SAVVAS

FLINN SCIENTIFIC PREVIEW

Experience Chemistry

Experience
Chemistry

Flinn is in!

Our Partner in Scientific Inquiry

Experience Chemistry is an incredible new science program that uses phenomena in three-dimensional investigations. In case you missed it, **Flinn Scientific is our EXCLUSIVE PARTNER!** Flinn is the #1 leading provider of lab equipment and resources. Every learning experience includes a Flinn lab. And 4 versions of every lab save you time. You won't have to modify or adapt a lab to help every student be successful. Flinn is in *Experience Chemistry*.

4 VERSIONS OF EVERY LAB

Open-ended • Guided • Short • Advanced

OCEAN pH LEVELS INQUIRY LABS

FLINN SCIENTIFIC

Flinn Inquiry Labs

- Explore concepts with an inquiry lab in every learning experience
- Differentiate instruction with four versions of every lab: Open-Ended, Guided, Short, and Advanced
- Customize teaching and learning on the award-winning Savvas Realize™ digital platform

Flinn Engineering Design Challenges

- Focus on defining and solving problems that can be solved through design
- Design and build models, test, and evaluate solutions to strengthen Science and Engineering Practices (SEPs)
- Analyze and interpret data, construct explanations to derive meaning

The Flinn Lab Experience

Flinn Performance Based-Assessments

- Demonstrate mastery of three-dimensional learning at the end of every Investigation
- Exhibit fluency with Science and Engineering Practices (SEPs)
- Reflect on Performance-Based Assessments in the Student Experience Notebook

Videos

- Connect to the phenomena while introducing the lab with engaging Background Videos
- Revisit lab concepts to prepare for assessments by viewing Summary Videos

Virtual Reality Simulations

- Immersive learning in 360° simulations brings chemistry to life
- Experience game-like interactions with key chemistry concepts
- Accessible interface motivates all types of learners

Lab Kits

- Simplify lab set-up and solution preparation with premade packages
- Flinn Performance Task kits save valuable time when assessing student skills
- Foster greater inquiry learning by having readily accessible lab materials

NAME ______________________ DATE __________ CLASS __________

OCEAN pH LEVELS INQUIRY LABS – BACKGROUND

The pH of Seawater

Concepts

- Ocean water pH
- Carbon dioxide uptake
- Seawater chemistry

Background

The pH of surface ocean waters is slightly basic (or alkaline), at approximately 8.1. The pH levels of ocean waters are directly linked to the equilibrium established between carbon dioxide in the atmosphere, and carbon dioxide dissolved in seawater.

Carbon dioxide has a limited solubility in water under normal atmospheric conditions, and its solubility decreases with increasing temperature and salinity (that is the content of salts or ionic species in seawater). Nonetheless, the dissolution of carbon dioxide in water generates carbonic acid, which readily dissociates into bicarbonate and hydrogen ions, as represented by Equation 1.

Equation 1: $CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

This process generates hydrogen ions, which determine the acidity levels and pH of seawaters.

Most of the inorganic carbon present in ocean waters is found in the form of HCO_3^- (89 percent), and smaller amounts correspond to aqueous CO_2 (0.5 %) and CO_3^{2-} (10.5 percent). The presence of carbonate ions in seawater is associated with the dissociation of bicarbonate, described in Equation 2.

Equation 2: $HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq)$

Oceans absorb approximately one quarter of the carbon dioxide emitted by human activities every year. However, the increased uptake of CO_2 is changing the chemistry and pH of seawater. Historical records show that, since the beginning of the industrial revolution, the pH of ocean waters has decreased by about 0.1 pH units. Given that the pH scale is logarithmic (Equation 3), this change is close to a 30 percent increase in acidity of seawater. Scientists predict that a continued rise in CO_2 emissions will drive the pH of seawater down to 7.9 by 2040, and to approximately 7.7 by 2155.

Equation 3: $pH = -\log[H^+]$

The acidification of ocean waters has detrimental consequences for marine organisms and entire ecosystems that depend on the availability of carbonate ions. For example, seashells and corals are composed of calcium carbonate, $CaCO_3$, which readily forms when calcium ions (Ca^{2+}) bind to carbonate ions. Calcium carbonate is highly insoluble in water. However, its solubility increases as seawater becomes more acidic, or less basic, as carbonate transforms into bicarbonate.

In this investigation, you will explore how the pH of levels of surface ocean waters are affected by dissolution of atmospheric carbon dioxide, and the equilibrium between bicarbonate and carbonate species in seawater.

NAME ______________________ DATE __________ CLASS __________

OCEAN pH LEVELS INQUIRY LABS – OPEN

The pH of Seawater

The surface of the ocean has an average pH of 8.1, that is approximately 0.1 units lower than before the industrial revolution started. The decrease in pH of seawater is directly related to the increase in carbon dioxide emissions to the atmosphere, mostly from human activities involving the burning of fossil fuels. In this laboratory, you will investigate the equilibrium between water, carbon dioxide, bicarbonate, and carbonate species, and its role in determining the pH levels of ocean water.

