Experiment C-8
Acid Rain

Chemistry

Objectives

- To study the acid rain phenomenon by producing carbon dioxide and dissolving it in water.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-206 pH logger sensor

Equipment and Accessories

▪ 50 ml beaker	2
▪ 250 ml beaker	1
▪ Gas generator	1
▪ Wash bottle	1
▪ Plastic container	1
▪ Sample container	1

- The gas generator is included in the NeuLog Oxygen and Carbon Dioxide kit, CGG-KIT. The rest of the items are included in the NeuLog Utility accessories, UTL-KIT.

Materials

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| ▪ 100 ml water |
| ▪ Water for the wash bottle |
| ▪ 50 ml vinegar |
| ▪ 10 g baking soda |
| ▪ 20 ml pH 7 buffer |

Introduction

Acid rain is a phenomenon associated with the development of urban and industrial areas. It is created by the incorporation of chemical compounds such as carbon dioxide, sulfur dioxide and nitrogen oxides to rain water. These compounds are emitted by car's exhausts, factories and thermoelectric centrals.

When these oxides are in contact with humidity in the atmosphere, they are transformed into secondary polluting agents which form solutions of Carbon, Sulfuric and Nitric acid. Rain carries these compounds to the Earth's surface, deposits them on the soil and in water bodies.

The persistent fall of acid rain damages lakes, rivers and underground waters, causing the death of fish and other organisms in aqueous ecosystems. It acidifies and demineralizes soils, damages forests, national parks and reserves and causes low producing crops. Also, the acidity of the water deteriorates archeological zones, historical monuments, buildings and metallic structures. The dimension of the damage depends on the degree of acidity.

In this experiment, you will produce CO_2, one of the gases responsible for acid rain by using vinegar and baking soda. Baking soda is sodium bicarbonate ($NaHCO_3$) and the key ingredient of vinegar is acetic acid (CH_3COOH).

$$CH_3COOH(aq) + NaHCO_3(s) \Rightarrow CO_2(g) + H_2O(l) + CH_3COONa(aq)$$
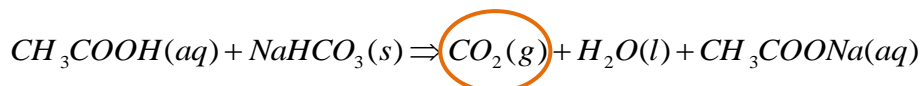
Carbon dioxide (CO_2) reacts reversibly with water (H_2O) and produces carbonic acid (H_2CO_3), a weak acid which dissociated into hydronium (H_3O^+) and bicarbonate (HCO_3^-) ions. This reaction occurs when acid rain forms:

$$2H_2O(l) + CO_2(g) \Leftrightarrow H_2CO_3(aq) + H_2O(l) \Leftrightarrow H_3O^+(aq) + HCO_3^-$$
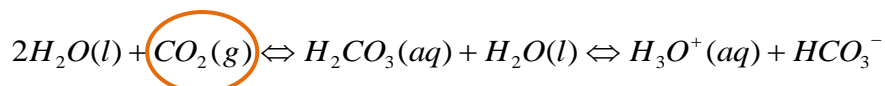
You will quantify the variation in the pH induced in the water after the carbon dioxide is dissolves in it.
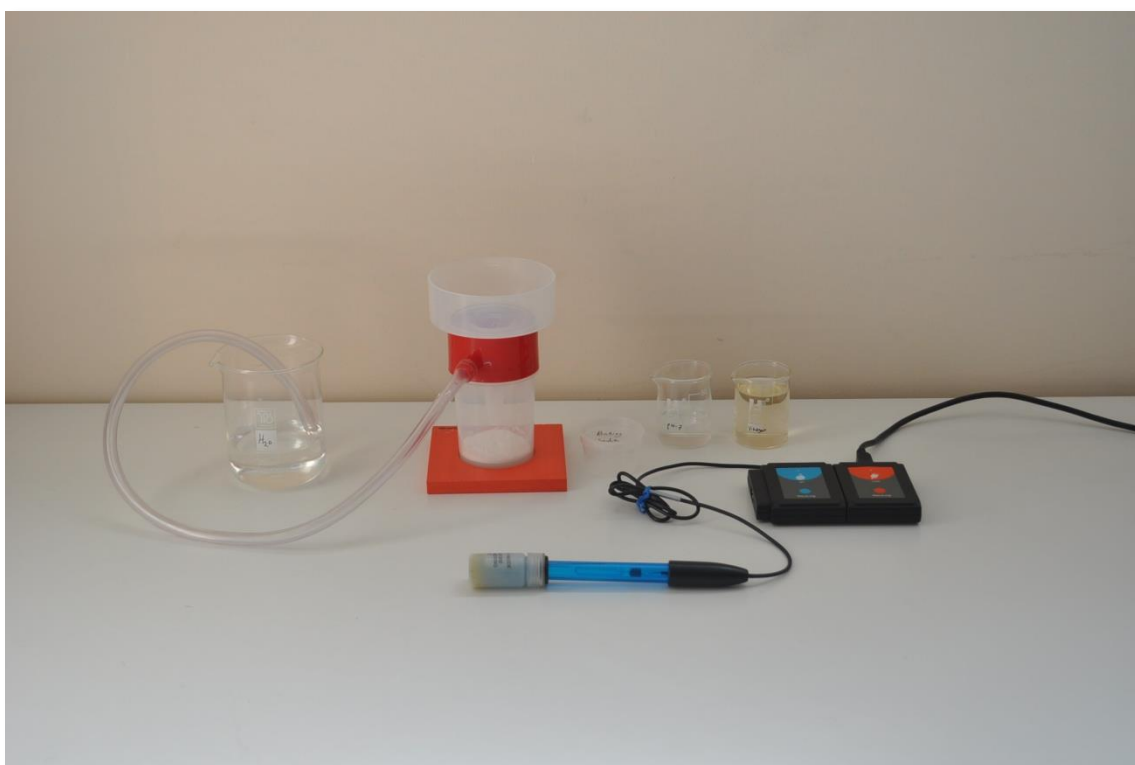
Procedure

