This is OUR Improved version:

pH

Introduction:

The purpose of this exercise is to examine pH and logarithms.

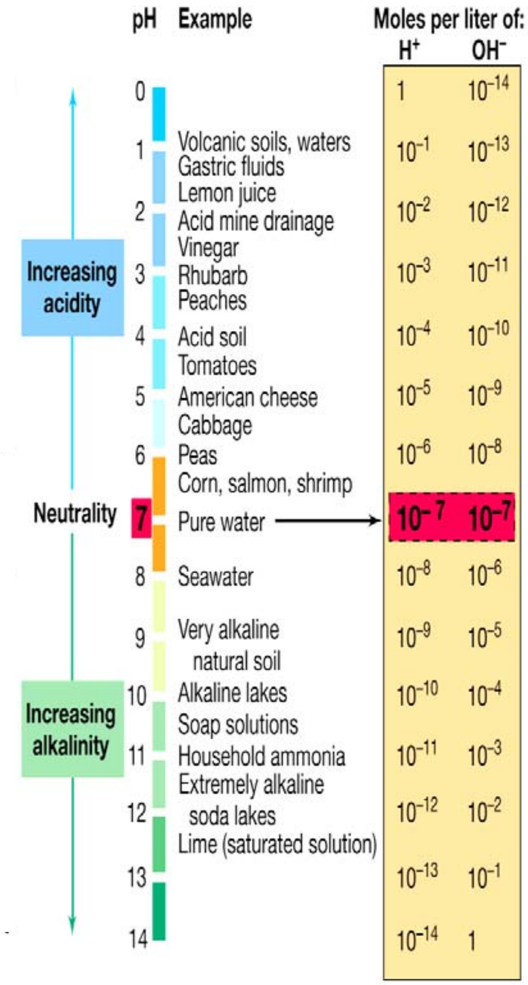
Objectives:

- Understand the mathematical meaning of logarithm.
- Be familiar with logs in base 10.
- Understand the significance of logarithm in biology.
- Calculate pH and understand different pH values.

pH: What is it? Why is it important in biology?

The pH scale is a measurement scale used to quantify the concentration of hydrogen ions, [H+], in a solution. It is a logarithmic scale, based on powers of 10, so that one pH unit change equals a 10 fold change in H+ ion concentration. So, increasing the amount of hydrogen ions (H+) in the solution lowers the pH. Human blood pH is about 7.4, being slightly alkaline. Metabolic disturbances in the body can create conditions where H+ is produced in excess thus, lowering the pH of the blood. If pH goes outside of the normal range significantly, enzymes, hormones, and other molecules can denature and become dysfunctional. What is critical to comprehend is that **small changes in pH** can signify **large changes in H+ concentration**; this is best understood by working problems involving pH.

Notice we added a figure of pH scale from their book.



Solving for pH:

Given the [H+], or concentration of hydrogen ions in a solution (expressed as moles per liter or Molarity (M)), pH can be determined as:

pH = - log [H+] = log 1/[H+]

Example:

What is the pH of a solution for which the hydrogen ions are present at a concentration of 0.000005 moles per liter (Molar, M)?

Solution:

pH = - log [H+]
= - log (0.000005)
= - (-5.30) = 5.3

Given the [OH-], or hydroxyl ion concentration in a solution (expressed as Molarity (M)), pH can be determined as:

Calculate the [H+] from the equation below.

$$[H+][OH-] = 1 \times 10^{-14} M^2$$

$$[H+] = 1 \times 10^{-14} M^2 / [OH-]$$

Then, plug in the [H+] into the pH equation below.

pH = - log [H+] = log 1/[H+]

Example:

What is the pH of a solution for which the hydroxyl ions are present at a concentration of 0.000005 moles per liter (M)?

Solution:

$[H+][OH-] = 1 \times 10^{-14} M^2$
$[H+] = 1 \times 10^{-14} M^2 / [OH-]$
$[H+] = 1 \times 10^{-14} M^2 / (0.000005\ M)$
$[H+] = 0.000000002\ M$ or $2.0 \times 10^{-9}\ M$

$pH = -\log [H+]$
$= -\log (2.0 \times 10^{-9})$
$= -(-8.7) = 8.7$

Solving for [H+]:

Given the pH for a solution, the concentration of hydrogen ions, H+, in moles per liter or solution molarity, M, can be determined as

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

Example:

What is the hydrogen ion concentration of a solution of pH 7.10?