Focus on Science Practices

SEP 2 Developing and Using Models
SEP 4 Analyzing and Interpreting Data
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Acetic acid solution, CH_3COOH, 2 M, 40 mL
- Sodium bicarbonate, $NaHCO_3$, 3.5 g
- Sodium carbonate, Na_2CO_3, 0.5 g
- Sodium chloride, NaCl, 15 g
- Phenolphthalein indicator, 1% solution, 0.5 mL
- Universal indicator solution, 0.5 mL
- Water, distilled or deionized
- Beakers, 400 mL and 250 mL
- Clamp
- Beral-type pipet, 2
- Heat-resistant gloves
- Hot plate
- Erlenmeyer flask for filtering, 250 mL
- Graduated cylinder, 50 mL and 100 mL
- pH meter
- pH test strips (optional)
- Plastic tubing, 2–3 feet long
- Ring stand
- Rubber stopper (for use with Erlenmeyer flask)
- Spatula
- Temperature sensor or thermometer
- Weighing dishes, 3

Safety

Sodium bicarbonate is slightly toxic by ingestion. Sodium carbonate is toxic by ingestion, and can cause skin and eye irritation. Acetic acid solution is toxic by ingestion

NAME ______________________________ DATE __________ CLASS __________

and inhalation, and is corrosive to skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron when handling these chemicals. Avoid exposure to eyes and skin, and clean up all spills promptly. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part 1. The Solubility of CO_2 in Water

1. Prepare 400 mL of a 0.5 M sodium chloride solution that will resemble seawater by dissolving the appropriate amount of NaCl in deionized/distilled water. Record your detailed calculations.

2. Transfer a known volume of the seawater solution prepared in Step 1 to a beaker. Measure and record the pH of the solution in the data table.

3. Boil the solution in the beaker. Once it boils for a few minutes, allow the solution to cool down to room temperature. Use heat-resistant gloves to grab the hot beaker. Use a thermometer/temperature sensor to make sure the water is back to room temperature.

4. Measure the pH of the seawater solution at room temperature. Record this pH value.

5. Add a few drops of universal indicator to the seawater solution. Record your observations in the data table.

6. Choose a volume of 2 M acetic acid solution and a mass of sodium bicarbonate to mix in the Erlenmeyer flask to generate carbon dioxide gas. Measure and record the amounts of each reagent to be used in the space.

7. Attach the plastic tubing to the short glass tube on the Erlenmeyer flask. At first, it may be helpful to heat up one end of the plastic tubing by placing it in hot water to stretch it out a little. This should facilitate sliding it onto the glass tube on the Erlenmeyer flask.

8. Bubble carbon dioxide into the seawater solution in the beaker.

9. Monitor the pH and color of the seawater solution. Continue to measure the pH of the seawater solution until it becomes stable. Record this pH value as the final pH of the solution. Record any other observations in the data table.

10. Rinse the pH meter with distilled/deionized water, and store it as indicated by your instructor.

11. Dispose of solutions and any other chemical waste as indicated by your instructor. Rinse it with distilled/deionized water.

Part 2. The Effect of CO_2 on the pH of Seawater Solution

12. Real seawater has a pH around 8.1. Using the materials and reagents available, develop a procedure in which you investigate the effect of dissolving carbon dioxide in seawater, using a sample of seawater that has a pH close to 8.1. Record the measured pH values and your observations in the data table. Write your procedure.

NAME ______________________ DATE __________ CLASS __________

Data Table—Part 1		
Parameter		**Observations (color, appearance, etc.)**
pH before boiling		
pH after boiling		
[H^+] after boiling (moles/liter)		
pH after treatment with CO_2		

Data Table—Part 2		
Parameter		Observations (color, appearance, etc.)
pH before treatment with CO_2		
$[H^+]$ before treatment with CO_2 (moles/liter)		

Analyze and Interpret Data

Part 1. The Effect of CO_2 on the pH of Water

1. **SEP Analyze Data** Compare the pH of the seawater solution before and after boiling the solution. How can you explain the differences in the pH before and after boiling the solution?

2. **SEP Use Models** Write a balanced chemical equation to represent the reaction(s) that takes place in the Erlenmeyer flask.

3. **SEP Use Models** The dissolution of carbon dioxide in water produces carbonic acid (H_2CO_3) at first, which then dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+). Write a balanced equation for this reaction (as an equilibrium).

4. **SEP Use Math** Using the equation that defines pH, calculate the concentration of hydrogen ions ($[H^+]$, in moles/liter) before and after treating the seawater solution with carbon dioxide.

5. **SEP Use Math** Based on the results of your calculations in question 4, determine the percent change in acidity, that is the percent change in $[H^+]$, for the seawater solution upon treatment with carbon dioxide.

6. **SEP Construct an Explanation** Explain what happens to the seawater solution when the gas generated in the Erlenmeyer flask bubbles into it. How does the pH and the color of the solution change, and why?

