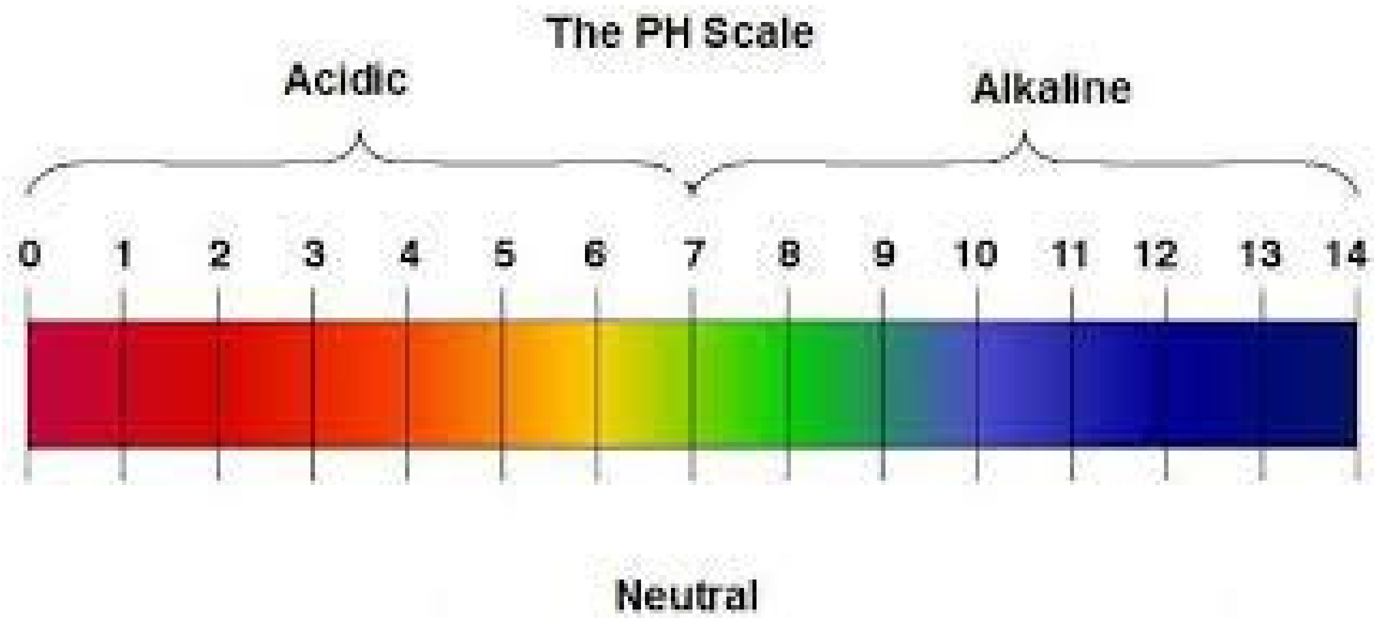
pH – The “Power” of Hydrogen



Outcomes:

- Discuss the hydronium and hydroxide concentrations in water. Include the ion product of water.
- Given and one of the values pH, $[H_3O^+]$, $[OH^-]$, find the remaining values.

Logarithms:

100 x^y 10^x

- Like **EXPONENTS**, logs are a way of working with very **LARGE** or **SMALL** numbers.
- A number's logarithm is its **EXPONENT** when **10** is the **BASE**. For example:

$$\log(10\,000) = 4 \qquad 10\,000 = 10^{4}$$

- The logs of some other numbers are not **WHOLE** numbers, but the **PROCESS** is the same:

$$\log(250) = 2.3979 \qquad 250 = 10^{2.3979}$$

Logarithms:

- A number **GREATER** than 1 represents a **POSITIVE** log, and a number **LESS** than 1 represents a **NEGATIVE** log:

$\frac{1}{10^3} = 0.001$

log(0.001) = -3 **$0.001 = 10^{-3}$**

log(0.000 25) = -3.602 **$0.001 = 10^{-3.602}$**

Try these ones…

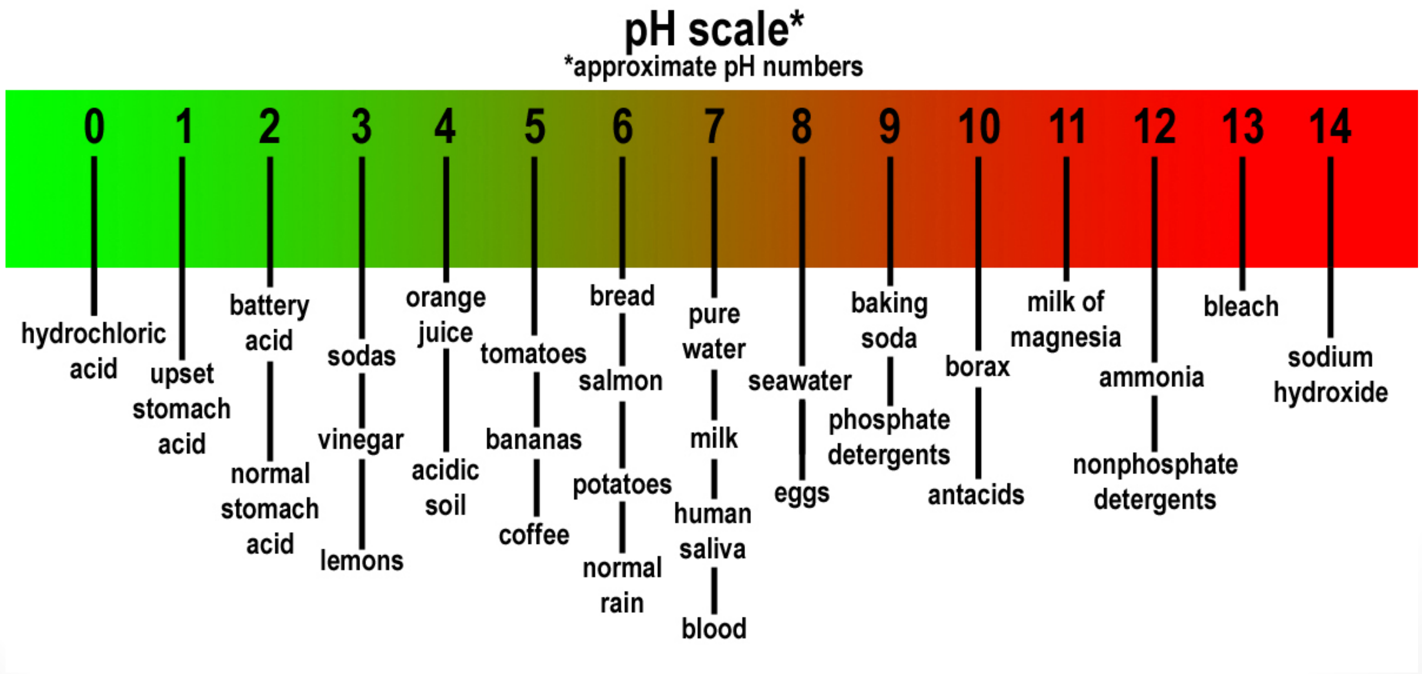
Find the log of the following:

1. 1.3×10^{-5} = -4.89
2. 7.2×10^{-11} = -10.14
3. 0.0054 = -2.27

$10^x \Rightarrow 10^{-2.27} = 0.0051$

pH:

- pH scale is a **LINEAR** scale from **0 TO 14.**
- It reflects the **CONCENTRATION** of **[H_3O^+]** and **[OH^-]** in a solution.
- **PURE WATER** is considered to be **NEUTRAL** (**pH = 7**).
- The **HIGHER** the pH, the more **ALKALINE** (**BASIC**), the **LOWER** the pH, the more **ACIDIC** the solution.



Calculating pH:

"pH is defined as the negative logarithm of the hydronium ion concentration."

(H_3O^+ or H^+)

$$pH = -\log[H_3O^+]$$

Example:

Calculate the pH of a solution with $[H_3O^+] = 7.3 \times 10^{-5}$ M

$pH = -\log 7.3\times10^{-5} = 4.14$

We can also calculate the $[H_3O^+]$ given pH, by using the **INVERSE** of a logarithm (**10^x**)

$$[H_3O^+] = 10^{-pH}$$

Example:

Calculate the $[H_3O^+]$ if pH = 4.14

$[H_3O^+] = 10^{-4.14} = 7.24\times10^{-5}\ \frac{mol}{L}$

pOH, The Counterpart To pH:

Since the pH scale deals with both the $[H_3O^+]$ and $[OH^-]$, there must be a value representing pOH.

