ANALYTICAL CHEMISTRY

Chemical Engineering Department

First Glass / third Term

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LECTURE THRE

…, pOH, and Buffer Solutions

pH (potential of hydrogen) is a numeric scale used to specify the acidity or basicity of an aqueous solution. It is approximately the negative of the base 10 logarithm of the molar concentration, measured in units of moles per liter of hydrogen ions. Solutions with a pH less than 7 are acidic and solutions with a pH greater than 7 are basic. Pure water is neutral, at pH 7 (25 °C), being neither an acid nor a base. The pH value can be less than 0 or greater than 14 for very strong acids and bases respectively.

Measurements of pH are important in medicine, biology, chemistry, agriculture, food science, civil engineering, chemical engineering, water treatment and purification, and many other applications.

The term "pH" comes from the German word potenz, which means "power" combined with H, the symbol for hydrogen, so pH is an abbreviation for "power of hydrogen". Examples of pH values of lab chemicals and household products include:

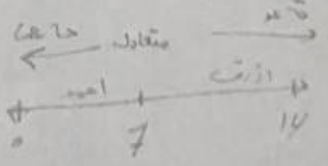
material	pH	material	pH
hydrochloric acid	0	lemon juice	2
vinegar	2.2	pure water (neutral)	7
human blood	7.4	sodium hydroxide	14

pH only has meaning in an aqueous solution (in water). Not all liquids have a pH value, i.e. many chemicals, including liquids, do not have pH values. e.g., there is no pH value for vegetable oil, gasoline, or pure alcohol.

The equation for calculating pH was proposed in 1909: $pH = -\log[H^+]$

How to measure pH

Rough pH measurements may be made using litmus paper or another type of pH paper that is known to change colors around a certain pH value. Most indicators and pH papers are only useful to tell whether a substance is an acid or a base. More accurate measurements are made using pH meter, whose electrode works by measuring the potential difference between a hydrogen electrode and a standard electrode.

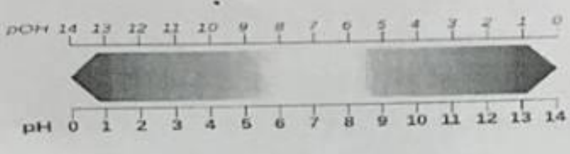


Finding the pH in acids: $pH = -\log[H^+]$

Finding the $[H^+]$ in acids: $[H^+] = 10^{-pH}$

pOH is sometimes used as a measure of the concentration of hydroxide ions, OH^-. pOH values are derived from pH measurements. The concentration of hydroxide ions in water is related to the concentration of hydrogen ions

(red = acidic region, blue = basic region)



Relation between p[OH^-] and p[H^+] $14 = pH + pOH$

Finding the pH in bases: $pOH = -\log[OH^-]$ $pH = 14 - pOH$

Finding the [OH^-] in bases: pH= [H^+] [OH^-] $[H^+][OH^-] = 1 \times 10^{-14}$

$[H^+] = 1$ M $pH = -\log(\mathbf{1}) = 0$ $[H^+] = 10^{-pH} = 10^{-0} = 1$ M

$[H^+] = 0.05$ M $pH = -\log(\mathbf{0.05}) = 1.3$ $[H^+] = 10^{-pH} = 10^{-1.3} = 0.05$ M

Problem 1: A solution of acetic acid (CH_3O_2H) has an H^+ concentration of 5×10^{-5} M. What is the pH of the solution?

Asked: pH of a solution

Given: $[H^+] = 5 \times 10^{-5}$ M

Solve: $pH = -\log[H^+]$

$pH = -\log(5 \times 10^{-5}) = 4.3$ This solution has a pH of 4.3, a relatively weak acid.

Problem 2: A solution of nitric acid (HNO_3) has a pH of 3. What will the pH be if you add 10 mL of the solution to 90 mL of pure water?

Asked: pH of the new solution

Given: old pH = 3

100 mL of the new solution contains 10 mL of the old solution

Relationships: A pH value is a power of 10.

A change in 1 pH unit means the concentration changes by a factor of 10.

Solve: Diluting an acidic solution means the pH increases (fewer H^+)

The new pH is 4 (not 2). The new solution has a pH of 4.

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Problem 3: Find the ~~pH~~ pOH of a 0.012 M sodium hydroxide (NaOH) solution.

Asked: ~~pH~~ pOH of the solution

Given: NaOH is a strong base that dissociates 100% in aqueous solution $[OH^-] = 0.012$ M

Relationships: $pOH = -\log[0.012] = 1.92$

$14 = pH + pOH$

Solve: $pH = 14.00 - 1.92 = 12.08$ the solution has a pH of 12.08 and is a strong base

Problem 4:

What is the pH of a solution of 0.36 M HCl, 0.62 M NaOH, and 0.15 M HNO_3? ? ?

Hydrochloric acid and nitric acid are strong acids, and sodium hydroxide is a strong base; these all dissociate completely. The total $[H^+]$ from the two acids is 0.51 M and $[OH^-]$ from NaOH is 0.62 M. Therefore, 0.51 moles per liter of H^+ will react with 0.51 moles per liter of OH^- to form water. That leaves a 0.11 M NaOH solution $(0.62 - 0.51) = 0.11$ M.

