Experiment GB-5: Acid Rain

Equipment Required

PC or Mac Computer

IXTA, USB cable, power supply

ISE-100 combination pH electrode

Magnetic stirrer and stir bar

Ringstand

Utility clamp

100 ml beakers (4)

500 ml beaker

Test tubes, 20 x 150 mm (3)

Test tube rack

Beral pipettes, long (3)

Pasteur pipette and pipette bulb

Culture tubes, 10 x 75 mm (3)

pH 4 and pH 7 buffer solutions

1.0N HCl solution

Sodium Bicarbonate ($NaHCO_3$), solid

Sodium Nitrite ($NaNO_2$), solid

Sodium Bisulfite ($NaHSO_3$), solid

Parafilm or plastic wrap

Spatula

pH Electrode Setup

1. Locate the ISE-100 pH electrode and plug the DIN8 connector of the ISE-100 pH electrode into the Channel A5.

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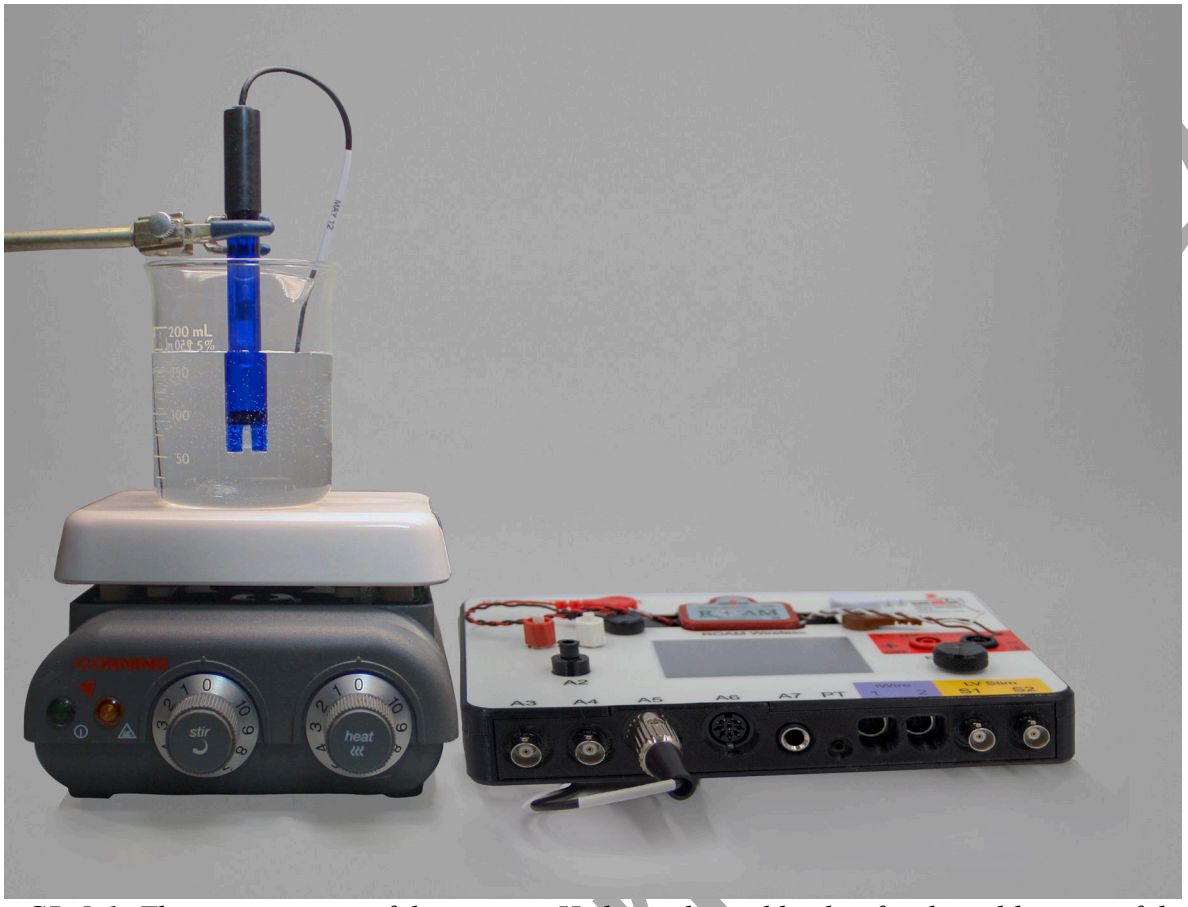

