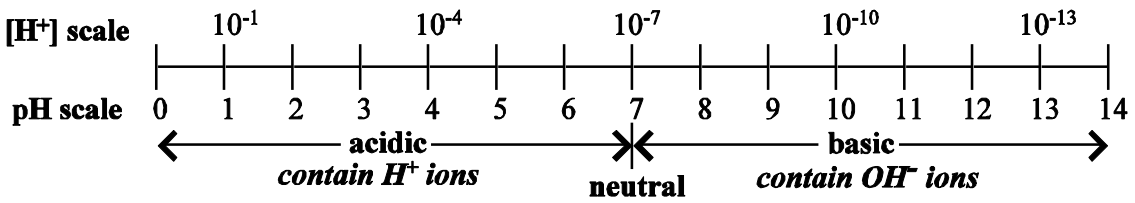
CHM 130LL: pH, Buffers, and Indicators

Many substances can be classified as acidic or basic. Acidic substances contain hydrogen ions, H^+, while basic substances contain hydroxide ions, OH^-. The relative acidity or basicity of a substance is indicated by its pH.

pH is a scale ranging from 0-14 and is defined as **-log[H^+]** where [H^+] is the molar concentration (or molarity) of the hydrogen ion, H^+. The following scale shows the relationship between pH and [H^+]:



Note: The lower the pH, the higher the [H^+]. The higher the pH, the lower the [H^+].

Substances with a **pH of 7** are **neutral**; for example, pure water and table salt, NaCl, are neutral. Substances with a **pH lower than 7 contain H^+ ions and are acidic**; for example, carbonated soda and lemon juice are both acidic. Substances with a **pH greater than 7 contain OH^- ions and are basic**; for example, soap and drain cleaner are both basic.

pH values can be approximated using substances called ***indicators***. These substances change color over a narrow range of pH values and can be used to determine the pH of different substances or to monitor acid-base neutralization reactions. Red cabbage contains a pigment that varies in color depending on pH; thus, it is a natural indicator that can be used to determine the pH of various substances

Buffer solutions resist changes in pH upon addition of small amounts of acid or base. For example, human blood acts as a buffer to absorb small amounts of acid or base resulting from biochemical reactions while maintaining a pH close to 7.4 because cells can only survive in a narrow pH range around 7.4. A buffer is a mixture of a special acid and base that don't neutralize each other. So when you add an acid to a buffer, the buffer's base neutralizes it keeping the pH about the same. And when you add a base to a buffer, the buffer's acid neutralizes it keeping the pH about the same. Cool huh?

In this experiment, you will use the color of the red cabbage indicator to determine the pH of some common household materials, and to classify the substances as acidic, basic, or neutral. You will also use the cabbage indicator to observe and compare changes in pH when small amounts of acid and base are added to a buffer solution and to water. Next, you will determine the pH of various solutions given their hydrogen ion concentration, [H^+]. Finally, you will use pH to classify various substances as strongly acidic (pH<2), weakly acidic (2<pH<7), neutral (pH=7), weakly basic (7<pH<12), or strongly basic (pH>12).

Procedure

A. Red Cabbage Indicator

1. Cut about 8 g of shreds from a head of red cabbage. Put the pieces in a 250-mL beaker. Add 50 mL of deionized water. Place the beaker on the hotplate, and heat at setting 4-5 to a gentle boil. Watch the solution carefully to make sure it does not all boil away. Stir often, until the liquid is ***dark purple*** (~10 minutes). Work on the problems on page 5 while you are waiting for your solution to turn purple.

   Note: If your solution is **blue**, you used tap water instead of deionized water. Prepare a new solution using deionized water.

2. Turn off the heat, carefully put the beaker on a paper towel, and allow the mixture to completely cool for 10 minutes. Pour the colored liquid into a 150-mL beaker to use as the indicator.

Waste disposal: Dispose of the boiled cabbage in the regular trash.

3. Put 7 small test tubes in a test tube rack. Place the rack on a paper towel. Write next to the test tubes on the paper towel the numbers for the following pH values: 2, 4, 6, 7, 8, 10 and 12.
4. Add about 20 drops of each pH solution into the test tube matching its number.
5. Use a disposable pipet to add 5-10 drops of the cabbage indicator (enough to determine a color) to each test tube. Tap the tubes gently with a finger to mix the contents. Record the colors you observe for each pH value. **Save these solutions** to complete Part B.

B. pH of Household Materials

1. Bring from home at least 3 small ***colorless*** samples of liquids (3-4 mL) and/or solids (size of a pea). Check to make sure that the substances will mix with or dissolve (are soluble) in water. Do NOT bring flammables, like perfume, or alcoholic beverages. (Juices, beverages, bottled drinks, vinegar, household cleaners, detergents, aspirin are some possibilities.)
2. If your sample is solid, crush if necessary and then dissolve a pea sized amount of it in 3-4 mL of deionized water. Excess solid goes into the waste jar. If your sample is liquid, it may be used as is. Pour about 1 mL or 15 drops of each substance to be tested into separate labeled small test tubes. Also do samples of 15 drops of tap water and then 15 drops of DI water in two separate test tubes. By the way the proper disposal of leftover medication is to crush the pills then add to coffee grounds in a zip lock bag and put in the trash. NEVER put leftover drugs into the sink or toilet!!! We do not need drugs in our water!!!
3. Add 5-10 drops of cabbage indicator to each test tube (enough to determine a color). Record the color and the exact pH for each substance. Classify each substance as acidic, basic or neutral.