Part 2. The Effect of CO_2 on the pH of Seawater Solution

7. **SEP Construct an Explanation** Based on your results for Part 2, are the changes in pH and color of the seawater solution in agreement with the explanation you constructed for question 6? Explain.

8. **SEP Use Math** Using the equation that defines pH, calculate the concentration of hydrogen ions ($[H^+]$ in moles/liter) before and after treating the seawater

solution with carbon dioxide.

9. **SEP Use Math** Based on the results of your calculations in question 8, determine the percent change in acidity, that is the percent change in $[H^+]$, for the seawater solution upon treatment with carbon dioxide.

10. **SEP Engage in Argument** Compare your results from Parts 1 and 2, and develop an argument about the possible relationship between initial pH, content of carbonate/bicarbonate ions, and the capacity of the seawater solutions to absorb carbon dioxide.

11. **SEP Engage in Argument** Surface ocean water has a pH of approximately 8.1, and it contains dissolved carbon dioxide in equilibrium with water, bicarbonate ions (HCO_3^-), and, to a lesser extent, carbonate ions (CO_3^{2-}). Based on your results from this investigation, how would an increase in atmospheric carbon dioxide influence the pH and acidity of seawater and why?

NAME ____________________ DATE __________ CLASS __________

OCEAN pH LEVELS INQUIRY LABS – GUIDED

The pH of Seawater

The surface of the ocean has an average pH of 8.1, that is approximately 0.1 units lower than before the industrial revolution started. The decrease in pH of seawater is directly related to the increase in carbon dioxide emissions to the atmosphere, mostly from human activities involving the burning of fossil fuels. In this laboratory, you will investigate the equilibrium between water, carbon dioxide, bicarbonate, and carbonate species, and its role in determining the pH levels of ocean water.

Focus on Science Practices

SEP 2 Developing and Using Models
SEP 4 Analyzing and Interpreting Data
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Acetic acid solution, CH_3COOH, 2 M, 40 mL
- Sodium bicarbonate, $NaHCO_3$, 3.5 g
- Sodium carbonate, Na_2CO_3, 0.5 g
- Sodium chloride, NaCl, 15 g
- Phenolphthalein indicator, 1% solution, 0.5 mL
- Universal indicator solution, 0.5 mL
- Water, distilled or deionized
- Beakers, 400 mL and 250 mL
- Clamp
- Beral-type pipet, 2
- Heat-resistant gloves
- Hot plate
- Erlenmeyer flask for filtering, 250 mL
- Graduated cylinder, 50 mL and 100 mL
- pH meter
- pH test strips (optional)
- Plastic tubing, 2–3 feet long
- Ring stand
- Rubber stopper (for use with Erlenmeyer flask)
- Spatula
- Temperature sensor or thermometer
- Weighing dishes, 3

Safety 

Sodium bicarbonate is slightly toxic by ingestion. Sodium carbonate is toxic by ingestion, and can cause skin and eye irritation. Acetic acid solution is toxic by ingestion

ıhalation, and is corrosive to skin and eyes. Wear chemical splash goggles, ical-resistant gloves, and a chemical-resistant apron when handling these icals. Avoid exposure to eyes and skin, and clean up all spills promptly. Wash s thoroughly with soap and water before leaving the laboratory.

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1. The Solubility of CO_2 in Water

Prepare 400 mL of a 0.5 M sodium chloride solution that will resemble seawater, by dissolving the appropriate amount of NaCl in deionized or distilled water. Record your detailed calculations.

Use a graduated cylinder to measure and transfer 100 mL of the seawater solution prepared in Step 1 into a beaker. Measure and record the pH of the solution in the data table.

Place the beaker on top of a hot plate and bring the solution to a boil. Once it boils for a few minutes, allow the solution to cool down to room temperature. Use heat-resistant gloves to grab the hot beaker. Use a thermometer or temperature sensor to make sure the water is back to room temperature.

Place a pH meter in the seawater solution, and measure its pH at room temperature. Record this pH value in the data table.

Add a few drops of universal indicator to the seawater solution.

6. Attach the plastic tubing to the short glass tube on the Erlenmeyer flask. At first, it may be helpful to heat up one end of the plastic tubing by placing it in hot water to stretch it out a little. This should facilitate sliding it onto the glass tube on the Erlenmeyer flask.

7. Measure 20 mL of 2 M acetic acid solution using a graduated cylinder, and transfer into the Erlenmeyer flask.

8. Measure approximately 3.0 g of sodium bicarbonate in a weighing dish or paper.

9. Dip the loose end of the plastic tubing into the beaker containing the seawater solution with the universal indicator. Secure the flask containing the seawater solution by placing it into a larger beaker/flask. Secure the Erlenmeyer flask containing the acetic acid solution using a clamp firmly attached to a ring stand.

10. Transfer the sodium bicarbonate solid into the Erlenmeyer flask containing the acetic acid solution, and quickly put on the rubber stopper to close the flask.