Figure GB-5-1: The arrangement of the stirrer, pH electrode, and beaker for the calibration of the pH probe.

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Calibration of the pH Electrode

1. If the ISE-100 pH electrode is still stored in its bottle of buffer, remove the electrode from the bottle. Rinse the electrode with deionized water while holding the electrode over a 1000 ml beaker used for the collection of waste liquids.
2. Place the tip of the ISE-100 pH electrode in a 100 ml beaker containing enough room temperature deionized water to submerge the tip. Keep the electrode in deionized water for at least ten minutes.
3. Prepare two 100 ml beakers, each filled with 50 ml of the pH buffers used for calibrating the pH electrode. The buffers should be at room temperature. Fill one beaker with pH 7 buffer and the other with pH 4 buffer. Each beaker should be filled with enough buffer to cover the tip of the pH electrode, and also allow the stir bar in the beaker to spin without touching the electrode.
4. Place the beaker containing the pH 7 buffer on the magnetic stirrer. Carefully place a stir bar in the beaker. Remove the electrode from the deionized water and blot any extra drops of water. Position the tip of the electrode in the beaker of pH 7 buffer so that the tip is away from the stir bar. Adjust the speed of the stirrer so the stir bar is rotating evenly at a slow speed.

5. Click Record. After a few seconds, the trace will reach a stable baseline toward the top of the recording channel. Type the words **pH 7** in the Mark box and click the mark button to mark the stable baseline of the recording. Continue recording while changing the beakers of buffers.
6. Turn off the stirrer and remove the ISE-100 pH electrode from the beaker of pH 7 buffer. Hold the electrode over the beaker used for collecting waste liquid and rinse it with deionized water. Blot any extra drops of water.
7. Place the beaker of pH 4 buffer on the stirrer. Carefully place a stir bar in the beaker. Position the tip of the electrode in the beaker of pH 4 buffer so that it is away from the stir bar. Adjust the speed of the stirrer so the stir bar is rotating evenly at a slow speed.
8. As you continue to record, the trace will reach a stable baseline toward the bottom of the recording channel. Type the words **pH 4** in the Mark box and click the mark button to mark the stable baseline of the recording.
9. Click Stop to halt the recording.
10. Select Save As in the File menu, type a name for the file. Click on the Save button to save the data file.
11. Turn off the stirrer. Remove the electrode from the beaker of pH 4 buffer. Hold the electrode over the beaker used for collecting waste liquid, and rinse it with deionized water from a wash bottle. Blot any extra drops of water and place the electrode in a beaker of deionized water.

Units Conversion

1. Scroll to the beginning of the calibration data for the ISE-100 pH electrode.
2. Use the Display Time icons to adjust the Display Time of the Main window to show the data collected at pH 7 and pH 4 on the Main window at the same time.
3. Click the 2-Cursor icon so that two cursors appear on the Main window. Place one cursor on the flat section of data collected when the ISE-100 pH electrode was in the pH 7 buffer and the second cursor on the flat section of data collected when the electrode was in the pH 4 buffer.
4. To convert the voltages at the positions of the cursors to pH values, use the Simple Units Conversion dialogue window. Click V2-V1 on the pH channel, then select Units, and select Simple.

