH of 7 indicates a solution is neutral

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

- Solutions with pH > 7 are basic/alkaline
- The carbon cycle describes the natural reuse of carbon atoms, which travel from the atmosphere in the form of CO_2 into organisms to be made into glucose ($C_6H_{12}O_6$) to be used as energy, and then back into the atmosphere over-and-over again:

$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2 \quad \text{(photosynthesis)}$$

$$6\ CO_2 + 6\ H_2O \leftarrow C_6H_{12}O_6 + 6\ O_2 \quad \text{(respiration)}$$

Lesson Introduction:

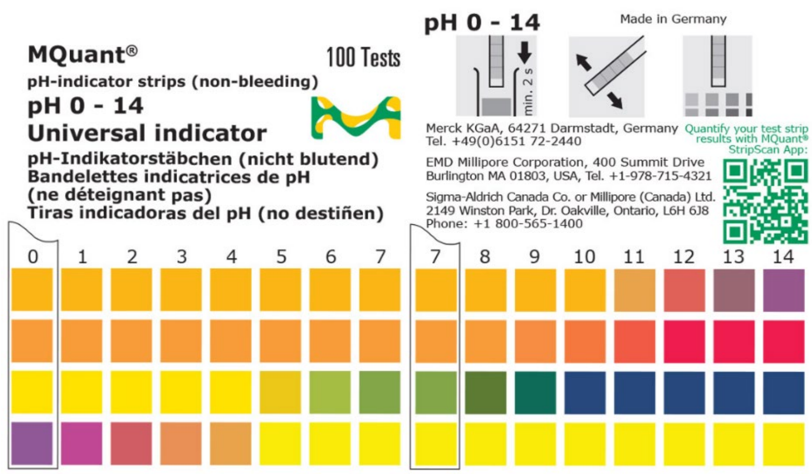
1. Create a Mind Map on pH: Begin by explaining the concept of pH and its significance in chemistry, particularly in determining acidity and basicity. Divide students into small groups and provide each group with a large sheet of paper or a whiteboard. Instruct the students to write “pH” in the center of the paper and draw branches radiating out for related terms and concepts. Encourage them to include:
   a. The definitions of acid, base, and neutral.
   b. The pH scale’s values and what those values indicate.
   c. Common substances that are acidic (e.g., lemon juice, vinegar) or basic (e.g., baking soda).
   d. pH measurement tools such as litmus paper, pH test strips, pH meter.

   After about 15-20 minutes, have each group share their mind maps with the class, fostering a discussion to clarify and expand on the concepts.
2. Review the “Red Cabbage Chemistry” Poster. Explain that red cabbage juice can be used as a natural pH indicator. Encourage students to explore the poster in pairs or small groups, looking for information on how red cabbage changes color in different pH environments, what chemical compounds can be responsible for color changes, and any practical applications of red cabbage as a pH indicator. After reviewing the poster, ask guiding questions to prompt discussion, such as: “What color did the cabbage juice turn in acidic vs. basic solutions?” or “How can we use this knowledge in real-life situations?”
3. Introduce pH Test Strips. Show students the pH test strips, explaining that these strips are a quick way to determine the acidity or basicity of a

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

solution. Highlight key features of the pH test strips, including the coating of different pH indicators that respond to various acidity levels and the packaging and instructions provided with the strips, emphasizing safety and correct usage, and the scale that is used with the test strips to help identify the correct pH value.

4. Demonstrate how to properly use the pH test strips:
    a. Select a sample solution (e.g., vinegar, baking soda solution, or distilled water) and place it in a small, clear container.
    b. Take a pH test strip and hold it by the edge to avoid contamination.
    c. Dip the strip into the solution for a few seconds, ensuring that the strip is fully immersed.
    d. Remove the strip and gently shake off any excess liquid.
    e. Allow the strip to develop color for the recommended time (usually 30 seconds). Important Note: Emphasize the importance of not touching the testing area of the strip to ensure accurate results.
    f. Instruct students to carefully compare the resulting colors on their test strip to the pH indicator scale.



    g. Encourage students to record their findings in their observation sheets, noting the solution tested, the color observed, and the corresponding pH value.

