# 1.0 Introduction

What does the term pH mean? We hear it used all the time, such as: men shouldn't use a type of deodorant because it is adjusted for a woman's pH, a certain shampoo is “better” because it is pH balanced and waste water needs to be pH neutral before it can be disposed of properly. 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 react with bases and visa versa. This process is called *neutralization*. When this reaction is done quantitatively, the process is called an acid-base titration.

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

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

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

   Use Equation (1) and 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 .

2) If pH = 2.69, what is the hydronium ion concentration?

   **The inverse log key may be labeled $10^x$.**

   Use Equation (2) and 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: $[H_3O^+] = 2.0 \times 10^{-3}$. Don't forget the negative sign of the inverse log.

Determining the pH of a basic solution involves solving for the hydroxide ion concentration first. 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.

3) What is the pH of 0.20 M NaOH? First determine the hydroxide ion concentration. $[OH^-] = 0.20$ M. Now, rearrange Equation (3) and solve for the hydronium ion concentration.

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

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

$[H_3O^+] = 5.0 \times 10^{-14}$ $\qquad$ therefore: $\qquad pH = 13.30$

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

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

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

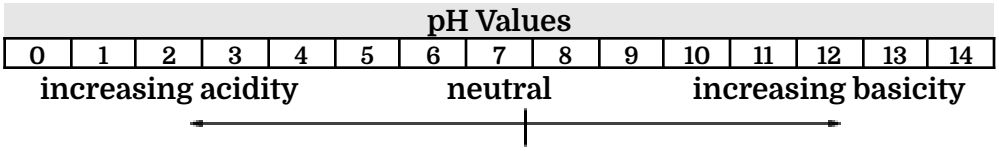
$$-\log[H_3O^+] - \log[OH^-] = +14.00$$

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

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.

**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 MeasureNet station.

The next method is pH paper. You will match the color the paper turns to the scale on the dispenser to determine the pH. As this paper is very expensive, please take only what you need.

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. People often use indicator papers when they test for chlorine or the pH of spas and pools.

# 2.0 Procedure

### 2.1 Preparation of the MeasureNet stations to measure pH

In order to measure pH with the MeasureNet stations you will need a pH electrode probe attached to your station. 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. To do this, each table of two MeasureNet stations will calibrate one station for base and one for acid. From then on, always use the basic station to measure the pH of the bases and the acid station for measuring the acid solutions. Also, when using a pH electrode the electrode tip must be completely submerged in the solution being tested.

**MeasureNet Task:** Setup for pH Measurements

| Your Actions: | | MeasureNet Response: |
|---|---|---|
| Press: **MAIN MENU** | | **LCD:** Shows Function Choices |
| Press: **F3 –** pH/mV | | **LCD:** Shows pH & mV options |
| Press: **F2 –** pH v VOLUME | | **LCD:** Shows SELECT OPTION screen |
| Press: **CALIBRATE** | | **LCD:** Asks for TEMP in Celsius |
| Use keypad to set temperature & Press **ENTER** (Use digital thermometer) | | **LCD:** Asks Enter pH of Buffer |
| Use keypad to set pH 7.0 & Press **ENTER** & Put the pH probe in pH 7.0 buffer soln | | **LCD:** Asks Put probe in buffer When Value Stops Changing Press Enter |
| Swirl the probe in the buffer & When value is steady Press: **ENTER** | | **LCD:** Shows For Single Point Cal. Press F1 or for 2 buffer calibration enter pH etc. |
| Since this is a 2 buffer calibration Use keypad to input pH =4 for acid station and pH = 10 for base station. Press **ENTER** | | **LCD:** Asks Put probe in buffer & When Value Stops Changing Press Enter |
| Put the probe in correct buffer, swirl and when reading is steady Press: **ENTER** | | **LCD:** Shows Select Option screen |
| Press: **DISPLAY** | | **LCD:** Shows pH Measurement screen |

Once the stations are calibrated be careful to measure acids and bases with the appropriate matching station. To read the pH set each station to **DISPLAY** and the pH will be read on the screen.

### 2.2 Preparation of the Sodium Hydroxide Solutions

Get four test tubes, four 50 or 100 mL beakers, one 10 mL graduated cylinder, one 100 mL cylinder and 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. Now, 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. To make it this concentration, 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.

The next dilution will be to take 2.0 mL of 0.01 M NaOH and pour it into the beaker labeled 0.001 M NaOH. Add 18.0 mL to this beaker and stir well. 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 station setup to measure basic solutions.

Take about 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.

### 2.4 Preparation of the Hydrochloric Acid Solutions

Get four test tubes, four 50 or 100 mL beakers, one 10 mL graduated cylinder, one 100 mL cylinder and 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. Now, 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. To make it this concentration, you need to add 18.0 mL of DI water and stir well. Remember to rinse and dry the cylinders and the stirring rod. The next dilution will be to take 2.0 mL of 0.01 M HCl and pour it into the beaker labeled 0.001 M HCl. Add 18.0 mL to this beaker and stir well. 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 MeasureNet station 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.

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! Let's not have the next lab group rubbing their hands and arms in acid spills.

# 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 | | |
|---|---|---|---|---|
| | $[OH^-]$ | pH paper | pH meter | Calculated pH |
| 1. | 0.1 M | | | |
| 2. | 0.01 M | | | |
| 3. | 0.001 M | | | |
| 4. | 0.0001 M | | | |
| | $[H_3O^+]$ | pH paper | pH meter | Calculated pH |
| 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 | | |
| bar soap | | |
| vinegar | | |
| de-ionized water | | |
| non-cola soda pop | | |
| cola soda pop | | |
| orange or grapefruit juice | | |
| detergent | | |
| milk of magnesia | | |
| coffee | | |
| tea | | |
| baking soda (solution) | | |