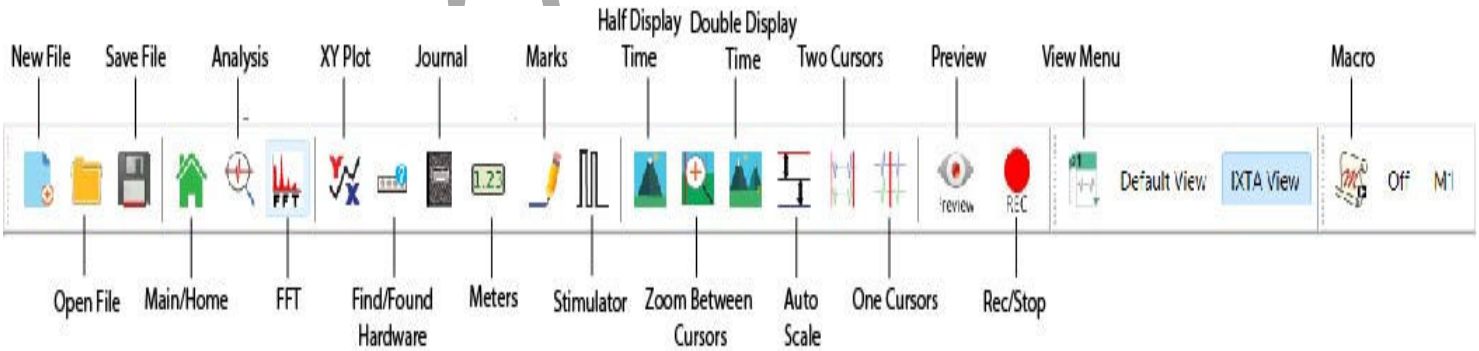

Figure GB-5-S2: The LabScribe toolbar.

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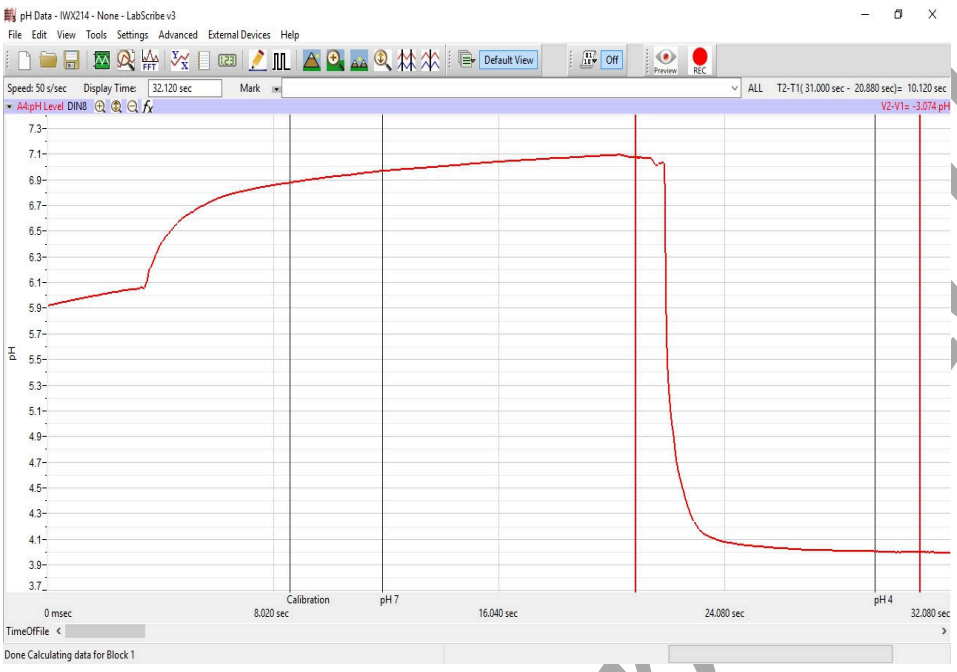

Figure GB-5-S3: pH calibration data recorded showing the positions of the cursors for changing the recorded voltage to pH values.