11. Loosen the Erlenmeyer flask from the clamp, and begin to stir the contents gently. Gaseous carbon dioxide will be produced in the flask, and it will flow into the seawater solution in the beaker through the plastic tubing.

12. Monitor the pH and color of the seawater solution. Write your observations in the data table.

13. Continue to measure the pH of the seawater solution until it becomes stable. Record this pH value as the final pH of the solution.

14. Remove the pH meter from the seawater solution, rinse it with distilled or deionized water, and store it as indicated by your instructor.

15. Dispose of the contents of the Erlenmeyer flask and the seawater solution as indicated by your instructor. Rinse it with distilled or deionized water.

Part 2. The Effect of CO_2 on the pH of Seawater Solution

16. Use a graduated cylinder to measure and transfer 100 mL of the seawater solution prepared in Step 1 into a clean beaker. Place a pH meter in the solution and measure its pH.

17. Use a spatula to add a very small amount of sodium carbonate (Na_2CO_3) to the solution to adjust its pH to make it as close as possible to 8.0. Use the tip of the

spatula to add the sodium carbonate. If the pH goes beyond 9, add small amounts of sodium bicarbonate to lower the pH to about 8.

18. Add a few drops of phenolphthalein indicator to the solution, and record your observations in the data table.

19. Repeat Steps 7-13 from Part 1, to measure the effect of dissolving carbon dioxide on the pH of this solution. Wait until the pH of the solution becomes stable to record it. Record the pH and your observations in the data table.

20. Remove the pH meter from the seawater solution, clean it, and store it as indicated by your instructor.

21. Dispose of the contents of the Erlenmeyer flask and the seawater solution as indicated by your instructor.

NAME ______________________ DATE __________ CLASS __________

Data Table—Part 1		
Parameter		**Observations (color, appearance, etc.)**
pH before boiling		
pH after boiling		
$[H^+]$ after boiling (moles/liter)		
pH after treatment with CO_2		
$[H^+]$ after treatment with CO_2 (moles/liter)		
Acidity percent change (%)		

NAME ______________________ DATE __________ CLASS __________

Data Table—Part 2		
Parameter		**Observations (color, appearance, etc.)**
pH before treatment with CO_2		
$[H^+]$ before treatment with CO_2 (moles/liter)		
pH after treatment with CO_2		
$[H^+]$ after treatment with CO_2 (moles/liter)		
Acidity percent change (%)		

Analyze and Interpret Data

Part 1. The Solubility of CO_2 in Water

1. **SEP Analyze Data** Compare the pH of the seawater solution before and after boiling the solution. How can you explain the differences in the pH before and after boiling the solution?

2. **SEP Use Models** Write a balanced chemical equation to represent the reaction(s) that takes place in the Erlenmeyer flask.

3. **SEP Use Models** The dissolution of carbon dioxide in water produces carbonic acid (H_2CO_3) at first, which then dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+). Write a balanced equation for this reaction (as an equilibrium).

4. **SEP Use Math** Using the equation that defines pH, calculate the concentration of hydrogen ions ($[H^+]$, in moles/liter) before and after treating the seawater solution with carbon dioxide.

5. **SEP Use Math** Based on the results of your calculations in question 4, determine the percent change in acidity, that is the percent change in $[H^+]$, for the seawater solution upon treatment with carbon dioxide.

6. **SEP Construct an Explanation** Explain what happens to the seawater solution when the gas generated in the Erlenmeyer flask bubbles into it. How does the pH and the color of the solution change, and why?

Part 2. The Effect of CO_2 on the pH of Seawater Solution

7. **SEP Construct an Explanation** Based on your results for Part 2, are the changes in pH and color of the seawater solution in agreement with the explanation you constructed for question 6? Explain.

8. **SEP Use Math** Using the equation that defines pH, calculate the concentration of hydrogen ions ($[H^+]$, in moles/liter) before and after treating the seawater solution with carbon dioxide.

9. **SEP Use Math** Based on the results of your calculations in question 8, determine the percent change in acidity, that is the percent change in $[H^+]$, for the seawater solution upon treatment with carbon dioxide.

10. SEP Engage in Argument Compare your results from Parts 1 and 2, and develop an argument about the possible relationship between initial pH, content of carbonate/bicarbonate ions, and the capacity of the seawater solutions to absorb carbon dioxide.

11. SEP Engage in Argument Surface ocean water has a pH of approximately 8.1, and it contains dissolved carbon dioxide in equilibrium with water, bicarbonate ions (HCO_3^-), and, to a lesser extent, carbonate ions (CO_3^{2-}). Based on your results from this investigation, how would an increase in atmospheric carbon dioxide influence the pH and acidity of seawater and why?