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

5. Ask students to share their findings and any patterns they observed in the pH levels of the different solutions tested. Ask students what they think the pH value would be of water, foods, drinks, and various other household items. Remind them that predictions/hypotheses that are made about an experiment or subject should always use an if/then statement.

Red Cabbage Juice Preparation:

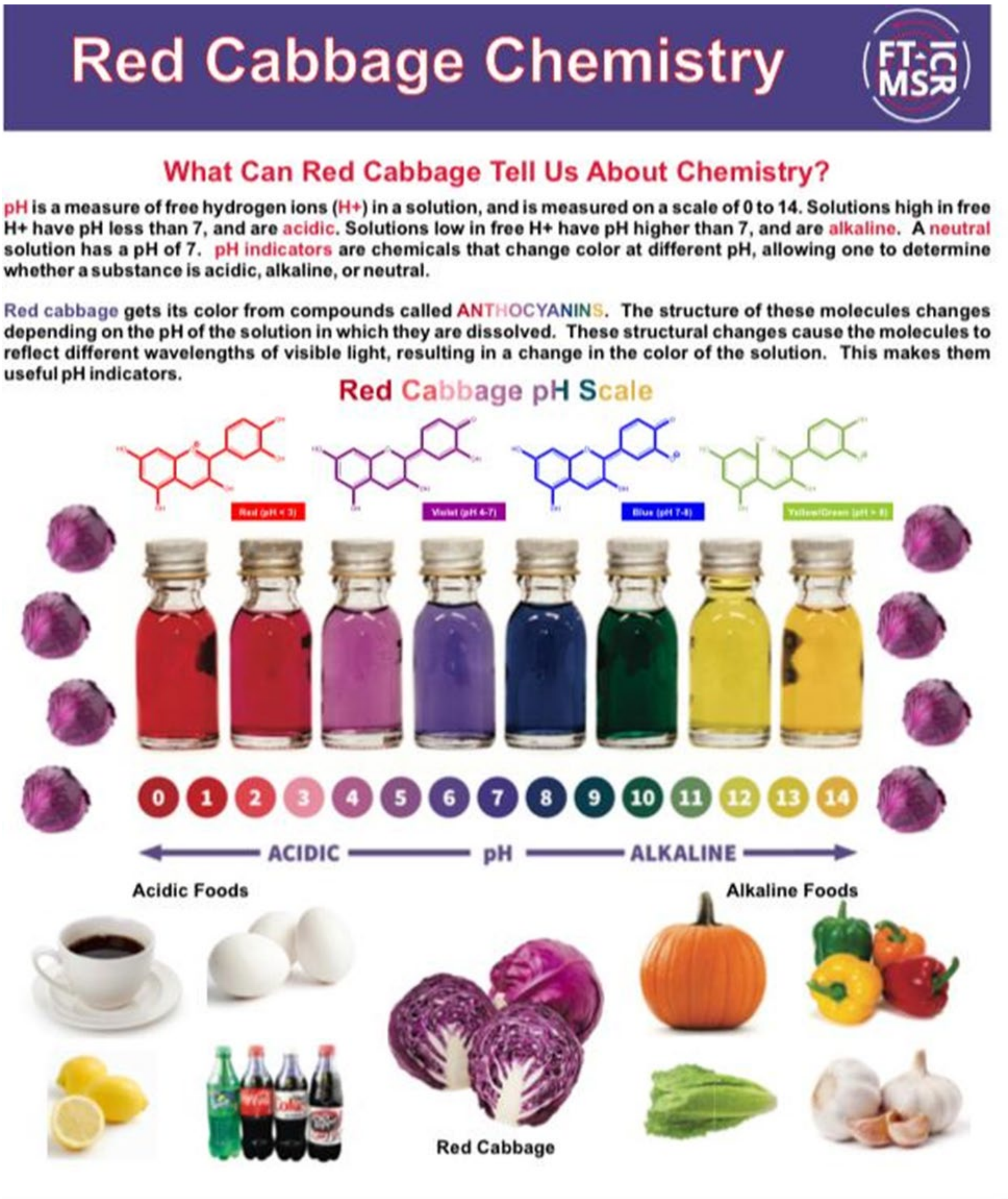
1. Tear the Cabbage: Take several leaves of the red cabbage and tear them into small pieces, roughly the size of a quarter. Aim for about 1-2 cups of torn leaves. Place the torn pieces into the zip-closing plastic bag.
2. Add Warm Water: Add about 1 cup of warm water to the bag with the cabbage leaves. The water should be warm but not boiling, to avoid burns.
3. Seal the Bag: Carefully remove as much air as possible from the bag to help the leaves release their color into the water. Seal the bag tightly.
4. Extract the Color: Hold the bag at the top with one hand to keep it secure. With your other hand, gently squish the leaves in the water for about 2-3 minutes. Continue until you notice that the water has turned a dark blue or purple color. This indicates that the pigments from the cabbage are being released into the water.
5. Transfer the Liquid: Carefully pour the liquid from the plastic bag into a cup or small clear container, being cautious not to spill.
6. Discard the Leaves: Dispose of the leftover cabbage leaves in the trash bin. The liquid in your cup is now your red cabbage indicator, which can be used for testing the pH of various substances.