5. On the units conversion window, make sure 2 point calibration is selected in the pull-down menu in the upper-left corner of the window. Put a check mark in the box next to Apply units to all blocks. Notice that the voltages from the positions of the cursors are automatically entered into the value equations. Enter the two buffers used in the calibration recording in the corresponding boxes on the right side of the conversion equations. Enter the name of the units, pH, in the box below the buffer values. Click OK.

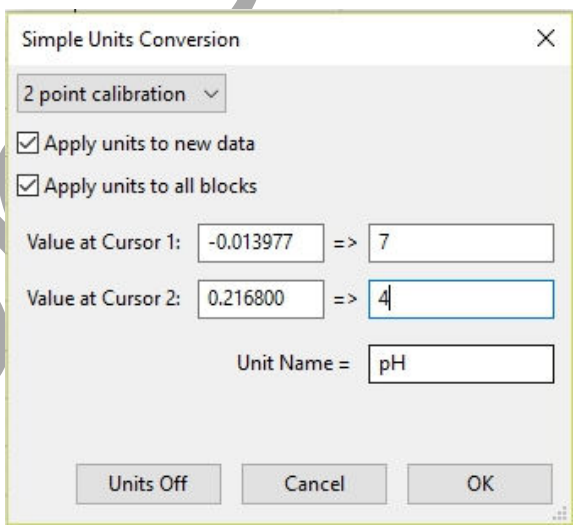

Figure GB-5-4: The Simple Units Conversion dialog window for pH conversion.

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Preparation before Performing Exercises

1. Obtain three culture tubes. These tubes will be used to generate each of the atmospheric pollutants used to treat samples of deionized water.
2. Label each of the three culture tubes with the formula of the solid chemical that it will contain. One culture tube is labeled $NaHCO_3$, a second tube is labeled $NaNO_2$, and the third tube is labeled $NaHSO_3$.
3. Use a spatula to place enough sodium bicarbonate ($NaHCO_3$) in the labeled culture tube to fill the rounded section at the bottom of the tube.
4. Use a spatula to fill the rounded bottom of each of the remaining culture tubes with the corresponding solid chemical, sodium nitrite ($NaNO_2$) or sodium bisulfite ($NaHSO_3$).
5. Cover each of the tubes with parafilm or plastic wrap, and stand them in the test tube rack or in a 100 ml beaker.

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Exercise 1: The Effect of Carbon Dioxide on the Acidity of Water.

Aim: To determine the changes in pH that take place in water when carbon dioxide gas is bubbled through the water.

Approximate Time: 15 minutes

Procedure

1. Place a large test tube with 5 ml of deionized water in the clamp on the ringstand. Remove the pH electrode from the beaker of deionized (DI) water. Blot the drops of DI water from the electrode. Place the electrode in the test tube.
2. Remove the parafilm or plastic wrap from the top of the culture tube containing $NaHCO_3$. Add 20 drops of 1.0N HCl solution to the tube with a Pasteur pipette. Swirl the culture tube to mix the $NaHCO_3$ and HCl. Cover the tube with the parafilm or plastic wrap. This mixture of chemicals will generate carbon dioxide gas.
3. Click Record. When the recording on the pH channel reaches a stable baseline, type **DI Water** in the Mark box. Click the mark button to mark the recording.
4. Type **CO_2 Added** in the Mark box.
5. Obtain a sample of carbon dioxide gas from the culture tube using a long, plastic Beral pipette.
    - Squeeze as much air as possible from the bulb of the Beral pipette.
    - Insert the tip of the pipette into the culture tube containing carbon dioxide by poking a hole in the parafilm or plastic wrap covering the end of the tube.

Warning: The tip of the pipette should not touch the solution at the bottom of the culture tube.

