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OCEAN pH LEVELS INQUIRY LABS – ADVANCED

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.

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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.

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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.

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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 (%)		

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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?