Experiment setup

Caution:

It is recommended to wear personal protective equipment. Material Safety Data Sheets (MSDS) are available online. Please note that the bottom part of the pH sensor consists of a fragile crystal sphere. Even though it has a plastic protection, be careful not to break it.

1.   Set up the experiment as shown in the picture below.

2.   Make sure you have a 250 ml beaker with 100 ml water, a 50 ml beaker with 50 ml vinegar, a 50 ml beaker with 20 ml of pH 7 buffer solution and a sample container with 10 grams of baking soda (or two teaspoons).

3.   Open the gas generator, add the baking soda and close the cap tightly.

4.   Insert the hose attached to the gas generator into the water.

Sensor setup

5.   Connect the USB-200 module to the PC.

6.   Check that the pH sensor is connected to the USB-200 module.

Note:

The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

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7.   Run the NeuLog application and check that the pH sensor is identified.

Settings

8.   Click on the **Run Experiment** icon in the NeuLog main icon bar.

9.   Set the:

        Experiment duration to 5 minutes
   Sampling rate to 2 per second

Testing and measurements

10. Wash the sensor's probe with the wash bottle and the plastic container.

11. In order to offset the sensor, insert the probe into the pH 7 buffer solution (If a buffer solution is not available distilled water can be used instead).

    Wait until the value has stabilized; press on the sensor's offset button continuously (3 seconds) or alternatively, click on the **Extra command** button in the **Module setup** menu and then on the **Reset** button. This will offset the sensor to a value of 7 (the value appears in the module window).

12. Wash the sensor's probe again and put it in the 250 ml beaker.

13. Click on the icon to go back to the **Run Experiment** menu.

14. Click on the **Record** icon to start the measurement.

15. After about 10 seconds, slowly add 50 ml of vinegar through the gas generator's cap. Shake the gas generator from time to time.