    - Release the bulb of the pipette to draw carbon dioxide gas into the pipette.
6. Insert the stem of the pipette containing the carbon dioxide gas into the test tube holding the water sample and the pH electrode. Lower the stem of the pipette into the tube until the tip of the stem is in the water at the bottom of the tube.
7. Click the mark button to mark the recording as you gently squeeze the bulb of the pipette to bubble carbon dioxide gas through the water. Squeeze as much carbon dioxide gas as possible from the pipette.
8. Record for two minutes. If all the gas has been expelled from the pipette before the end of the recording period, remove the pipette from the test tube

Warning: When removing the pipette from the test tube, do not release the pressure on the bulb of the pipette until the tip of the pipette is out of the test tube.

9. Click Stop to halt the recording.

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10. Select Save in the File menu.
11. Remove the pH electrode from the test tube. Hold the electrode over the beaker used for collecting waste liquid, and rinse it with deionized water from a wash bottle. Blot any drops of DI water from the electrode and place the electrode in a clean, empty beaker. The electrode will be used in the next section of the exercise.
12. Discard the contents of the test tube as directed by your instructor.
13. Obtain a large test tube with 5 ml of fresh deionized water and place it in the clamp on the ringstand. Place the pH electrode in the test tube and proceed to the next exercise.

Exercise 2: The Effect of Nitrogen Dioxide on the Acidity of Water.

Aim: To determine the changes in pH that take place in water when nitrogen dioxide gas is bubbled through the water.

Approximate Time: 15 minutes

Procedure

1. Remove the parafilm or plastic wrap from the top of the culture tube containing $NaNO_2$. Add 20 drops of 1.0N HCl solution to the tube with a Pasteur pipette. Swirl the culture tube to mix the $NaNO_2$ and HCl. Cover the tube with parafilm or plastic wrap. This mixture of chemicals will generate nitrogen dioxide gas.
2. Click Record. When the recording on the channel reaches a stable baseline, type **DI Water** in the Mark box. Click the mark button to mark the recording.
3. Type **NO_2 Added** in the Mark box.
4. Obtain a sample of nitrogen dioxide gas from the culture tube using the same technique used in Exercise 1.
5. Use the same techniques used in Exercise 1 to add nitrogen dioxide gas to the water sample in the test tube.
6. Click the mark button to mark the recording as you gently squeeze the bulb of the pipette to bubble nitrogen dioxide gas through the water.

Warning: When removing the pipette from the test tube, do not release the pressure on the bulb of the pipette until the tip of the pipette is out of the test tube.

7. Click Stop to halt the recording.
8. Select Save in the File menu.
9. Remove the pH electrode from the test tube. Hold the electrode over the beaker used for collecting waste liquid, and rinse it with deionized water from a wash bottle. Blot any drops of DI water from the electrode and place the electrode in a clean, empty beaker.
10. Discard the contents of the test tube as directed by your instructor.

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11. Obtain a large test tube with 5 ml of deionized water and place it in the clamp on the ringstand. Place the pH electrode in the test tube and proceed to the next exercise.

Exercise 3: The Effect of Sulfur Dioxide on the Acidity of Water.

Aim: To determine the changes in pH that take place in water when sulfur dioxide gas is bubbled through the water.

Approximate Time: 15 minutes

Procedure

1. Remove the parafilm or plastic wrap from the top of the culture tube containing $NaHSO_3$. Add 20 drops of 1.0N HCl solution to the tube with a Pasteur pipette. Swirl the culture tube to mix the $NaHSO_3$ and HCl. Cover the tube with parafilm or plastic wrap. This mixture of chemicals will generate sulfur dioxide gas.
2. Click Record. When the recording on the channel reaches a stable baseline, type **DI Water** in the Mark box. Click the mark button to mark the recording.
3. Type **SO_2 Added** in the Mark box.
4. Obtain a sample of sulfur dioxide gas from the culture tube using the same technique used in Exercise 1.
5. Use the same techniques used in Exercise 1 to add sulfur dioxide gas to the water sample in the test tube.
6. Click the mark button to mark the recording as you gently squeeze the bulb of the pipette to bubble sulfur dioxide gas through the water.

