Name:

Skill Sheet 23-C Calculating pH

The pH of a solution is a measure of the concentration of hydrogen ions (H+) in the solution. The pH scale, which ranges from 0 to 14, provides a tool to assess the degree to which a solution is acidic or basic. As you may remember, solution's with low pH values are very acidic and contain high concentrations of hydrogen ions. Why does a **low** pH value mean a **high** concentration of H+? The answer has to do with what pH means mathematically. In this skill sheet, we will examine the mathematical method that explains how pH values are calculated,

1. What is the formula for pH?

The pH value for any solution is equal to the negative logarithm of the hydrogen ion (H+) concentration in that solution. The formula is written this way:

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

Concentration of hydrogen ions is implied by placing brackets ("[ ]") around H+.

A term used by scientists to describe the concentration of a substance in a solution is *molarity*. Molarity (M) means how many moles of a substance are present in a given volume of solution.

For hydrogen ions in solutions, the concentration generally ranges from 10 to 10^{-14} M. The larger the molarity, the greater the concentration of H+ in the solution. If a solution had a H^+ concentration of 10^{-3} M, the corresponding pH value would be:

$$pH = -\log[10^{-3}]$$

$$10^{pH} = -[10^{-3}]$$

$$pH = -[-3]$$

$$pH = 3$$

For a solution with an H^+ concentration of 10^{-5} M, the corresponding pH value would be:

$$pH = -\log[10^{-5}]$$

$$10^{pH} = -[10^{-5}]$$

$$pH = -[-5]$$

$$pH = 5$$

The first solution has a higher H^+ concentration than the second solution (10^{-3} M versus 10^{-5} M); however, its pH value is a smaller number. Strong acids have small pH values. Larger pH values (like 14) have lower concentrations of H^+, and the solutions represent weaker acids.

2. Practice problems

1. Practice working with numbers that have exponents. In the blank provided, write greater than, less than, or equal to.
   a. 10^{-2} _____ 10^{-3}
   b. 10^{-14} _____ 10^{1}
   c. 10^{-7} _____ 0.0000001
   d. 10^{0} _____ 10^{1}
2. Solutions that range in pH from 0 to 7 are acidic. Solutions that range in pH from 7 to 14 are basic. Solutions that have pH of 7 are neutral. The hydrogen ion concentrations for some solutions are given below. Use the pH formula to determine which is an acid, which is a base, and which is neutral.
   a. Solution A: The hydrogen ion concentration is equal to 10^{1}.
   b. Solution B: The hydrogen ion concentration is equal to 0.0000001
   c. Solution C: The hydrogen ion concentration is equal to 10^{-13}.
3. Orange juice has a hydrogen ion concentration of approximately 10^{-4} M. What is the pH of orange juice?

4. Black coffee has a hydrogen ion concentration of roughly 10^{-5} M. Is black coffee a stronger or weaker acid than orange juice? Justify your answer and provide all relevant calculations for supporting evidence.

5. Pure water has a hydrogen ion concentration of 10^{-7} M. What is the pH of water? Would you say water is an acid or a base? Explain your answer.

6. A solution has a pH of 11. What is the H^{+} concentration of the solution? Is this solution an acid or a base?

7. A solution has a pH of 8.4. What is the H^{+} concentration of this solution?

8. Acids are very good at removing hard water deposits from bathtubs, sinks, and glassware. Your father goes to the store to buy a cleaner to remove such deposits from your bathtub. He has a choice between a product containing lemon juice ($H^{+} = 10^{-2.5}$ M) and one containing vinegar ($H^{+} = 10^{-3.3}$ M). Which product would you recommend he purchase? Explain your answer.