pH Measurements of Common Substances

Introduction

The concentration of an acid or base is frequently expressed as pH. Historically, pH stands for the “power of the Hydrogen ion concentration” and it is a powerful and widely used way of describing the acidity or alkalinity of substances. In this experiment, you will learn how a modern pH meter works, how to calibrate it, and how to make reliable measurements. You will measure the pHs of a variety of substances in water, including some pure chemicals, some rain and water samples, and various foods and household products. You may also have the opportunity to try some simple "dip sticks," which are disposable pH test strips.

Because this experiment includes measuring the pH’s of a variety of common foods and household substances, you may wish to bring a few substances of your own choosing to the laboratory so you can check their pHs.

Background Information

The pH scale is a convenient way of expressing hydrogen ion concentration in solutions. Section 6.4 of Chemistry in Context – 5th Ed., discusses pH and the pH scale. pH is defined as the negative of the logarithm of the hydrogen ion molarity. (See Appendix 3 of Chemistry in Context – 5th Ed for more detail.) In equation form, this is

\[ pH = - \log[M_{H^+}] \]  

Modern pH meters are wonderfully easy to use and generally reliable. But the science behind their operation is far more complicated. They rely on an extremely small electric current flowing through the solution and the meter, and thus they are highly susceptible to a variety of interferences. Probably the most important considerations in making accurate pH measurements are (a) careful adjustment and rechecking of the meter, (b) thorough rinsing of the electrode with distilled water between each measurement, and (c) care in handling the electrode because it is very fragile (and also expensive).

Although the following directions describe the use of an electronic instrument for measurement of pH, there is a much simpler method for measuring approximate pH values using special pH test paper strips. These have been impregnated with colored dyes that change color depending on the pH. Most of this experiment can be done satisfactorily with pH test strips instead of a pH meter. One disadvantage of test strips is that most of them are reliable only to the nearest whole-number pH unit. For some brands of test strips, the pH can be estimated to within a few tenths of a pH unit.

Overview of the Experiment

1. Learn the operation of a pH meter and calibrate the meter.
2. Measure the pH of pure acid and base solutions.
3. Measure the pH of various foods and household products.
4. Measure the pH of tap water, rainwater, and surface water.
5. Measure the pH of water containing an atmospheric gas: CO₂.
Materials Needed

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• calibrating solutions: pH 6.86 and 4.01</td>
<td>• pH meter with attached electrode</td>
</tr>
<tr>
<td>• HCl solutions: 0.00025, 0.00250, 0.0250,</td>
<td>• wash bottle filled with distilled water</td>
</tr>
<tr>
<td>and 0.250 M</td>
<td>• 2 small beakers</td>
</tr>
<tr>
<td>• NaOH solution: 0.00250 M</td>
<td>• large beaker (waste container)</td>
</tr>
<tr>
<td>• foods and household products to be tested</td>
<td>• box of tissues</td>
</tr>
<tr>
<td>• source of carbon dioxide gas</td>
<td>• test-tube rack</td>
</tr>
<tr>
<td>• source of compressed air</td>
<td>• supply of large test tubes (at least 10)</td>
</tr>
<tr>
<td></td>
<td>• pH test strips</td>
</tr>
</tbody>
</table>

Experimental Procedure

I. Learn the Operation of a pH Meter and Calibrate the Meter

1. Obtain a pH meter with an attached probe called a "pH electrode." Your instructor will explain the type of pH meter to be used and arrangements for sharing meters between students. If the pH meter requires AC voltage, be sure it is plugged in and warmed up.

2. Obtain the other equipment items listed.

3. Obtain two small beakers containing calibrating solutions labeled "pH 7.00" and "pH 4.00."

4. Learn how to operate the pH meter, including the functions of whatever knobs or buttons it has. Most meters have three knobs: SELECTOR, CALIBRATE and TEMPERATURE.

5. Hold the electrode over a waste container and rinse the electrode thoroughly with distilled water from the wash bottle. Blot the end of the electrode gently with a tissue to remove most of the water.

6. Insert the electrode into the pH 6.86 calibrating solution, stir gently for a few moments, and observe the reading on the meter. Set the SELECTOR to "pH" and use the CALIBRATE knob to adjust the meter until it displays 6.86. You may need to keep stirring. The meter may not settle down to display exactly 6.86, but it should be within the range 6.8 to 7.0.

7. Rinse the electrode thoroughly with distilled water, blot the end of the electrode gently with a tissue, then insert the electrode into the pH 4.01 calibrating solution. With the SELECTOR set on "pH" stir and observe until the reading is steady. If necessary, adjust the TEMP control until it reads very close to 4.01. (Optional: Check the pH 6.86 again to be sure.)

8. Recommended: Repeat with both pH 6.86 and 4.01 (rinsing and blotting each time the electrode is moved) to be sure the readings are steady.

II. Measure the pH of Chemical Solutions of Known Concentration

1. Remove the electrode and rinse it very thoroughly with distilled water, since it is now coated with a concentrated pH 4 or pH 7 solution, which could make subsequent readings erroneous. Blot the end of the electrode gently with a tissue to remove most of the water.

2. Immerse the electrode into a 0.00025 M solution of HCl (in a test tube or small beaker), stir the solution for a few moments, and record the pH. Calculate the predicted pH (calculated based on equation 1) for this solution and record that also.
3. Remove the electrode, rinse it well, blot with a tissue, then immerse the electrode into 0.00250 M HCl, stir, and record the pH along with the predicted pH.

4. Rinse the electrode and measure the pH of 0.0250 M HCl and subsequently the pH of the 0.250 M HCl solution. Record and calculate pH’s as before.