Warning: When removing the pipette from the test tube, do not release the pressure on the bulb of the pipette until the tip of the pipette is out of the test tube.

7. Click Stop to halt the recording.
8. Select Save in the File menu.
9. Remove the pH electrode from the test tube. Hold the electrode over the beaker used for collecting waste liquid, and rinse it with deionized water from a wash bottle. Blot any drops of DI water from the electrode and place the electrode in the beaker of deionized water.
10. Discard the contents of the test tube as directed by your instructor.

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Data Analysis

Exercise 1: The Effect of Carbon Dioxide on the Acidity of Water

1. Scroll to the section of the data file recorded during Exercise 1.
2. Use the Display Time icons on the LabScribe toolbar to position the complete recording on the Main window. The required data can also be selected by:
    - Placing the cursors on either side of the section of data needed. Place one cursor on the stable pH level recorded from pure deionized water. Place the second cursor on the stable pH level recorded after 2 minutes of recording during the addition of CO2 to the deionized water
    - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the segment of data to the width of the Main window.
3. Look at the Function Table that is above the uppermost channel displayed in the Analysis window. The mathematical functions that are listed should include Title, Value1, Value2, and V2-V1. The values for these parameters from each channel are seen in the table across the top margin of each channel.
4. Once the cursors are placed in the correct positions for determining the pH, the values for pH can be recorded in the on-line notebook of LabScribe by typing the names and values directly into the Journal.
5. The functions in the channel pull-down menus of the Analysis window can also be used to enter the names and values of the parameters from the recording to the Journal. To use these functions:
    - Place the cursors at the locations used to measure the pH from the pH channel.
    - Transfer the name of the mathematical function used to determine the pH to the Journal using the Add Title to Journal function in the pH channel pull-down menu.
    - Transfer the value for the pH to the Journal using the Add Ch. Data to Journal function in the pH channel pull-down menu.
6. Place one cursor on the stable pH level of the pure deionized water. Place the second cursor on a data point in the recording that is at least two minutes after beginning the bubbling of carbon dioxide through the water.
7. Measure the values for the following parameters from the pH channel for the region of data selected:
    - pH-DI Water, which is Value1 on the pH channel.
    - pH-DI Water and CO_2, which is Value2 on the pH channel.
8. Record the values for these parameters in the Journal using one of the procedures described in Step 5, and in Table 1.

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Exercise 2: The Effect of Nitrogen Dioxide on the Acidity of Water

1. Scroll to the section of the data file recorded during Exercise 2.
2. Use the same techniques used in Exercise 1 to measure the pH levels of the water before and after nitrogen dioxide was bubbled through the water.
3. Use the same techniques explained in Exercise 1 to record the values of the pH levels in the Journal, and in the data table.

Exercise 3: The Effect of Sulfur Dioxide on the Acidity of Water

1. Scroll to the section of the data file recorded during Exercise 3.
2. Use the same techniques used in Exercise 1 to measure the pH levels of the water before and after sulfur dioxide was bubbled through the water.
3. Use the same techniques explained in Exercise 1 to record the values of the pH levels in the Journal, and in the data table.

Table GB-5-L1: Effect of Atmospheric Pollutants on the Acidity of Water

Gas Added	pH Before Addition	pH After Addition	Change (Δ) in pH
Carbon Dioxide			
Nitrogen Dioxide			
Sulfur Dioxide			

Questions

1. Which gas caused the greatest change in pH when it was added to the water?
2. Which gas caused the smallest change in pH when it was added to water?
3. From the data in this experiment, identify the gas that would cause the pH of unpolluted rainwater to be only slightly acidic.
4. Is the acidity of unpolluted rainwater higher or lower than the acidity of the water measured in this experiment?
5. Is the acidity of highly polluted rainwater higher or lower than the acidity of the water measured in this experiment?
6. Make a list of the items or services that you use each day that could contribute to the pollutants that cause acid rain.
7. List some of the solutions for reducing the acidity of natural rainwater.

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