NAME ______________________________ DATE __________ CLASS __________

OCEAN pH LEVELS INQUIRY LABS – SHORT

The pH of Seawater

The surface of the ocean has an average pH of 8.1, that is approximately 0.1 units lower than before the industrial revolution started. The decrease in pH of seawater is directly related to the increase in carbon dioxide emissions to the atmosphere, mostly from human activities involving the burning of fossil fuels. In this laboratory, you will investigate the equilibrium between water, carbon dioxide, bicarbonate, and carbonate species, and its role in determining the pH levels of ocean water.

Focus on Science Practices

SEP 2 Developing and Using Models
SEP 4 Analyzing and Interpreting Data
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Acetic acid solution, CH_3COOH, 2 M, 30 mL
- Sodium bicarbonate, $NaHCO_3$, 3.5 g
- Sodium carbonate, Na_2CO_3, 0.5 g
- Sodium chloride, NaCl, 6 g
- Phenolphthalein indicator, 1% solution, 0.5 mL
- Water, distilled or deionized
- Beakers, 400 mL and 250 mL
- Beral-type pipet
- Clamp
- Heat-resistant gloves
- Hot plate
- Erlenmeyer flask for filtering, 250 mL
- Graduated cylinder, 50 mL and 100 mL
- pH meter
- pH test strips (optional)
- Plastic tubing, 2–3 feet long
- Ring stand
- Rubber stopper (for use with Erlenmeyer flask)
- Spatula
- Weighing dishes, 3

Safety

Sodium bicarbonate is slightly toxic by ingestion. Sodium carbonate is toxic by ingestion, and can cause skin and eye irritation. Acetic acid solution is toxic by ingestion and inhalation, and is corrosive to skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron when handling these *chemicals. Avoid exposure to eyes and skin, and clean up all spills promptly. Wash hands thoroughly with soap and water before leaving the laboratory.*

Procedure

1. Prepare 100 mL of a 0.5 M sodium chloride solution that will resemble seawater, by dissolving the appropriate amount of NaCl in deionized/distilled water. Record your detailed calculations.

2. Use a graduated cylinder to measure and transfer 100 mL of the seawater solution prepared in Step 1 into a clean beaker. Place a pH meter in the solution and measure its pH.

3. Use the spatula to add a very small amount of sodium carbonate (Na_2CO_3) to the solution to adjust its pH to make it as close as possible to 8.0. Use the tip of the spatula to add the sodium carbonate. If the pH goes beyond 9, add small amounts of sodium bicarbonate to lower the pH to about 8.

4. Add a few drops of phenolphthalein indicator to the solution, and record your observations in the data table.

5. Attach the plastic tubing to the short glass tube on the Erlenmeyer flask. At first, it may be helpful to heat up one end of the plastic tubing by placing it in hot water to stretch it out a little. This should facilitate sliding it onto the glass tube on the Erlenmeyer flask.

6. Measure 20 mL of 2 M acetic acid solution using a graduated cylinder, and transfer into the Erlenmeyer flask.

7. Measure approximately 3.0 g of sodium bicarbonate in a weighing dish or paper.

8. Dip the loose end of the plastic tubing into the beaker containing the seawater solution with the universal indicator. Secure the flask containing the seawater solution by placing it into a larger beaker/flask. Secure the Erlenmeyer flask containing the acetic acid solution using a clamp firmly attached to a ring stand.

9. Transfer the sodium bicarbonate solid into the Erlenmeyer flask containing the acetic acid solution, and quickly put on the rubber stopper to close the flask.

10. Loosen the Erlenmeyer flask from the clamp, and begin to stir the contents gently. Gaseous carbon dioxide will be produced in the flask, and it will flow into the seawater solution in the beaker through the plastic tubing.

11. Monitor the pH and color of the seawater solution. Write your observations in the data table.

12. Continue to measure the pH of the seawater solution until it becomes stable. Record this pH value as the final pH of the solution.

13. Remove the pH meter from the seawater solution, rinse it with distilled/deionized water, and store it as indicated by your instructor.

14. Dispose of the contents of the Erlenmeyer flask and the seawater solution as indicated by your instructor.

Data Table—The pH of Seawater	
Parameter	**Observations (color, appearance, etc.)**

pH before treatment with CO_2		
$[H^+]$ before treatment with CO_2 (moles/liter)		
pH after treatment with CO_2		
$[H^+]$ after treatment with CO_2 (moles/liter)		
Acidity percent change (%)		

Analyze and Interpret Data

1. **SEP Use Models** Write a balanced chemical equation to represent the reaction(s) that takes place in the Erlenmeyer flask.

2. **SEP Use Models** The dissolution of carbon dioxide in water produces carbonic acid (H_2CO_3) at first, which then dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+). Write a balanced equation for this reaction (as an equilibrium).

3. **SEP Use Math** Using the equation that defines pH, calculate the concentration of hydrogen ions ($[H^+]$ in moles/liter) before and after treating the seawater solution with carbon dioxide.

4. **SEP Use Math** Based on the results of your calculations in question 3, determine the percent change in acidity, that is the percent change in $[H^+]$, for the seawater solution upon treatment with carbon dioxide.