Solution:

$[H+] = 10^{(-pH)}$
$= 10^{(-7.1)}$
$= 0.000000079432 = 7.9432 \times 10^{-8}\ M$

Solving for pH changes:

Given two pH measurements, the change in [H+] can be determined by:

1. Calculate the [H+] for each separate pH.
2. Calculating the percent change in [H+] from one pH to the other pH.

The percent change in [H+] can be calculated as:

% change = 100(new [H+] – original [H+])/original [H+]

Example:

What is the percent change in [H+] if the pH of a solution, such as blood, changes from pH 7.35 to pH 7.15 (a 2% drop in pH)?

Solution:

At pH 7.35, [H+] = $10^{-7.35}$ = 0.000000045 or 4.5×10^{-8} M

At pH 7.15, [H+] = $10^{-7.15}$ = 0.000000071 or 7.1×10^{-8} M

% change [H+]= 100(new [H+]-original [H+])/original[H+]
= $100(7.1 \times 10^{-8} - 4.5 \times 10^{-8}) / 4.5 \times 10^{-8}$
= 100 (0.58)
= 58 %

58% change in [H+] for a 2% pH change. WOW! That's a BIG DIFFERENCE!

Problems:

Notice that we have added problems that follow the stepwise process.
Level one problems are under the tadpole.
Level two problems are under the froglets.
Level three problems are under the frog.

1. What is the pH of a solution with a hydrogen ion concentration, [H+], of 1X 10^{-7} M?

2. The [H+] = 1 X 10^{-5} M. What is the pH of the solution?

3. What is the pH of a solution with a hydrogen ion concentration of 5.5 X 10^{-6} M?

4. What is the pH of a solution with a hydroxyl ion concentration, [OH-], of 1 X 10^{-3} M?

5. The [OH-] = 1 X 10^{-10} M. What is the pH of the solution?

6. What is the hydrogen ion concentration of a solution at pH 5?

7. What is the hydrogen ion concentration of a solution at pH 7.4?

8. What is the hydrogen ion concentration of a solution at pH 7.2?

9. What is the hydroxyl concentration, [OH-], of a solution at pH 8?

    a. What equation would you use to figure out the hydrogen ion concentration of a solution at pH 8?
    b. What is the hydrogen ion concentration, [H+], of a solution at pH 8?
    c. What equation would you use to figure out the hydroxyl ion concentration, [OH-], of the solution with a [H+] in the above question (7b)?
    d. What is the [OH-]?

10. Human stomach fluid pH is about 2.0. The pH of human saliva is about 8.0.

    a. Is the stomach fluid acidic or basic (alkaline)?
    b. Given the answer above, is this an acid or base which is strong or weak?
    c. Is human saliva acidic or basic (alkaline)?
    d. Given the answer above, is this an acid or base which is strong or weak?
    e. What is the hydrogen ion concentration ([H+]) of human saliva? Of human stomach fluid?
    f. Which has more hydrogen ions, saliva or stomach fluid?
    g. How many times more H+ ions (per unit volume) does stomach fluid have than human saliva?

11. What is the percent change in [H+] if the pH of a solution, such as blood, changes from pH 7.4 to pH 7.2?
    a. What is the [H+] of a solution at pH 7.4?
    b. What is the [H+] of a solution at pH 7.2?
    c. What is the % change of [H+]?

12. What is the percent change in [H+] if the pH of a solution, such as blood changes from pH 7.4 to pH 7.0?

13. Anthrax toxin, PA, is a protein that is sensitive to pH changes in its environment. If the pH of a solution is 7.4, then the PA toxin is active. If the pH of the solution is 7.2, then the PA toxin is inactive. Why is this very small change in pH a significantly large environmental change for this toxin to function properly?

    a. What is the [H+] for pH = 7.4?
    b. What is the [H+] for pH = 7.2?
    c. What is the % change of [H+]?