Acids and Bases

Water: Acid and Base in One

A. Even in pure water, two water molecules will very occasionally react with each other to form one ion each of H_3O^+ and OH^- as follows: $H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$
   1. The equilibrium sign ($\rightleftharpoons$) is used to indicate that as soon as these ions form, they react with each other to reform two water molecules.
   2. Chemists use the idea of moles per liter to express the concentration of these ions in a solution. One mole of H_3O^+ ions weighs 19 grams, and one mole of OH^- ions weighs 17 grams.
   3. In pure water at room temperature, the concentrations of these two ions are equal and are 0.0000001 moles per liter. This very small number can be written in scientific notation as 1.0×10^{-7} moles per liter.
   4. A solution in which the concentration of each of these ions is 1.0×10^{-7} moles per liter is called a **neutral** solution.
   5. Adding a type of substance known as an **acid** to pure water will increase the concentration of H_3O^+ ions and will decrease the concentration of OH^- ions.
   6. Adding a type of substance known as a **base** to pure water will have the opposite effect.

B. Since people customarily do not like to think in terms of very small numbers, the pH scale has been devised so that the pH of a given solution is defined as negative logarithm of the H_3O^+ concentration. pH values range from about 0 to about 14 (see Figure 1).

C. On this scale, a neutral solution will have a pH of 7, an acidic solution will have a pH less than 7, and a basic solution will have a pH greater than 7.
   (*Introduction by Dr. Tom Hodgkins*)

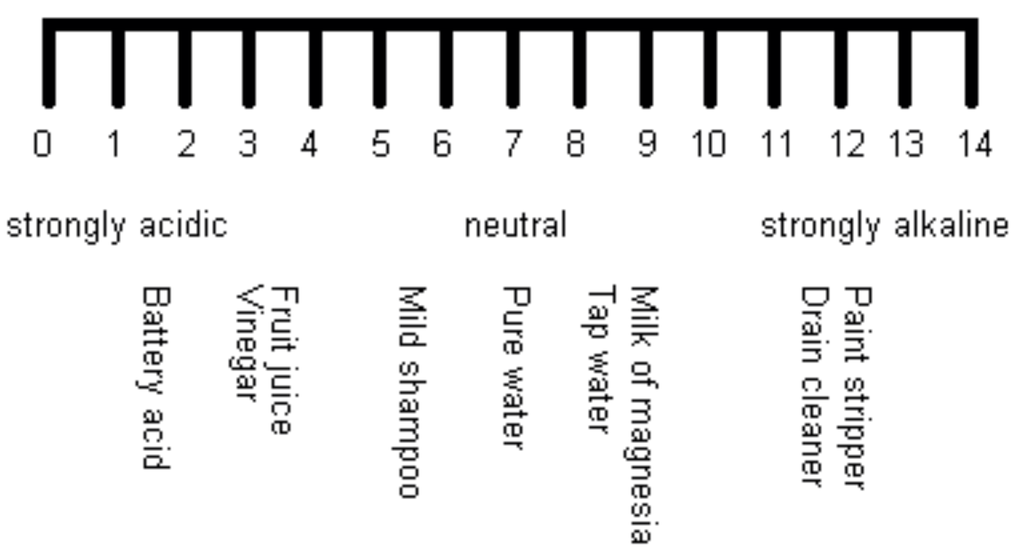

Figure 1: the Acid-base scale from http://www.york.ac.uk/res/sots/activities/acidtest.htm

Properties of acids and bases

- Acids increase the concentration of H^+ in a solution
- Because pH is a logarithmic scale (base 10 log), a solution that is pH 3 has 10x H^+ than a solution that is pH 4; it is in effect 10 times more acidic at pH 3 than the pH 4 solution
- Acids may be corrosive or poisonous
- Acids neutralize bases (and vice versa)

- Bases decrease the concentration of H^+ in a solution
- Bases are also known as alkaline
- Bases may be corrosive or poisonous
- Bases feel slippery

Note: Start red cabbage extract before proceeding

Procedure 1: pH of common substances

You will not directly measure the concentration of H^+ ions, but instead use pH indicators. An example of a pH indicator is litmus. Litmus is a substance that will change color in the presence of an acid or base. Indicators may either be in a liquid form, or may be dried onto a paper.

Bring your favorite beverage to test!

Methods

1. Obtain the solutions you will be testing (as many as will fit in the table)
2. Briefly (1-2 seconds) dunk a pH indicator strip into the solution
3. Allow the indicator strip to change color, and then match the color of the strip with the container to estimate the pH of the solution
4. Write the pH of the substance in Table 1

Table 1: the pH of some common solutions

Substance	pH
Baking soda solution	
Tap water	
Black coffee	

Questions:

1. Which of the substances you tested is the worst for your teeth? Why?

2. Did the pH of any of the substances surprise you?

3. Why is the pH of body care products like shampoo slightly acidic?

Procedure 2: Buffers

Buffers are mixtures of weak acids and weak bases that resist changes to pH. The difference between a weak acid and a strong acid is explained in figure 2. Living things need to maintain a stable internal environment (this is called **homeostasis)**, and maintaining a constant pH is an important component of that. Organisms have buffering systems to help maintain stable internal pH.