16. You should see gas bubbles in the water.

17. Observe the pH changes in the graph on the computer screen (stop the measurement if the value has stabilized).

18. Click on the **Arrows** icon in order to see the sensor's values during the measurement.

19. To see the entire graph after one minute, use the mouse's scroll wheel.

20. Click on the **Zoom Fit** icon .

21. Your graph should be similar to the following:
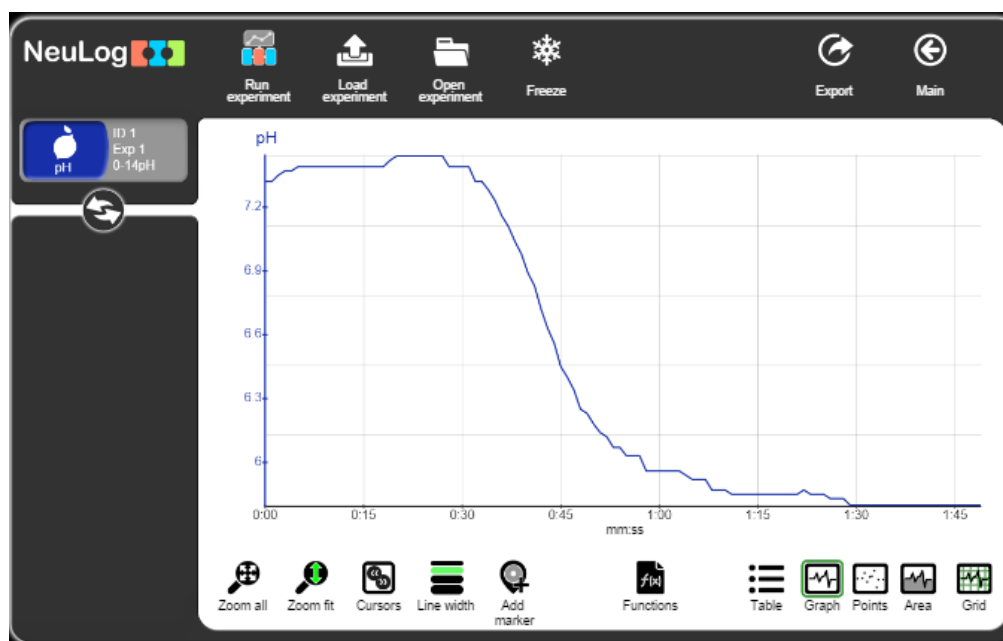
22. Click on the **Export** Icon and then on the **Save value table (.CSV)** button to save your graph.

23. Click on the icon to go back to the graph.

24. We can see that when the vinegar (which contains acetic acid, CH_3COOH) was added to the baking soda (which is sodium bicarbonate, $NaHCO_3$), CO_2 was produced and flew through the hose into the water.

   The pH was decreased as the CO_2 dissolved in the water exactly like the formation of acid rain.

25.   In order to calculate the pH decrease, click on the **Cursors** icon ![cursors icon] and select the part between the beginning and ending of the measurement.
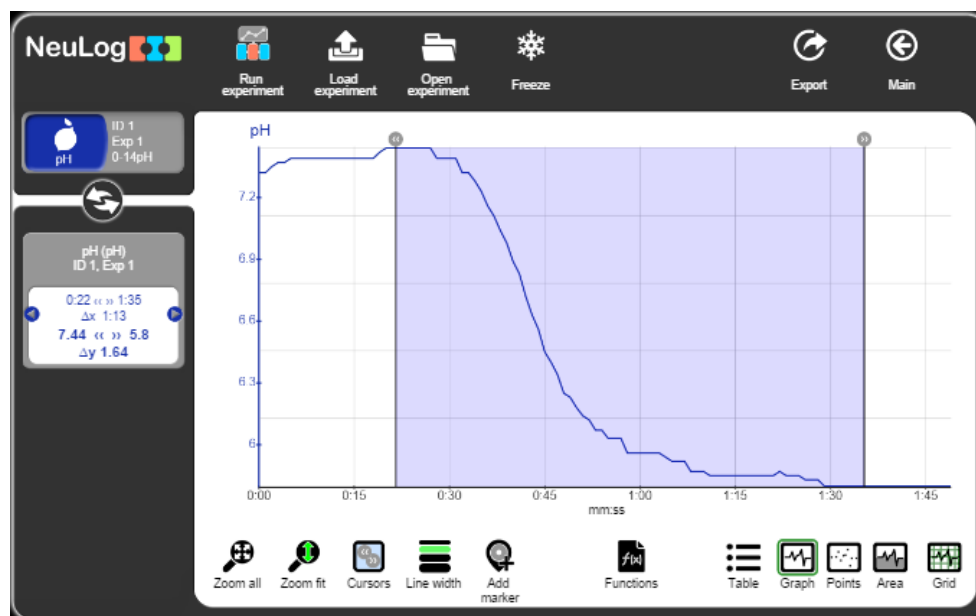

26.   Look at the data at the bottom of the graph, we can see that the pH changed in our example from 7.44 to 5.8 (a 1.64 decrease in pH).

      It is important to be aware that the pH scale is logarithmic therefore each whole pH value below 7 is ten times more acidic than the next higher value.

Summary questions

1.   What was the change in the pH in your measurement?

2.   Develop the chemical reaction of acid rain from Sulfur trioxide plus water.

$$SO_{3(g)} + H_2O_{(l)} \Rightarrow$$
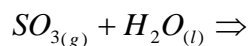
3.   Choose one example of the effects of acid rain on the environment from the introduction and elaborate on the subject.

4.   What can we do to prevent the formation of acid rain?