"pOH is defined as the negative logarithm of the hydroxide ion concentration."

$$pOH = -\log[OH^-] \quad \textbf{AND} \quad pH + pOH = 14$$

$[OH^-] = 10^{-pOH}$

Examples:

1. Calculate the pOH of a solution with $[OH^-] = 3.0 \times 10^{-6}$ M

$pOH = -\log[OH^-] = -\log 3\times10^{-6} = 5.5$

pOH, The Counterpart To pH:

We can also calculate the $[OH^-]$ given pOH, by using the **INVERSE** of a logarithm (**10^x**) ***$[OH^-] = 10^{-pOH}$***

2. Calculate the $[OH^-]$ if pOH = 3

$[OH^-] = 10^{-pOH} = 10^{-3} = 0.001 \frac{mol}{L}$

Relationship Between pH & pOH:

pH	pOH	$[H^+]$ (M)	$[OH^-]$ (M)
0	14	1.0	10^{-14}
2	12	0.01	10^{-12}
4	10	0.0001	10^{-10}
6	8	10^{-6}	10^{-8}
8	6	10^{-8}	10^{-6}
10	4	10^{-10}	0.0001
12	2	10^{-12}	0.01
14	0	10^{-14}	1.0

Overall, we get the important relationship:

$$pH + pOH = -\log K_w = 14$$

Relationship Between pH & pOH:

Using **STOICHIOMETRY**, we can calculate the **pH** or **pOH** of any solution (assuming **COMPLETE DISSOCIATION**).

Example:

Calculate the pH and pOH of a solution made by dissolving **5.0g** of magnesium hydroxide in 250mL.

Solution:

$$Mg(OH)_2 \longrightarrow Mg^{2+} + 2OH^-$$

$$5g \times \frac{1\,mol}{58.32g} = \frac{0.086\,mol}{0.25\,L} = 0.343\,\frac{mol}{L} \longrightarrow 0.686\,\frac{mol}{L} = [OH^-]$$

$$pOH = -\log[OH^-] = -\log 0.686 = 0.164 = pOH$$

$$pH = 14 - 0.164 = 13.84 = pH$$

pH, pOH, $[H_3O^+]$, $[OH^-]$, and Kw:

Here are all the relationships that you need to know:

$pH=-\log[H_3O^+]$

$pOH=-\log[OH^-]$

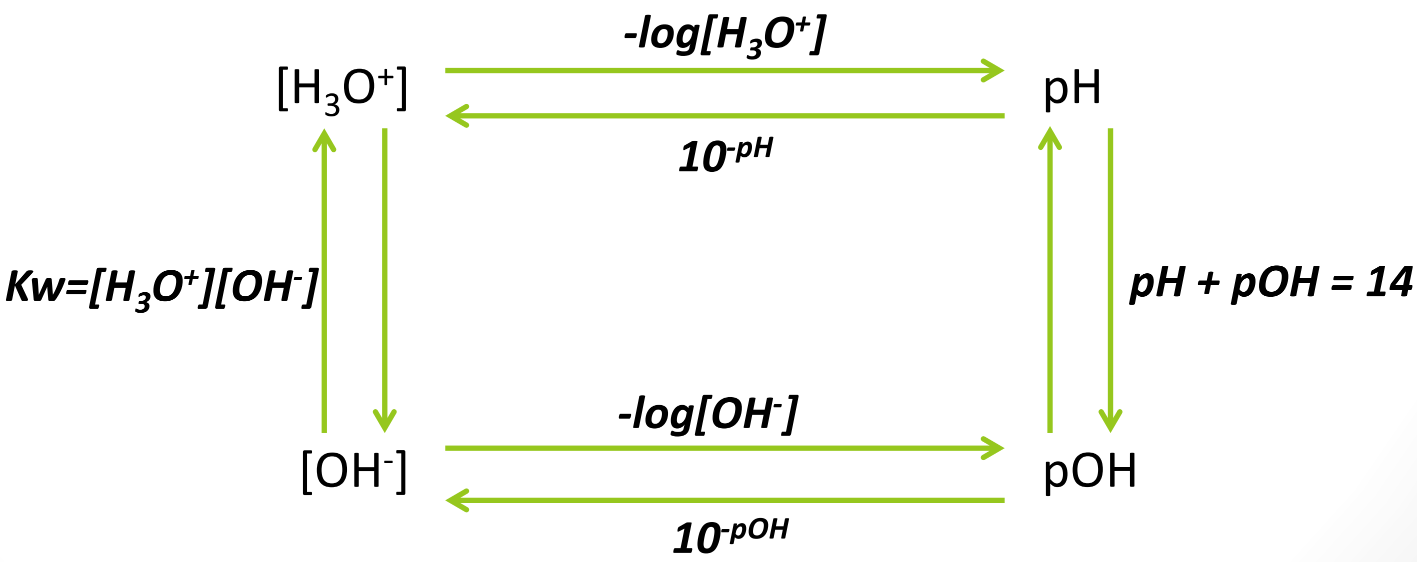
$pH + pOH = 14$

$[H_3O^+] = 10^{-pH}$

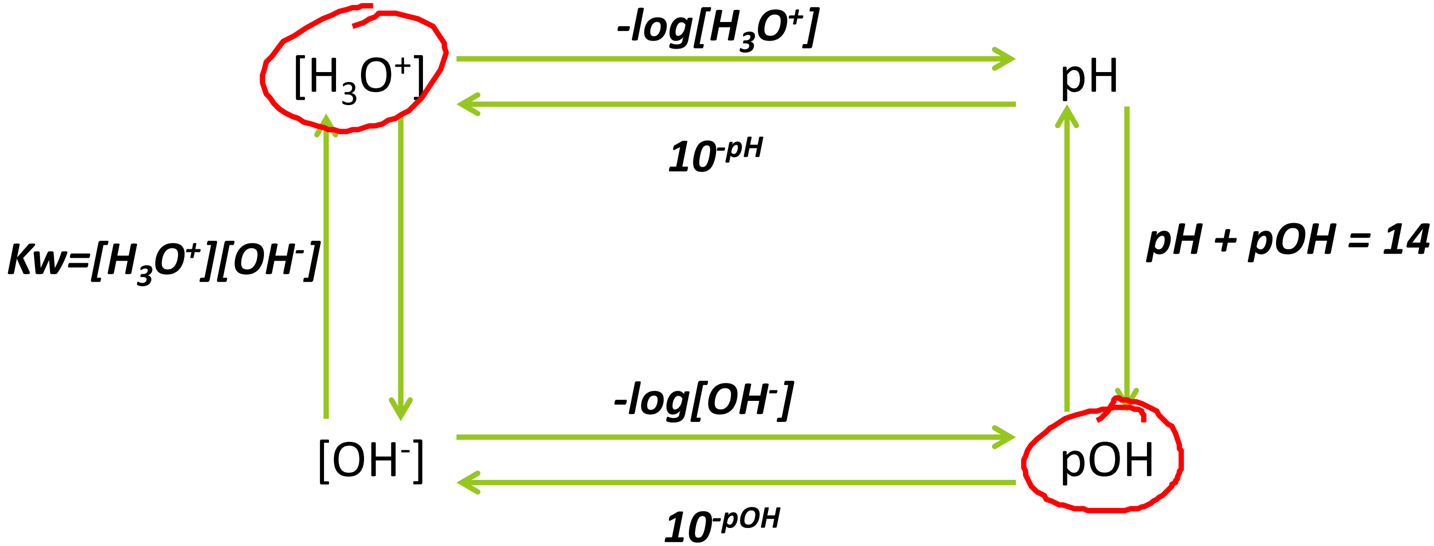
$[OH^-] = 10^{-pOH}$

$Kw=[H_3O^+][OH^-]$

Here is a way to put them all together:



pH, pOH, $[H_3O^+]$, $[OH^-]$, and Kw:



Example:

Determine the pOH of a 0.15 mol/L solution of the strong acid H_2SO_4.

$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$

$0.15\ \frac{mol}{L} \longrightarrow 0.3\ \frac{mol}{L}$

$pH = -\log 0.3 = 0.52$

$pOH = 14 - 0.52 = 13.48$