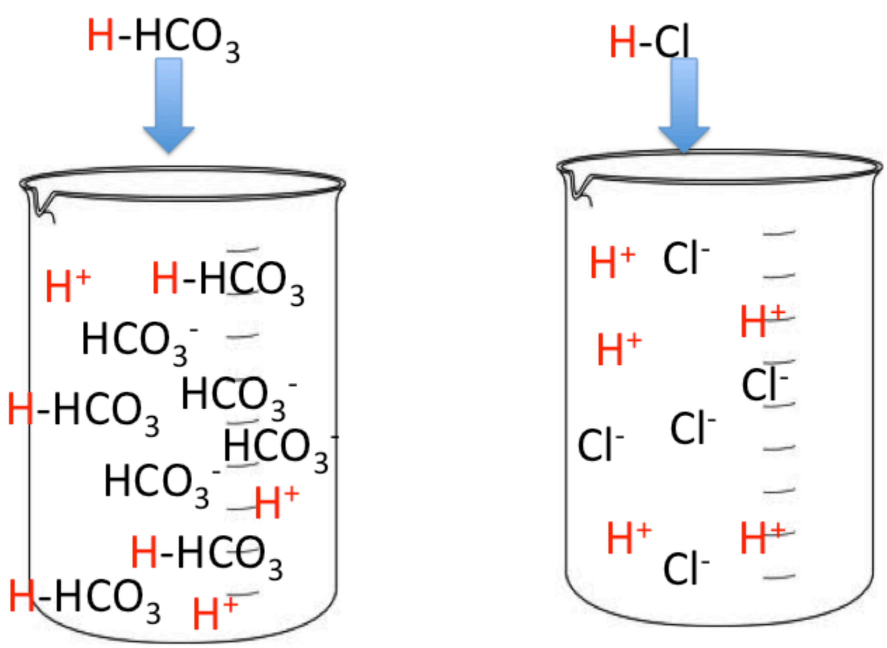

Figure 2: A weak acid (H_2CO_3) vs. a strong acid (HCl). When a strong acid is added to a solution ALL the molecules separate into an H^+ and the corresponding ion (called a conjugate base). With a weak acid or base, not all the molecules separate, but they can separate if another source of H^+ is added.

A buffer will resist changes of pH in EITHER direction! If either an acid or base is added, a buffer should prevent the pH from changing. Buffers work best within a specific pH range.

Materials

0.1 M phosphate buffer
Skim milk
0.1 M NaCl solution
Water
0.1 M HCl (a strong acid)
0.1 M NaOH (a strong base)
pH indicator paper

Methods

1. Obtain 8 test tubes and label them 1a, 1b, 2a, 2b, 3a, 3b, 4a, and 4b
2. Add 5 ml of phosphate buffer to test tubes 1a and 1b
3. Add 5 ml of milk to test tubes 2a and 2b
4. Add 5 ml of NaCl solution to test tubes 3a and 3b
5. Add 5 ml of water to test tubes 4a and 4b
6. Measure the pH of each of the solutions, and record the answer in Table 2
7. To test tubes 1a, 2a, 3a and 4a, add 5 drops of 0.1 M HCl
8. To test tubes 1b, 2b, 3b and 4b, add 5 drops of 0.1 M NaOH
9. Measure the pH of the solutions in all test tubes and record your results in Table 2

Table 2: The effectiveness of different buffers

Test tube #	Substance	Initial pH	pH after adding acid	pH after adding base
1a	phosphate buffer			XXXXXXXXXXXXX XXXXXXXXXXXXX
1b	phosphate buffer		XXXXXXXXXXXXX XXXXXXXXXXXXX	
2a	milk			XXXXXXXXXXXXX
2b	milk		XXXXXXXXXXXXX	
3a	NaCl			XXXXXXXXXXXXX
3b	NaCl		XXXXXXXXXXXXX	
4a	water			XXXXXXXXXXXXX
4b	water		XXXXXXXXXXXXX	

Questions:

1. Based on the above results, which of the four substances is the best buffer?
2. Is milk an effective buffer?
3. Why would milk be an effective buffer? (Hint: think of what it is and where is comes from)

4. What is the point of testing water in this procedure?

Procedure 3: Exploring natural pH indicators: red cabbage

Many plant pigments are pH indicators. Hydrangeas, for example, have different color flowers depending on the pH of the soil. The pigment in red cabbage is a pH indicator. We can extract the pigment and test it to see how it works and how effective it is.

Methods

1. Chop up 1 leaf (~40 g) of red cabbage and place it into a mortar
2. Add 20 ml of 70% isopropanol
3. Gently crush up the leaves to extract the pigment into the isopropanol
4. Leave for 45 minutes
5. Collect the extract into a clean beaker

Using results from Procedure 1, design an experiment to test how red cabbage extract works as a pH indicator.

Use the space below to describe your methods and the results of your experiment. Although you should write up your methods and results individually, we want you to work on the problem as a team with your lab partners.

Questions:

1. How much of each substance do you need to add to get your results?

2. Does the extract work as well as the pH paper?

3. What are some of its limitations?