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:



The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

NATIONAL MAGLAB
Research Experiences FOR TEACHERS

Lesson Instructions:

Part 1:

1. Navigate to the appropriate location where the POE template (POE template-2.docx) is available for download. Once downloaded, rename the file to include your name and the date (e.g., "POE_Template_JohnDoe_10-14-2024") for easy identification. Save the file to your OneDrive or designated folder to ensure it is accessible for later use. If you prefer a paper copy, ask your teacher for one.
2. Open your saved POE document. At the top of the sheet, write or type your name(s), the date, and your class period number. Ensure this information is clearly visible.
3. If you are working with a partner or in a group, engage in a discussion about what you expect to happen when the pH strip is placed in vinegar. In the "Predict" section of your POE sheet, formulate your prediction using the if/then statement format. For example: "If the pH strip is placed in vinegar, then it will turn red, indicating that vinegar is acidic."
4. Once the teacher provides the pH strip and vinegar, carefully dip the strip into the vinegar. After removing the strip, observe the resulting color change. Hold the strip against the pH chart provided with the strips to identify the corresponding pH level.
5. In the "Observe" section of your POE sheet, write or type a detailed description of the color change you observed on the pH strip. Include the specific color and the pH value that corresponds to that color, if possible.
6. In the "Explain" section of your POE sheet, address whether your observation matched your prediction. Provide a clear explanation for your reasoning. If your prediction was accurate, explain why you expected that result based on your understanding of acids and bases. If it was not accurate, discuss any factors that may have led to the difference between your prediction and the actual observation.
7. If you completed the assignment digitally, upload your completed POE sheet to Canvas following your teacher's instructions. If you filled out a paper copy, hand it in directly to your teacher at the designated collection point.

Class discussion of responses and verbal and written feedback given after grading. The best response can be shared with the class to provide a guide for the other POEs. You may choose to display the best POE example on Bulletin Board under “Student Work” (recognition).

Part 2:

1. Ensure that the red cabbage indicator solution is ready for use. This should have been prepared earlier by boiling red cabbage and filtering out the solids to obtain a vibrant purple-blue liquid. Begin by explaining to the class that you will be testing the pH of various household items using the red cabbage indicator solution. Pour a small amount of the indicator into a clear cup for each item to be tested.
2. Before adding each household solution to the red cabbage indicator, ask students to predict the color change they expect to see. Facilitate a group discussion, encouraging students to share their thoughts on what color they think the indicator will change to when a specific solution is added. Prompt them to think about why they expect those colors based on their prior knowledge of acids and bases.
3. One by one, add each household item to the corresponding cup with red cabbage indicator. For example, start with vinegar, then proceed to lemon juice, baking soda, and finally clear soda. After each addition, allow students to observe the color change. Ask them to note the new color and discuss as a class what they observed. Facilitate a discussion on why they think the color changed as it did. Encourage students to connect their predictions to their observations and to articulate their reasoning based on the properties of acids and bases.
4. Explain that while the red cabbage indicator is useful, pH test strips can provide a more accurate pH measurement of the solutions. Emphasize that it is better to test solutions directly with the strips because the red cabbage juice can stain the strips, potentially affecting their accuracy.
5. When testing the clear soda, take a moment to highlight the connection between the carbonation in soda (carbon dioxide, CO_2) and pH levels. Explain that when CO_2 dissolves in water, it forms carbonic acid, which can lower the pH of the water. Connect this concept to ocean acidification, discussing its effects on marine life and ecosystems.

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

6. Invite students to ask questions or share their thoughts on how carbonation and pH relate to environmental issues, Reinforce the importance of understanding these concepts in the context of real-world challenges.

Part 3:

1. Provide each student or group with two plastic cups: one filled with water and the other with red cabbage indicator. Cover both cups with clear plastic wrap to prevent spillage.
2. Designate a student to carefully pierce a hole in the plastic wrap over the cup with the red cabbage indicator. Using a straw, have the student blow CO_2 into the indicator solution for about one minute. Emphasize the respiration reaction and the role of CO_2.
3. After one minute, discuss as a group any changes seen in the red cabbage indicator solution. Record observations collectively.
4. Designate another student to repeat the process with the cup of water. Have them blow CO_2 into the water for the same duration (about one minute).
5. Students will complete their POE worksheets, where they will:
    a. Predict: What they think will happen to the pH of the water and the red cabbage indicator when CO_2 is added.
    b. Observe: Record their observations of the color changes in both solutions after the CO_2 is added.
    c. Explain: Provide an explanation of the results, particularly focusing on the effects of CO_2 on pH.
6. Use a pH test strip to measure the pH of the water after blowing CO_2 into it.
7. Discuss and explain any color changes observed on the test strip, connecting these changes to acidity levels.
8. Once the POE worksheets are collected or submissions are made via Canvas, hold a discussion about the results. Encourage students to share their predictions, observations, and explanations. Discuss the scientific principles behind their findings, including the relationship between CO_2, pH, and acidity.

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

Part 4:
https://oceanservice.noaa.gov/facts/acidification.html

1. Show video (1:03 minutes) showing a quick overview of Ocean acidification, its cause and effects.
2. After the video, facilitate a discussion asking students to recapitulate the following key points:
    a. When fossil fuels (coal, crude oil, natural gas) are burned, carbon dioxide is released into the atmosphere.
    b. Approximately 30% of this carbon dioxide dissolves in oceans.
    c. Millions of tons of carbon dioxide enter oceans daily.
    d. CO_2 increases ocean acidity through chemical reactions.
    e. Increased acidity harms many marine organisms.
    f. Corals struggle to build their exoskeletons.
    g. Clams, mussels, sea urchins, and some zooplankton (like pteropods) find it harder to form shells.
    h. Some fish face challenges in detecting predators and finding habitats.
    i. Ocean acidification impacts the entire world's oceans and coastal waters.
3. Before the chalk experiment, ask students if they know what chalk is. Explain that chalk is calcium carbonate ($CaCO_3$). Discuss that chalk consists of tiny fragments of $CaCO_3$ shells or skeletons of plankton. Highlight that chalk and seashells are both made of $CaCO_3$.Perform chalk in vinegar experiment.
4. Distribute chalk pieces and clear cups or containers for each group. Procedure:
    a. Place a piece of chalk in the cup.
    b. Pour vinegar over the chalk to fully submerge it.
    c. Observe the reaction as the vinegar (acetic acid) reacts with the chalk (calcium carbonate).
    d. Allow students to observe the fizzing reaction, which indicates the release of carbon dioxide gas (CO_2).
5. After the experiment, discuss what students observed. Ask questions such as:
    a. What happened when the vinegar was added to the chalk?
    b. Why do you think this reaction occurred?
    c. How does this relate to the effects of ocean acidification on marine life?