5. **SEP Construct an Explanation** Explain what happens to the seawater solution when the gas generated in the Erlenmeyer flask bubbles into it. How does the pH and the color of the solution change, and why?

6. **SEP Engage in Argument** Surface ocean water has a pH of approximately 8.1,

and it contains dissolved carbon dioxide in equilibrium with water, bicarbonate ions (HCO_3^-), and, to a lesser extent, carbonate ions (CO_3^{2-}). Based on your results from this investigation, how would an increase in atmospheric carbon dioxide influence the pH and acidity of seawater and why?

NAME ______________________ DATE __________ CLASS __________

The pH of Seawater

The surface of the ocean has an average pH of 8.1, that is approximately 0.1 units lower than before the industrial revolution started. The decrease in pH of seawater is directly related to the increase in carbon dioxide emissions to the atmosphere, mostly from human activities involving the burning of fossil fuels. In this laboratory, you will investigate the equilibrium between water, carbon dioxide, bicarbonate, and carbonate species, and its role in determining the pH levels of ocean water.

Focus on Science Practices

SEP 2 Developing and Using Models
SEP 4 Analyzing and Interpreting Data
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Acetic acid solution, CH_3COOH, 2 M, 40 mL
- Sodium bicarbonate, $NaHCO_3$, 3.5 g
- Sodium carbonate, Na_2CO_3, 0.5 g
- Sodium chloride, NaCl, 15 g
- Phenolphthalein indicator, 1% solution, 0.5 mL
- Universal indicator solution, 0.5 mL
- Water, distilled or deionized
- Beakers, 400 mL and 250 mL
- Clamp
- Beral-type pipet, 2
- Heat-resistant gloves
- Hot plate
- Erlenmeyer flask for filtering, 250 mL
- Graduated cylinder, 50 mL and 100 mL
- pH meter
- pH test strips (optional)
- Plastic tubing, 2–3 feet long
- Ring stand
- Rubber stopper (for use with Erlenmeyer flask)
- Spatula
- Temperature sensor or thermometer
- Weighing dishes, 3

Safety 

Sodium bicarbonate is slightly toxic by ingestion. Sodium carbonate is toxic by ingestion, and can cause skin and eye irritation. Acetic acid solution is toxic by ingestion

and inhalation, and is corrosive to skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron when handling these chemicals. Avoid exposure to eyes and skin, and clean up all spills promptly. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part 1. The Solubility of CO_2 in Water

1. Prepare 400 mL of a 0.5 M sodium chloride solution that will resemble seawater by dissolving the appropriate amount of NaCl in deionized/distilled water. Record your detailed calculations.

2. Transfer 100 mL of the seawater solution prepared in Step 1 into a beaker. Measure and record the pH of the solution in the data table.

3. Boil the solution in the beaker on a hot plate. Once it boils for a few minutes, allow the solution to cool down to room temperature. Use heat-resistant gloves to grab the hot beaker. Use a thermometer/temperature sensor to make sure the water is back to room temperature.

4. Place a pH meter in the seawater solution, and measure its pH at room temperature. Record this pH value in the data table.

5. Add a few drops of universal indicator to the seawater solution.

6. Attach the plastic tubing to the short glass tube on the Erlenmeyer flask. At first, it may be helpful to heat up one end of the plastic tubing by placing it in hot water to stretch it out a little. This should facilitate sliding it onto the glass tube on the Erlenmeyer flask.

7. Measure 20 mL of the 2 M acetic acid solution, and transfer into the Erlenmeyer flask.

8. Measure approximately 3.0 g of sodium bicarbonate in a weighing dish/paper.

9. Dip the loose end of the plastic tubing into the seawater solution.

10. Transfer the sodium bicarbonate into the Erlenmeyer flask containing the acetic acid solution and quickly put on the stopper to close the flask.

11. Gently stir the contents of the Erlenmeyer flask. Gaseous carbon dioxide will be produced in the flask, and it will flow into the seawater solution in the beaker.

12. Monitor the pH and color of the seawater solution. Write your observations in the data table.

13. Continue to measure the pH of the seawater solution until it becomes stable. Record this pH value as the final pH of the solution.

14. Remove the pH meter from the seawater solution, rinse it with distilled/deionized water, and store it as indicated by your instructor.

15. Dispose of the contents of the Erlenmeyer flask and the seawater solution as indicated by your instructor. Rinse it with distilled/deionized water.

NAME ______________________ DATE __________ CLASS __________

Part 2. The Effect of CO_2 on the pH of Seawater Solution

16.  Real seawater has a pH around 8.1. Using the materials and reagents available, develop a procedure in which you investigate the effect of dissolving carbon dioxide in seawater, using a sample of seawater that has a pH close to 8.1. Record the measured pH values and your observations in the data table. Write your procedure.

