Experiment 24 - Finding the pH of Solutions

Aqueous solutions that contain H_3O^+ in concentrations greater than 1×10^{-7} M are acidic; those with concentrations of this ion less than 1×10^{-7} M are basic. Solutions with $[H_3O^+]$ equal to 1×10^{-7} M are neither acidic nor basic; they are neutral. Instead of stating the ion concentration, it is convenient to state the pH value. The pH is defined as the negative log of the hydrogen ion concentration.

$$pH = -\log\left[H^+\right]$$

If you know the hydrogen ion concentration (in molarity), you can calculate its pH by taking the negative log of that number on your calculator. If the hydrogen ion concentration is a simple number, such as 1.0×10^{-5} M or 1.0×10^{-10} M, figuring out the pH is simple: it is equal to the power of ten of the H_3O^+ concentration, except that it is positive, not negative. Therefore, a solution which has a hydrogen ion concentration of 1.0×10^{-5} M has a pH of 5.00, and a solution in which $[H^+] = 1.0 \times 10^{-10}$ M has a pH of 10.00. What is the pH of a solution in which $[H^+] = 1.0 \times 10^{-3}$ M? What is the hydrogen ion concentration of a solution with a pH of 9.00? (Note: the significant figure rules for pH are different from the normal rules, since pH values are logarithms. Ask your instructor about these significant figure rules if you are curious.) If the numeric part of the hydrogen ion concentration is not equal to 1, then you must use your calculator to find the pH. For example, in a solution that has $[H^+] = 2.0 \times 10^{-5}$, the pH is 4.70. Ask your instructor for directions on how to calculate pH using your calculator.

The concentration of $H^+_{(aq)}$ (or $H_3O^+_{(aq)}$ as it is sometimes written) affects a wide variety of things, from the taste of foods to rates of chemical reactions. It is therefore important to be able to measure this concentration quickly and accurately. In the following exercises you will learn several ways of doing this. In terms of pH, a solution is acidic if its pH is less than 7, neutral if its pH is equal to 7, and basic if its pH is greater than 7.

Part 1: Testing Everyday Things for Acidity or Basicity

In this part of the experiment you will test some common, everyday household chemicals to see whether they are acidic, basic, or neutral. You will do this using litmus paper, an indicator which turns red in acidic solutions (pH below 7) and turns blue in basic solutions (pH above 7). In a neutral solution, litmus paper that is red to start with barely changes color: if it was red to begin with, it stays red, and if it was blue, it remains blue. Litmus paper is most useful for detecting solutions that are either decidedly acidic or decidedly basic.

Part 2: pH Using Red Cabbage Indicator

Red cabbage contains a substance that changes color depending on the pH of its surroundings. This substance is an acid-base indicator. (Litmus is another example of an acid-base indicator that changes color based on the pH.) You will be finding the color of red cabbage juice at different pH values and then using the red cabbage juice to determine the approximate pH of different substances.

Safety Precautions:

- Wear your safety goggles.

Waste Disposal:

- All of the waste in this experiment can be poured down the drain.

Procedure

Part 1 - Testing Everyday Things for Acidity or Basicity

1. On a square of paper towel, put three pieces of red and three pieces of blue litmus paper. (Do not use paper that is faded; ask the instructor if you are in doubt.)
2. You will test the following substances:
   Tap water (let a drop fall directly on the paper)
   Deionized water (squirt a drop directly on the paper)

Milk	Household ammonia
Buttermilk	Pink liquid lab soap
Orange juice	Cake of soap
Lemon juice	Scouring powder
Egg yolk	Laundry detergent
Egg white	Vinegar

3. To test a substance, dip a clean glass stirring rod into the substance, then touch that end to a piece of red and a piece of blue litmus paper. Note which color changes, if any. If the red paper turns blue, the substance tested was basic; if the blue paper turns red, the substance tested was acidic. Note: litmus paper will not work properly if it is touched by a dry sample, so when testing dry things, moisten the paper first with *one* drop of deionized water. The same strip of paper can be used for several tests, as long as you use a different region of the paper for each test.
4. Discard used paper in the wastebasket, not the sink.
5. The instructor will demonstrate how the pH meter can be used to measure the pH of strongly colored liquids such as tea, coffee, and cola.

Part 2 - pH Using Red Cabbage Indicator

6. Tear up some red cabbage leaves and place them in a beaker. Add some deionized water to *barely cover* the leaves (the less water you add, the more intensely colored your indicator will be). Set up a ring stand with an iron ring and a piece of wire gauze. Place the beaker on the wire gauze, and heat the water with a Bunsen burner (but do not let it boil vigorously) for 5-10 minutes. The solution should have a dark purple color. Let it cool.
7. While the red cabbage is cooking and cooling, prepare your reference set of solutions. You will need 10 test tubes, a test tube rack, and a set of known pH solutions. Label each of the test tubes with its pH value (1-10). In each tube, place about 1 mL of the appropriate pH solution. (For example, in the tube labeled 1, put about 1 mL of the pH 1 solution.)
8. When the red cabbage juice has cooled, use a dropper to add about 10 drops of cabbage juice to each of the labeled test tubes. (Add enough cabbage indicator to get a definite, easy to see color, but make sure to add the same amount of indicator to each tube.) Mix each test tube well by swirling vigorously. Record the color you see in each tube. Keep this reference set of solutions.

9. Use the cabbage juice to test a few of the household items you already tested with litmus paper. To do this, mix a small amount of the household item with 10 drops of cabbage indicator in a test tube. Compare its color with the set of reference tubes in your test tube rack. Come up with a more precise pH for that household item. You may not be able to narrow down the pH to one value, but you can state a range of possible pH values for that substance.
10. Use the cabbage juice to determine the approximate pH of an unknown solution. Again, you may not be able to narrow it down to one pH, but you can determine a range of possible pH values. Each person must use his or her own unknown solution.

Questions

1. If a solution has a pH of 4.50, what is the concentration of hydrogen ions in this solution?
2. If a particular solution has $[H^+] = 1.0 \times 10^{-9}$ M, what is the concentration of hydroxide ion? What is the pH?
3. If some red cabbage indicator is added to a solution with an unknown pH and the color of the indicator turns to blue, what can be said about the pH of the unknown?