

10.5: Working with pH

Learning Objectives

- Calculate pH from $[H_3O^+]$ and $[H_3O^+]$ from pH.

Calculating pH from Hydronium Concentration

The pH of solutions can be determined by using logarithms as illustrated in the next example for stomach acid. Stomach acid is a solution of HCl with a hydronium ion concentration of $1.2 \times 10^{-3} M$, what is the pH of the solution?

$$\begin{aligned} pH &= -\log[H_3O^+] \\ &= -\log(1.2 \times 10^{-3}) \\ &= -(-2.92) = 2.92 \end{aligned} \quad (10.5.1)$$

Logarithms

To get the **log value** on your calculator, enter the number (in this case, the hydronium ion concentration) first, then press the LOG key.

If the number is 1.0×10^{-5} (for $[H_3O^+] = 1.0 \times 10^{-5} M$) you should get an answer of "-5".

If you get a different answer, or an error, try pressing the LOG key before you enter the number.

✓ Example 10.5.2: Converting Ph to Hydronium Concentration

Find the pH, given the $[H_3O^+]$ of the following:

- $1 \times 10^{-3} M$
- $2.5 \times 10^{-11} M$
- $4.7 \times 10^{-9} M$

Solution

Steps for Problem Solving	
Identify the "given" information and what the problem is asking you to "find."	<p>Given:</p> <ol style="list-style-type: none"> $[H_3O^+] = 1 \times 10^{-3} M$ $[H_3O^+] = 2.5 \times 10^{-11} M$ $[H_3O^+] = 4.7 \times 10^{-9} M$ <p>Find: ? pH</p>
Plan the problem.	<p>Need to use the expression for pH (Equation ???).</p> $pH = -\log [H_3O^+]$
Calculate.	<p>Now substitute the known quantity into the equation and solve.</p> <ol style="list-style-type: none"> $pH = -\log [1 \times 10^{-3}] = 3.0$ (1 decimal places since 1 has 1 significant figure) $pH = -\log [2.5 \times 10^{-11}] = 10.60$ (2 decimal places since 2.5 has 2 significant figures) $pH = -\log [4.7 \times 10^{-9}] = 8.30$ (2 decimal places since 4.7 has 2 significant figures) <p>The other issue that concerns us here is significant figures. Because the number(s) before the decimal point in a logarithm relate to the power on 10, the number of digits <i>after</i> the decimal point is what determines the number of significant figures in the final answer:</p> <div style="text-align: center;"> $\begin{array}{c} X.YYY \\ \swarrow \quad \searrow \\ Y.YY \times 10^x \end{array}$ </div>

? Exercise 10.5.2

Find the pH, given $[H_3O^+]$ of the following:

- $5.8 \times 10^{-4} \text{ M}$
- 1.0×10^{-7}

Answer a

3.22

Answer b

7.00

Calculating Hydronium Concentration from pH

Sometimes you need to work "backwards"—you know the pH of a solution and need to find $[H_3O^+]$, or even the concentration of the acid solution. How do you do that? To convert pH into $[H_3O^+]$ we solve Equation ??? for $[H_3O^+]$. This involves taking the **antilog** (or inverse log) of the negative value of pH.

$$[H_3O^+] = \text{antilog}(-pH) \quad (10.5.2)$$

or

$$[H_3O^+] = 10^{-pH} \quad (10.5.3)$$

As mentioned above, different calculators work slightly differently—make sure you can do the following calculations using **your** calculator.

📌 Calculator Skills

We have a solution with a pH = 8.3. What is $[H_3O^+]$?

With some calculators you will do things in the following order:

- Enter 8.3 as a negative number (use the key with both the +/- signs, not the subtraction key).
- Use your calculator's 2nd or Shift or INV (inverse) key to type in the symbol found above the LOG key. The shifted function should be 10^x .
- You should get the answer 5.0×10^{-9} .

Other calculators require you to enter keys in the order they appear in the equation.

- Use the Shift or second function to key in the 10^x function.
- Use the +/- key to type in a negative number, then type in 8.3.
- You should get the answer 5.0×10^{-9} .

If neither of these methods work, try rearranging the order in which you type in the keys. Don't give up—you must master your calculator!

✓ Example 10.5.3: Calculating Hydronium Concentration from pH

Find the hydronium ion concentration in a solution with a pH of 12.6. Is this solution an acid or a base? How do you know?

Solution

Steps for Problem Solving	
Identify the "given" information and what the problem is asking you to "find."	Given: pH = 12.6 Find: $[H_3O^+] = ? \text{ M}$
Plan the problem.	Need to use the expression for $[H_3O^+]$ (Equation 10.5.3). $[H_3O^+] = \text{antilog}(-pH)$ or $[H_3O^+] = 10^{-pH}$

Steps for Problem Solving

Calculate.

Now substitute the known quantity into the equation and solve.

$$[\text{H}_3\text{O}^+] = \text{antilog}(12.60) = \underline{2.5} \times 10^{-13} \text{ M (2 significant figures since 4.7 has 12.60 2 decimal places)}$$

or

$$[\text{H}_3\text{O}^+] = 10^{-12.60} = \underline{2.5} \times 10^{-13} \text{ M (2 significant figures since 4.7 has 12.60 2 decimal places)}$$

The other issue that concerns us here is significant figures. Because the number(s) before the decimal point in a logarithm relate to the power on 10, the number of digits *after* the decimal point is what determines the number of significant figures in the final answer:

$$\begin{array}{c} \text{X.YYY} \\ \swarrow \quad \searrow \\ \text{Y.YY} \times 10^x \end{array}$$

? Exercise 10.5.3

If moist soil has a pH of 7.84, what is $[\text{H}_3\text{O}^+]$ of the soil solution?

Answer

$$1.5 \times 10^{-8} \text{ M}$$

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