17. Remove the pH meter from the seawater solution, clean it, and store it as indicated by your instructor.

18. Dispose of the contents of the Erlenmeyer flask and the seawater solution as indicated by your instructor.

NAME ______________________ DATE ____________ CLASS ____________

Data Table—Part 1		
Parameter		**Observations (color, appearance, etc.)**
pH before boiling		
pH after boiling		
[H^+] after boiling (moles/liter)		
pH after treatment with CO_2		
[H^+] after treatment with CO_2 (moles/liter)		
Acidity percent change (%)		

NAME ______________________________ DATE ____________ CLASS ____________

Data Table—Part 2		
Parameter		**Observations (color, appearance, etc.)**
pH before treatment with CO_2		
$[H^+]$ before treatment with CO_2 (moles/liter)		
pH after treatment with CO_2		
$[H^+]$ after treatment with CO_2 (moles/liter)		
Acidity percent change (%)		

Analyze and Interpret Data

Part 1. The Solubility of CO_2 in Water

1. **SEP Analyze Data** Compare the pH of the seawater solution before and after boiling the solution. How can you explain the differences in the pH before and after boiling the solution?

2. **SEP Use Models** Write a balanced chemical equation to represent the reaction(s) that takes place in the Erlenmeyer flask.

3. **SEP Use Models** The dissolution of carbon dioxide in water produces carbonic acid (H_2CO_3) at first, which then dissociates into bicarbonate (HCO_3^-) and hydrogen ions (H^+). Write a balanced equation for this reaction (as an equilibrium).

4. **SEP Use Math** Using the equation that defines pH, calculate the concentration of hydrogen ions ($[H^+]$, in moles/liter) before and after treating the seawater solution with carbon dioxide.

5. **SEP Use Math** Based on the results of your calculations in question 4, determine the percent change in acidity, that is the percent change in $[H^+]$, for the seawater solution upon treatment with carbon dioxide.

6. **SEP Construct an Explanation** Explain what happens to the seawater solution when the gas generated in the Erlenmeyer flask bubbles into it. How does the pH and the color of the solution change, and why?

Part 2. The Effect of CO_2 on the pH of Seawater Solution

7. **SEP Construct an Explanation** Based on your results for Part 2, are the changes in pH and color of the seawater solution in agreement with the explanation you constructed for question 6? Explain.

8. **SEP Use Math** Using the equation that defines pH, calculate the concentration of hydrogen ions ([H^+] in moles/liter) before and after treating the seawater solution with carbon dioxide.

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9. SEP Use Math Based on the results of your calculations in question 8, determine the percent change in acidity, that is the percent change in [H^+], for the seawater solution upon treatment with carbon dioxide.

10. SEP Engage in Argument Compare your results from Parts 1 and 2, and develop an argument about the possible relationship between initial pH, content of carbonate/bicarbonate ions, and the capacity of the seawater solutions to absorb carbon dioxide.

11. SEP Engage in Argument Surface ocean water has a pH of approximately 8.1, and it contains dissolved carbon dioxide in equilibrium with water, bicarbonate ions (HCO_3^-), and, to a lesser extent, carbonate ions (CO_3^{2-}). Based on your results from this investigation, how would an increase in atmospheric carbon dioxide influence the pH and acidity of seawater, and why?

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ENGINEERING DESIGN CHALLENGE

Design a Model of Ocean Acidification

Your school science club has been tasked with making topics in the news more relatable to the general public. One of these topics is climate change. In particular, your science club has to come up with a straightforward way to demonstrate two ideas related to ocean acidification: the cycling of carbon between Earth's ocean and the atmosphere, as well as the effects of ocean acidification on coral reef formation.

Focus on Engineering Practices

SEP 1 Defining the Problem
SEP 3 Planning and Carrying Out Investigations
SEP 6 Designing Solutions

Materials Per Group

- Bromcresol green indicator solution, 0.04% aqueous
- Calcium hydroxide solution, saturated $Ca(OH)_2$, 400 mL
- Drinking straws
- Hot plate
- Ice bath
- Seltzer water

Safety

Calcium hydroxide is a skin irritant. Avoid dust inhalation. The solution is a weak base. Avoid ingestion of the limewater solution. Wear safety goggles and gloves while carrying out your investigation. Alert your teacher if you break a glass object. At the end of the lab, wash your hands thoroughly with soap and warm water.

Develop a Solution

1. **SEP Define the Problem** In your own words, briefly define the problem.

2. **SEP Identify Criteria and Constraints** List criteria and constraints you have identified or that your teacher has provided.

Criteria	Constraints

3. **Conduct Research** Go online and research the equilibrium equations that exist in ocean water and relate to its acidification. Record these equations in the space that follows and discuss the relationship between the amount of dissolved CO_2 in the oceans and pH. Also, discuss the relationship between the amount of dissolved CO_2 in the oceans and coral reef persistence, or the solubility of $CaCO_3$. Are the relationships direct or indirect? Explain in terms of LeChatelier's principle.

