1.0 Introduction

What does the term pH mean?

Ans: The pH of a substance is a measurement of the acidity of the substance.

Acidic and **basic** solutions occur often in nature. Acids are substances that yield **hydronium** ions, H_3O^+, in an aqueous solution. Bases are substances that can accept a proton in an aqueous solution. The most familiar base is the hydroxide ion, OH^-. However, there are many other bases.

Acids and bases will react with one another. This process is called *neutralization*.

The acidity of a solution is measured by the amount of H_3O^+ ion present in the solution. The greater the concentration of the hydronium ion, the more acidic the solution. Another way to talk about the strength of an acid is pH. The pH of a solution is defined by the formula:

$$pH = -\log [H_3O^+] \qquad (1)$$

where [ ] stands for molarity (M or Concentration)

If we know the pH of a solution, we can calculate the $[H_3O^+]$ using the formula:

$$[H_3O^+] = 10^{-pH} \qquad (2)$$

Let us try using these two equations::

- Example 1: A solution has $[H_3O^+] = 1.7 \times 10^{-4}$ what is the pH of this solution?

Answer: Using Equation 1, we substitute the value of the concentration into the formula:

$$pH = -\log (1.7 \times 10^{-4})$$

Using your calculator, take the log of the concentration and change the sign to get:

$$pH = 3.77$$

- Example 2: If pH = 2.69, what is the hydronium ion concentration?

Answer: The inverse log key may be labeled 10^x.

Using Equation 2, we substitute the value of the pH into the formula:

$$[H_3O^+] = 10^{-2.69}$$

Use your calculator to take the inverse log of −2.69 to get:

$$[H_3O^+] = 2.0 \times 10^{-3}$$

Take care not to forget the negative sign of the inverse log.

What about determining the pH of a **basic solution?** We must first solve for the hydroxide ion concentratio, and then use the following relationship to solve for the hydronium ion concentration.

$$[H_3O^+] \times [OH^-] = 1.0 \times 10^{-14} = K_w \qquad (3)$$

The above value for K_w is valid *only at 25° C*. Once the hydronium ion concentration is known you can use the procedure given in the previous example.

- Example 3: What is the pH of 0.20 M NaOH?

Answer: First determine the hydroxide ion concentration.

$$[OH^-] = 0.20\ M$$

Now, rearrange Equation 3 and solve for the hydronium ion concentration.

$[H_3O^+] = 1.0 \times 10^{-14} / [OH^-]$ $\qquad$ $pH = -\log [H_3O^+]$

$[H_3O^+] = 1.0 \times 10^{-14} / 0.20$ $\qquad$ $pH = -\log 5.0 \times 10^{-14}$

$[H_3O^+] = 5.0 \times 10^{-14}$

therefore: $pH = 13.30$

Alternatively, you can take the logarithm of Equation (3):

$$\log[H_3O^+] + \log[OH^-] = \log (1.0 \times 10^{-14})$$

$$\log[H_3O^+] + \log[OH^-] = -14.00$$

$$-\log[H_3O^+] - \log[OH^-] = +14.00$$

$$pH + pOH = 14.00 \qquad (4)$$

From the previous example, $[OH^-] = 0.20$, so $pOH = 0.70$, $pH = 13.30$.

Table I summarizes the acid-base pH scale between 0 and 14. The scale begins with 0 and ends with 14 merely for convenience. It is certainly possible to have a pH less than zero or greater than 14! Consider 10M HCl.

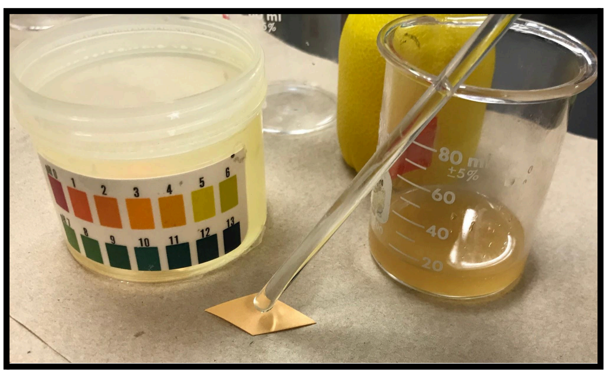
pH Values														
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
		increasing acidity					neutral					increasing basicity		

Table I

In this experiment you will be using **two** of the three most common ways to measure the pH of a solution:

- The first method will be the **pH meter**. This is a delicate instrument. Handle the (expensive) electrode carefully. You read the pH of the solution directly from the readout of a pH meter.

- The next method is **pH paper**. You will match the color the paper turns to the scale on the dispenser to determine the pH. The best method is transfer material using a clean glass rod like so:



- A third method that is the most challenging is to use **indicators to judge pH**. The challenge with this method is for you must both judge colors and work with inequalities. The pH paper is actually a blotter paper that contains various pH indicators. Indicators are acids and bases which gain and lose protons to produce color changes. Many indicators are found in colored plants such as red cabbage or flower petals.

2.0 Procedure

2.1 Measuring the pH with a meter

In order to measure pH with the pH meters, you will use a pH electrode probe attached to the meter. Be careful these are sensitive glass electrodes.

They work by absorbing the solution to be tested into the porous electrode and should be washed with DI water between solutions to be tested. Since these electrodes are biased toward acid or base when they measure (absorb) acidic or basic solutions, the electrode should be calibrated with either and acidic or basic calibration buffers and then used to measure ONLY solutions of similar pH ranges.