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

Accommodations: Choice of work, Use of technology to translate work.

ELLs: Key Vocabulary words in Native language, Google Translate, Teaching Assistant, pairing with ELL students who are more proficient in English.

English	Spanish	Haitian Creole
Acid	ácido, ácida	asid
Alkaline	alcalina	alkalin
Baking Soda	bicarbonato	bikabonat
Carbon Dioxide	dióxido de carbono	gaz kabonik
Chalk	tiza	lakre
Coffee	café	kafe
Lemon Juice	jugo de limon	ji sitwon
Ocean	océano	oseyan
Red Cabbage	repollo rojo	chou wouj
Shellfish	mariscos	kristase

Lesson by: Valerie Hucey
School: Whiddon Rogers Education Center
Contact info: valerie.hucey@browardschools.com

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

Chalk in Vinegar Experiment

Research Experiences FOR TEACHERS

Name: ________________________________ Date: _____________

Ask a question: What will happen to Chalk if it is placed in Vinegar?

Formulate a hypothesis: Write down a hypothesis, using an "if, then" statement: If I put chalk in vinegar, then ___________________________

____

____

EXPERIMENT (TEST YOUR HYPOTHESIS)
Use materials and follow the instructions given by your teacher.

COLLECT AND ANALYZE DATA
When chalk was placed in vinegar, ______________________________

____

____

CONCLUSION (ACCEPT OR REJECT YOUR HYPOTHESIS)

I accept/reject my hypothesis because ____________________________

____

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

Analogy: Knowing what you know about chalk in vinegar, what would likely happen to corals and shells in an acidic environment?

____

____

Answer the following question:
How does this relate to ocean acidification and impact on marine organisms?

____

____

Lesson Assessment: Students will write a Claim, Evidence, Reasoning that answers one of the following questions:

a. How does ocean acidification affect marine organisms with shells or exoskeletons?
b. Write one paragraph on ways in which you and your classmates can play a part in reducing ocean and coastal acidification.

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**

STEM Lesson Plan:

NATIONAL MAGLAB Research Experiences FOR TEACHERS

Sources:

https://oceanservice.noaa.gov/facts/acidification.html

https://www.epa.gov/ocean-acidification/your-family-can-help-limit-ocean-and-coastal-acidification#:~:text=Fight%20ocean%20acidification%20by%20reducing,yard%2C%20and%20in%20your%20community

https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

https://www.acs.org/education/outreach/activities/red-cabbage-indicator.html

https://www.nist.gov/how-do-you-measure-it/how-do-you-measure-acidity-ph-ocean#:~:text=A%20widely%20used%20instrument%20is,making%20it%20harder%20to%20break

https://www.unep.org/explore-topics/oceans-seas/why-do-oceans-and-seas-matter#:~:text=Oceans%20feed%20us%2C%20regulate%20our,to%20fisheries%20to%20international%20shipping

https://edis.ifas.ufl.edu/publication/FA227

https://www.futurelearn.com/info/courses/climate-change-the-solutions/0/steps/121535#:~:text=If%20we%20add%20limestone%20powder,a%20year%20across%20the%20oceans

https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-fl.pdf

https://www.aims.gov.au/research-topics/environmental-issues/ocean-acidification/modelling-ocean-acidification

https://ib.bioninja.com.au/standard-level/topic-4-ecology/44-climate-change/ocean-acidification.html

https://en.unesco.org/ocean-acidification

Castro, Peter, and Michael E. Huber. Marine Science: Peter Castro, Michael E. Huber. McGraw-Hill, 2016.

The National MagLab is funded by the **National Science Foundation** (DMR-1644779) and the **State of Florida**