4. **SEP Design a Solution** Using only the materials listed in the constraints section, design models of chemical systems that demonstrate the indirect relationship between dissolved CO_2 and pH, and the direct relationship between dissolved CO_2 and $CaCO_3$ solubility. In the space, describe the two chemical systems you will use to demonstrate these relationships and thereby model the effects of increased global CO_2 production.

5. **SEP Test Your Solution** Describe how your group will evaluate the efficacy of your models.

6. **SEP Evaluate Your Solution** Review your group's criteria and constraints. Based on your observations, do you consider your models suitable for communicating the effects of CO_2 production on Earth's oceans to the public? Why or why not?

7. **SEP Refine Your Solution** How might you improve your models to better demonstrate the relationships between CO_2 absorption and pH, and $CaCO_3$ solubility?

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PERFORMANCE BASED ASSESSMENT

Calcium Carbonate and Shell Production

How does carbon dioxide absorption impact the health of the ocean? The ocean has a natural buffering system that absorbs the carbon dioxide. As more and more carbon dioxide is produced the ocean will reach its limit and the buffering capability will decline, leading to a more acidic environment. Rising carbon dioxide levels in the atmosphere are directly harming the ocean ecosystems through ocean acidification, which is interfering with many organisms' ability to form shells. When atmospheric carbon dioxide dissolves in the ocean, it produces carbonic acid. This lab will focus on different concentrations of acid and how that plays a role in shell formation.

Focus on Science Practices

SEP 4 Analyzing and Interpreting Data
SEP 6 Constructing Explanations and Designing Solutions

Materials Per Group

- Calcium carbonate (marble chips) $CaCO_3$, 0.9 g
- Hydrochloric acid solution, 6 M, 5 mL
- Hydrochloric acid solution, 4 M, 5 mL
- Hydrochloric acid solution, 2 M, 5 mL
- Petroleum jelly, foilpac, 1
- Balance, 0.001 g precision
- Clamp, single, buret
- Erlenmeyer flasks, 125 mL, 3
- Gas collection apparatus
  - Syringe, 60 mL
  - Syringe adapter
  - Stopper, one-hole (to fit flask)
- Support stand
- Timer or stopwatch
- Wash bottle

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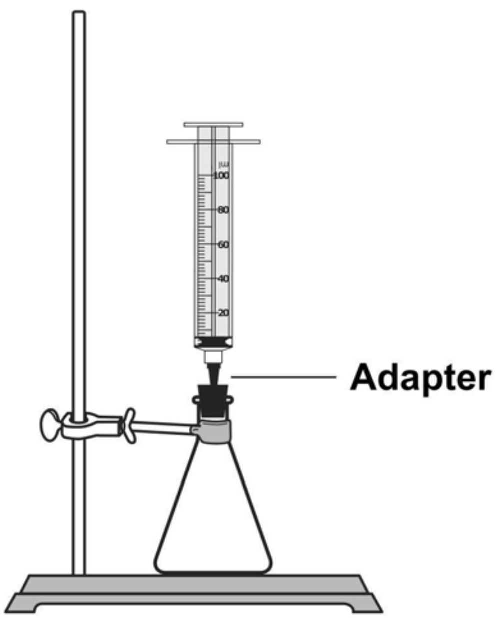
Safety

Hydrochloric acid is corrosive to skin and eyes and toxic by inhalation or skin absorption. Avoid contact with eyes and skin and clean up all spills immediately. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. For the gas collection experiment, do not use more than 0.3 g of calcium carbonate. The concentration of hydrochloric acid must not exceed 6 M in any experiment.
Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines.

Procedure

1. Set up the gas-collection apparatus as shown in Figure 1. Make sure the rubber stopper fits securely in the flask. Lubricate the plunger of the syringe with silicone grease or petroleum jelly to reduce friction. Apply a small dab of grease to the black rubber gasket only.

Figure 1



2. **SEP Plan an Investigation** Using the materials provided, develop a method to test the effects of different concentrations of hydrochloric acid on calcium carbonate. Describe your testing method and procedure in the space. Show your method to your teacher before conducting the investigation.

   a. Each test will require 0.3 g of calcium carbonate and 5 mL of hydrochloric acid.

   b. The stopper and syringe assembly must be immediately placed back on the flask to prevent any loss of gas.

   c. Data collection should occur for 10 minutes.

3. Record all data in the blank table provided and graph your results.

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Calcium Carbonate and HCl			
Time	*y*-axis measurement:________________________		
	Concentration of HCl		
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

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Analyze and Interpret Data

1. **CCC Identify Patterns** How did the change in concentration of hydrochloric acid affect the gas produced by the calcium carbonate?

2. **SEP Interpret Data** What gas is being produced in the reaction? How does the addition of this gas to the ocean buffering system affect its equilibrium?

3. **SEP Construct an Explanation** How does an increase in the acidity of the ocean affect calcifying organisms and their efforts to produce shells?

4. **SEP Apply Scientific Reasoning** How could the amount of available calcium carbonate affect the ocean food web? How could that, in turn, affect humans?

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