C. Buffers

1. Add about 15 drops of the buffer solution into a clean small test tube, then add 5-10 drops of cabbage indicator to the same test tube. Record the color and pH under Buffer for the "Original (Before HCl added)" row.
2. Next, use the water bottle to add about 1 mL (about 15 drops) of deionized water into another clean small test tube, then add 5-10 drops of cabbage indicator. Record the color and pH under DI Water for the "Original (Before HCl added)" row.
3. Add 2 drops of 0.10M hydrochloric acid, HCl (aq), to each of the test tubes prepared in steps 1 and 2. Use a glass stirring rod to mix the solutions, and record the color and pH for each solution in the second row.
4. Repeat Step 1 with a new test tube, and record the color and pH under Buffer for the "Original (Before NaOH added)" row. Repeat Step 2 with a new test tube, and record the color and pH under DI Water for the "Original (Before NaOH added)" row.
5. Repeat Step 3 using drops of 0.10M NaOH (aq), a strong base, in place of the hydrochloric acid, HCl (aq), and recording the color and pH for the Buffer and for DI Water in the table for "Effects of NaOH(aq)".

Waste disposal: Dispose of all solutions down the drain with plenty of water, and wash and rinse the test tubes.

Wash your hands and your bench.

CHM 130LL:
pH, Buffers, and Indicators

Name: _____

Partner: _____

Section Number: _____

A. Cabbage Indicator

pH	Color of Standard Solutions
2	
4	
6	
7	
8	
10	
12	

B. Household Materials

Substance	Color	pH	Acidic, Basic, or Neutral
Tap Water			
DI Water			

1. What ion do acids produce in aqueous solutions? _____ ions
2. What ion do bases produce in aqueous solutions? _____ ions
3. As $[H^+]$ increases, the pH: circle one: increases decreases stays the same
4. How did you determine the pH of the household materials?

5. Do you think the cabbage indicator would help us determine the pH of coca-cola? Explain.

C. Buffers – A buffer is a mixture of a weak acid and weak base pair that don't neutralize each other. So when you add an acid to a buffer, the buffer's base can neutralize it thus keeping the pH about the same. When you add a base to a buffer, the buffer's acid can neutralize it thus keeping the pH about the same!

Effects of HCl(aq):	**Buffer**		**DI Water**	
	Color	**pH**	**Color**	**pH**
Original (Before HCl added)				
with 2 drops of HCl				

Effects of NaOH(aq):	**Buffer**		**DI Water**	
	Color	**pH**	**Color**	**pH**
Original (Before NaOH added)				
with 2 drops of NaOH				

Questions:

1. When **HCl(aq)** was added to the **buffer**, its pH _____. (Circle below)

   ↑ a lot ↓ a lot stayed about the same

2. When **HCl(aq)** was added to the **water**, its pH _____. (Circle below)

   ↑ a lot ↓ a lot stayed about the same

3. When **NaOH(aq)** was added to the **buffer**, its pH _____. (Circle below)

   ↑ a lot ↓ a lot stayed about the same

4. When **NaOH (aq)** was added to the **water**, its pH _____. (Circle below)

   ↑ a lot ↓ a lot stayed about the same

5. Why did the buffer solution stay about the same in pH when HCl was added? Be specific.

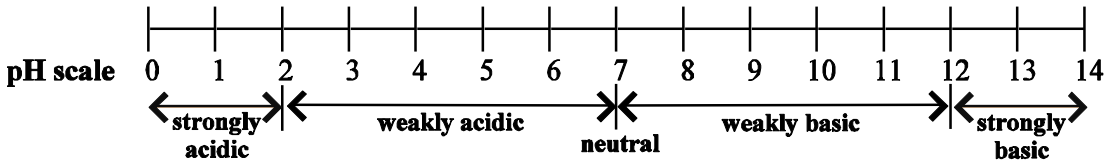
6. Why did the buffer solution stay about the same in pH when NaOH was added? Be specific.

Follow up Questions:

1. Determine the pH for each of the solutions below, and state whether the solution is acidic, basic, or neutral. (Refer to page 1.)

Solution	pH	Acidic, Basic, or Neutral
1.0×10^{-3} M HCl		
1.0×10^{-6} M HCl		
0.0001 M HCl		
0.01 M HCl		
Pure water		

2. Consider the following pH scale below: Consider 2 and 12 to be strong.



Categorize each of the following substances as strongly acidic, weakly acidic, neutral, weakly basic, or strongly basic.

Substance	pH	Category
carbonated water	3.9	
stomach acid	1.3	
saline solution	7.0	
tears	7.4	
saliva	6.8	
Codeine	10.3	
carrots	5.1	
drain cleaner	13	
maple syrup	6.0	
Baking soda in water	8.4	