$pH = -\log[H^+] = -\log[0.11] = 0.96$

The pOH of a 0.11 M NaOH solution = 14 - pH = 13.04

Buffer Solution

A buffer solution is an aqueous solution consisting of a mixture of a weak acid and its conjugate base, or vice versa. Its pH changes very little when a small amount of strong acid or base is added to it. Buffer solutions are used as a means of keeping pH at a nearly constant value in a wide variety of chemical applications. In nature, there are many systems that use buffering for pH regulation. For example, the bicarbonate buffering system is used to regulate the pH of blood.

Types			
	Acidic Buffer (pH < 7)	weak acid +	its sodium or potassium salt
		ethanoic acid	sodium ethanoate
	Alkaline Buffer (pH > 7)	weak base +	its chloride
		ammonia	ammonium chloride

Acidic buffer solutions

An acidic buffer solution is one which has a pH less than 7, and commonly made from a weak acid and one of its salts often a sodium salt. A common example would be a mixture of ethanoic acid and sodium ethanoate in solution. In this case, if the solution contained equal molar concentrations of both the acid and the salt, it would have a pH of 4.76. It wouldn't matter what the concentrations were, as long as they were the same.

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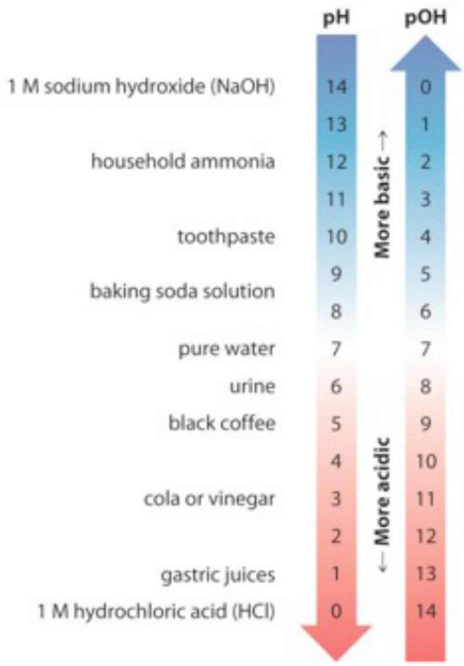
Relationship Between pH and pOH for Acids and Bases

pH vs. pOH scale:

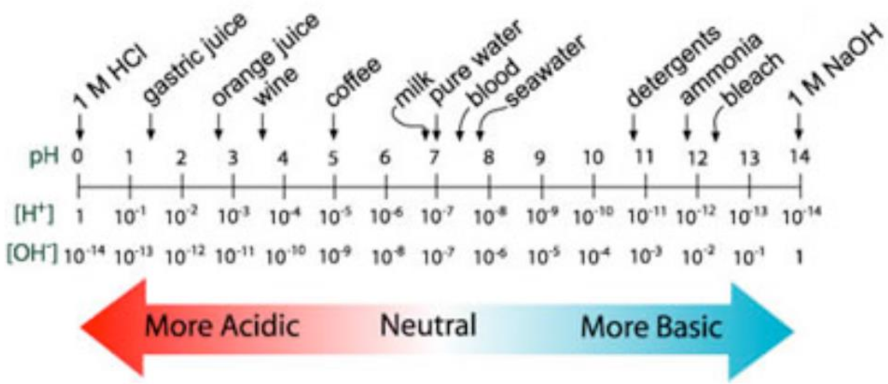
Both acids and bases can measured using the pH or pOH scale. Both scales provide a measure of either the H+ concentration or the OH- concentration.
Notice that each scale shows were acids and bases both are located.

- **When acids are measured, the pH is less than 7, but the pOH is greater than 7.**
- **When bases are measured, the pH is greater than 7, but the pOH is less than 7.**

Both scales are dependent on what ion you are measuring.



[H+] vs. [OH-]:



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pH and pOH are related to one another; **THEY ARE NOT INDEPENDENT OF EACH OTHER**. As pH increases, pOH decreases. As pH decreases, pOH increases. By knowing what ion you are measuring on which scale, this will tell you whether or not the solution is acidic or basic.

Ion Concentration	Solution Type	pH	pOH
[H+] > [OH-]	**Acidic**	pH < 7	pOH > 7
[H+] < [OH-]	**Basic**	pH > 7	pOH < 7
[H+] = [OH-]	**Neutral**	pH = 7	pOH = 7

Because these scales are related, an equation can be used to explain their correlation.

$$pH + pOH = 14$$

$$pH = 14 - pOH$$

$$pOH = 14 - pH$$

The bottom equations are manipulations of the top equation

The **KEYS** to calculations are knowing:

1. Knowing what type of solution you are working with
2. What equation to use first

Example Calculations:

1. Calculate the pH and pOH of a 0.33 M H_2SO_4 solution.

- Are you working with an acid or a base? ____________
- Are you given the concentration, or *Molarity* of that solution? ____________
- Next, plug the concentration or Molarity into the correct equation.

Because this is an acidic solution, we have to calculate pH first.

$$pH = -\log[0.33] = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

Now we can calculate the pOH, because we have calculated the pH.

$$pOH = 14 - pH = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

2. Calculate the pH and pOH of a 0.25 M NaOH solution.

- Are you working with an acid or a base? ____________
- Are you given the concentration, or *Molarity* of that solution? ____________
- Next, plug the concentration or Molarity into the correct equation.

Because this is a basic solution, we have to calculate pOH first.

$$pOH = -\log[0.25] = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

Now we can calculate the pH, because we have calculated the pOH.

$$pH = 14 - pOH = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$