The meters will be calibrated and marked, one meter for base and one for acid solutions. Always use the basic meter to measure the pH of the bases and the acid meter for measuring the acid solutions. Also when using the electrode, make sure the glass tip is completely submerged in the solution being tested.

2.2 Preparation of the Sodium Hydroxide Solutions

Procure::

1. Four test tubes
2. Four 50 or 100 mL beakers
3. One 10 mL graduated cylinder
4. One 100 mL cylinder
5. One glass stirring rod.

Clean and dry all of the glassware.

Measure 20.0 mL of 0.1 M NaOH into your clean, dry 100 mL graduated cylinder. Pour this solution into a clean, dry 50 mL beaker. Label the beaker 0.1 M NaOH.

You will now do a series of **dilutions**.

Label one of the clean, dry 50 mL beakers 0.01 M NaOH, another 0.001 M NaOH and a third 0.0001 M NaOH. Each time you use a graduated cylinder or a stirring rod, make sure you clean and dry it before the next use.

0.01 M solution: Using the 10 mL graduated cylinder measure out 2.0 mL of the 0.1 M NaOH solution and pour it into the beaker labeled 0.01 M NaOH. Then, you need to add 18.0 mL of DI water and stir well. Remember to rinse and dry the cylinders and the stirring rod between uses.

0.001 M solution: Take 2.0 mL of 0.01 M NaOH and pour it into the beaker labeled 0.001 M NaOH. Add 18.0 mL of DI water to this beaker and stir well.

0.0001 M solution: For the last dilution, take 2.0 mL of the 0.001 M NaOH and pour it into the beaker labeled 0.0001 M NaOH. Add 18.0 mL of DI water to this beaker and stir well.

You now have the four NaOH solutions to be analyzed.

2.3 Analysis of the NaOH Solutions

As already stated, measure the pH of these solutions using the pH meter and pH paper.

Measure and record the pH of each solution on the report sheet using the meter setup to measure basic solutions.

Use the stirring rod to place a drop of solution on the paper. Label the drop.

Remember to clean and dry the stirring rod between each use. Now, take the paper to the dispenser and determine the pH of each solution by matching the color to the chart on the dispenser.

2.4 Preparation of the Hydrochloric Acid Solutions

Procure::

1. Four test tubes
2. Four 50 or 100 mL beakers
3. One 10 mL graduated cylinder
4. One 100 mL cylinder
5. One glass stirring rod

Clean and dry all of the glassware.

Measure 20.0 mL of 0.1 M HCl into your clean, dry 100 mL graduated cylinder. Pour this solution into a clean, dry 50 mL beaker. Label the beaker 0.1 M HCl.

You will now do a series of dilutions.

Label one of the clean, dry 50 mL beakers 0.01 M HCl, another 0.001 M HCl and a third 0.0001 M HCl. Each time you use a graduated cylinder or a stirring rod, make sure you clean and dry it before the next use.

0.01 M solution: Using the 10 mL graduated cylinder measure out 2.0 mL of the 0.1 M HCl solution and pour it into the beaker labeled 0.01 M HCl. Then, you need to add 18.0 mL of DI water and stir well. Remember to rinse and dry the cylinders and the stirring rod between uses.

0.001 M solution: Take 2.0 mL of 0.01 M HCl and pour it into the beaker labeled 0.001 M HCl. Add 18.0 mL of DI water to this beaker and stir well.

0.0001 M solution: For the last dilution, take 2.0 mL of the 0.001 M HCl and pour it into the beaker labeled 0.0001 M HCl. Add 18.0 mL of DI water to this beaker and stir well.

You now have the four HCl solutions to be analyzed.

2.5 Analysis of the HCl Solutions

As already stated, measure the pH of these solutions using the pH meter and pH paper. Use the pH meter devoted to measuring the acidic solutions. Do not use the one for the basic solutions! Measure and record the pH of each solution on the report sheet.

Next, take approximately 2 inches of pH paper to your lab station.

Use the stirring rod to place a drop of solution on the paper. Label the drop.

Remember to clean and dry the stirring rod between each use.

Now, take the paper to the dispenser and determine the pH of each solution by matching the color to the chart on the dispenser.

2.6 Determination of the pH of Common Household Substances

Using the pH paper, determine the pH of the substances on the report sheet and anything else that you brought from home.

Any dry material needs to be wetted with DI water first.

3.0 Before You Leave

Place all solutions in the designated waste container. Then return all the beakers, tubes and cylinders to their proper storage locations.

Make sure to clean up your work area including spilled water and ESPECIALLY any spilled acids or bases.

4.0 Calculations

Calculate the pH that each of the diluted solutions should have given. Which way of measuring pH the paper or the pH electrode gave the most consistent value for pH?

5.0 Report Sheet

		pH		
	$[H_3O^+]$	Calculated pH	pH paper	pH meter
1.	0.1 M			
2.	0.01 M			
3.	0.001 M			
4.	0.0001 M			
	$[OH^-]$			
5.	0.1 M			
6.	0.01 M			
7.	0.001 M			
8.	0.0001 M			

Substance	pH from pH Paper	Acidic or Basic?
Lemon Juice		
Orange or Grapefruit Juice		
De-Ionized Water		
Cola Soda Pop		
Non-Cola Soda Pop (7up or Sprite)		
Coffee		
Tea		
Detergent (May need to wet)		
Soap - any (May need to wet)		
Vinegar		
Milk of Magnesia		
Baking Soda (solution)		