5. Finally, switch to an alkaline (basic) solution, as follows. Rinse the electrode thoroughly and measure the pH of a 0.00250 M solution of sodium hydroxide, NaOH. Compare your result with the calculated pH for this solution. (Review how to calculate pH for a base.)

III. pHs of Foods and Household Substances

Now that you know how to measure pH, you should measure the pHs of some common substances, using samples provided by the instructor and samples brought from home. In each case, put a small amount in one of the wells of a plastic wellplate or in a small test tube (or in a very small beaker). Use only enough so that the bulb end of the electrode is immersed. If in doubt about this, check with the instructor.

Some possible samples to test include the following substances. You should test a minimum of 8 substances or whatever number your instructor specifies.

- a. Vinegar
- b. Lemon juice
- c. Fruit juices
- d. Soft drinks
- e. Coffee or tea
- f. Liquid dish detergent
- g. Dishwasher detergent
- h. Laundry detergent
- i. Shampoo or hand soap
- j. Household ammonia
- k. Liquid laundry bleach
- l. Baking soda (sodium bicarbonate)
- m. Drain cleaner (Caution: see note below)

The following substances should be diluted before testing the pH. To do this, mix a few drops of the substance (or a small pinch of solid) with distilled water.

- f. Liquid dish detergent
- g. Dishwasher detergent
- h. Laundry detergent
- i. Shampoo or hand soap

SAFETY NOTE: Some drain cleaners are extremely caustic. They are designed to dissolve hair and other debris! Be especially cautious about getting any drain cleaner on your skin. Safety glasses are essential. In case of any skin contact, consult the instructor immediately.

IV. pH of Tap Water, Rain and Surface Water, and CO₂ (aq)

1. Measure the pH of tap water. You can try water from the lab, from a drinking fountain, or from elsewhere on campus or where you live.

2. The pH of rain or snow is particularly interesting because of concern about "acid rain," but good measurements are slightly difficult to do. Your instructor may provide samples that have been collected recently or you can set a clean wide-mouth jar outside just before a rain event. Remember that rain is nearly distilled water, and this makes the measurements more difficult.

3. It is instructive to compare the pH of rain to the pH of river water. If river samples are available in the lab, check the pH of one or more. If they are different from the pH of rain, try to suggest an explanation.

4. If water from a swimming pool is available, check its pH. Is it different from tap water?
5. Test the pH of water that is saturated with carbon dioxide. One easy way to do this is to use seltzer water that has been left open so that the excess CO₂ has escaped and it has gone "flat." Another way is to bubble some CO₂ gas (from a pressurized tank) into water. Yet another way is to use the procedure described in Experiment 1. Test the pH of the water containing CO₂. Is the solution acidic?

6. Test the pH of water that is saturated with air. Remember that CO₂ is only a very small fraction of the gases that make up air. How does your measured pH value compare to the value stated in the text?

Possible Extension: Use of pH Test Strips for Tests Outside the Lab

Your instructor may give you some extra pH test strips to take with you so that you can test samples outside of the laboratory, for example, in the dorm, cafeteria, or dining room. If so, make a record of your observations and be prepared to report back to the class at a later date. The color card is shown at the right. Use it to determine approximate pH.

Clean Up

Leave the pH electrode soaking in water. Clean all glassware, first with plenty of tap water, then finally with distilled water.

Reporting Your Results

Record all of your pH results on the data sheet. If requested by the instructor, post the pHs of common substances for other students to see.

CAUTION: Any tests done on food or beverage samples MUST be done on small portions (in a separate container) that will NOT be consumed.

Questions To Be Answered After Completing This Experiment

Write out answers to the following questions in the space provided and turn them in along with the entire experiment (procedures and data sheets). BE NEAT AND WELL ORGANIZED!

Questions

1. Were the pH results for HCl and NaOH solutions approximately what you expected? Explain your reasoning. What general rule can you propose for how the pH should change (up or down and by how much) any time the acid concentration increases by a factor of 10? (For example, when the HCl concentration changes from 0.00025 M to 0.00250 M to 0.0250 M, the acid concentration increases by a factor of 10 each time.)
2. What, if any, conclusions can you draw about the pHs of the different categories of common substances, e.g., (a) pHs of beverages? (b) pHs of soaps and detergents? (c) pHs of substances that normally touch human skin?

3. Explain briefly why pH is a useful way of describing acid and base solutions over a very wide range of concentrations.

4. Why was it necessary to dilute substances $f$ to $m$ before measuring the pH? How do you think the measured pH of the diluted sample compares with the pH of the sample itself?

5. (If Part IV was done) (a) Was the rain acidic or alkaline? Since rain is formed by evaporation and condensation in clouds, why is the pH not that of distilled water? (b) Were tap water and surface water acidic or alkaline? What substances may account for this?

6. Was the pH of CO$_2$ in water about what you expected? Write chemical equations for the reactions of this gas with water.
**Data Sheet – pH Measurements of Common Substances**

**Part II:**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Measured pH</th>
<th>Predicted pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000250 M HCl</td>
<td></td>
<td></td>
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<tr>
<td>0.00250 M HCl</td>
<td></td>
<td></td>
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<tr>
<td>0.0250 M HCl</td>
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<tr>
<td>0.250 M HCl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00250 M NaOH</td>
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<td></td>
</tr>
</tbody>
</table>

**Part III:**

<table>
<thead>
<tr>
<th>Sample, including source or description</th>
<th>Measured pH</th>
<th>Test Strip</th>
</tr>
</thead>
</table>

**Part IV:**

<table>
<thead>
<tr>
<th>Solution or Sample</th>
<th>Source</th>
<th>Measured pH</th>
<th>Test Strip</th>
</tr>
</thead>
<tbody>
<tr>
<td>tap water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rain</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>river or lake</td>
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<td></td>
<td></td>
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<tr>
<td>CO₂ in water</td>
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