Weak Acid / Base calculations

Just to note, the Ka/Kb calculation method from the previous set of notes made a small assumption.

Ex. $HC_2H_3O_{2\,(aq)} \leftrightarrow H^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$

$[HC_2H_3O_2] = 0.10M$

$K_a = 1.8 \times 10^{-5}$ Calculate $[H^+]$

The assumption made is that we assumed the x was zero *similar to our equilibrium type questions*

1. Setup ICE table

	$HC_2H_3O_{2\,(aq)}$	$\leftrightarrow H^+_{(aq)}$	$+ C_2H_3O_2^-{}_{(aq)}$
I	0.10M	0M	0M
C	-x	+x	+x
E	0.10 – x	+x	+x

Weak Acid / Base calculations

$$Ka = \frac{[H+][C_2H_3O_2^-]}{[HC_2H_3O_2]}$$

$$1.8 \times 10^{-5} = \frac{[H+][C_2H_3O_2^-]}{[HC_2H_3O_2]}$$

$$1.8 \times 10^{-5} = \frac{(x)(x)}{(0.10 - x)}$$

Assume zero

Why?
Because once we calculate the "x", we will see the number is so small that it is negligible to the concentration

pH & pOH Calculations

Concentration of Hydrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH= 0	Battery acid, Strong Hydrofluoric Acid
1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
100,000	pH = 2	Lemon Juice, Gastric Acid Vinegar
10,000	pH = 3	Grapefruit, Orange Juice, Soda
1,000	pH = 4	Acid rain Tomato Juice
100	pH = 5	Soft drinking water Black Coffee
10	pH = 6	Urine Saliva
1	pH = 7	"Pure" water
1/10	pH = 8	Sea water
1/100	pH = 9	Baking soda
1/1,000	pH = 10	Great Salt Lake Milk of Magnesia
1/10,000	pH = 11	Ammonia solution
1/100,000	pH = 12	Soapy water
1/1,000,000	pH =13	Bleaches Oven cleaner
1/10,000,000	pH = 14	Liquid drain cleaner

Weak Acids	Ka	Chemical Formula	Concentration of [H+] assuming acid concentration is 1M
Acetic	1.8×10^{-5}	$HC_2H_3O_2$	
Ascorbic	7.9×10^{-5}	$H_2C_6H_6O_6$	
Benzoic	6.4×10^{-5}	$HC_7H_5O_2$	
Carbonic	4.5×10^{-7}	H_2CO_3	
Formic	1.8×10^{-4}	$HCHO_2$	
lactic	8.3×10^{-4}	$HC_3H_5O_3$	

Calculation:

$$1.8 \times 10^{-5} = \frac{x * x}{1M}$$

$$x = 4.24 \times 10^{-3}$$

$$[H] = 4.24 \times 10^{-3}$$

Acid	Ka	Chemical Formula	Concentration of [H+] assuming acid concentration is 1M
Acetic	1.8×10^{-5}	$HC_2H_3O_2$	4.24×10^{-3}
Ascorbic	7.9×10^{-5}	$H_2C_6H_6O_6$	8.9×10^{-3}
Benzoic	6.4×10^{-5}	$HC_7H_5O_2$	8×10^{-3}
Carbonic	4.5×10^{-7}	H_2CO_3	6.7×10^{-4}
Formic	1.8×10^{-4}	$HCHO_2$	0.0134
lactic	8.3×10^{-4}	$HC_3H_5O_3$	0.029

What is the trend here?

The more [H+] we have… the stronger the acid.

Can we develop a scale to put them in a range?

WEAK Acid	Ka	Chemical Formula	Concentration of [H+] assuming acid concentration is 1M
Acetic	1.8×10^{-5}	$HC_2H_3O_2$	4.24×10^{-3}
Ascorbic	7.9×10^{-5}	$H_2C_6H_6O_6$	8.9×10^{-3}
Benzoic	6.4×10^{-5}	$HC_7H_5O_2$	8×10^{-3}
Carbonic	4.5×10^{-7}	H_2CO_3	6.7×10^{-4}
Formic	1.8×10^{-4}	$HCHO_2$	0.0134
lactic	8.3×10^{-4}	$HC_3H_5O_3$	0.029

Least acidic ←--→ Most acidic

Carbonic acid 6.7×10^{-4} | Benzoic 8×10^{-3} | Lactic 0.029

Are we statisfied?

The numbers are too small to be made useful. So how can we make them **bigger**?

Logarithms

- As with exponents, **logarithms**, or **logs**, are a way of working with very large and very small numbers.
- “Logs” have a natural base 10 so calculating the “log” of a number is determining the exponent when it is raised to a base of 10
- For example, $\log(250) = 2.3979 \qquad 250 = 10^{2.3979}$
- Example: Find the log of 10000.
- The log of 10000 is to determine the exponent of a base 10?
- Log(10000) = 4 → meaning $10^4 = 10000$

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

Find the log of each of the following values:

a) 1.3×10^{-5}

b) 7.2×10^{-11}

c) 0.0054

Answers

a) $\log(1.3 \times 10^{-5}) = -4.886$ $10^{-4.886} = 1.3 \times 10^{-5}$

b) $\log(7.2 \times 10^{-11}) = -10.14$

c) $\log(0.0054) = -2.26$

What is pH?

- pH is just another way to express $[H^+]$ or $[H_3O^+]$, the hydrogen ion concentration of an acidic or basic solution.
- But what is the ‘p’?
  - ‘p’ is the ‘power’ or power of hydrogen for pH

- Hydrogen acid concentrations are often small numbers, such as 1.3×10^{-3}.
- pH is a method of transforming this number into something that is a little easier to work with.

What about pH?

- pH is defined as the negative log of hydrogen ion concentration.
  - **$pH = - \log [H^+]$**
- Because hydrogen ion concentrations are generally less than one (for example 1.3×10^{-3}), the log of the number will be a negative number.
- To make pH even easier to work with, pH is defined as the ***negative*** **log of $[H^+]$**, which will give a positive value for pH.
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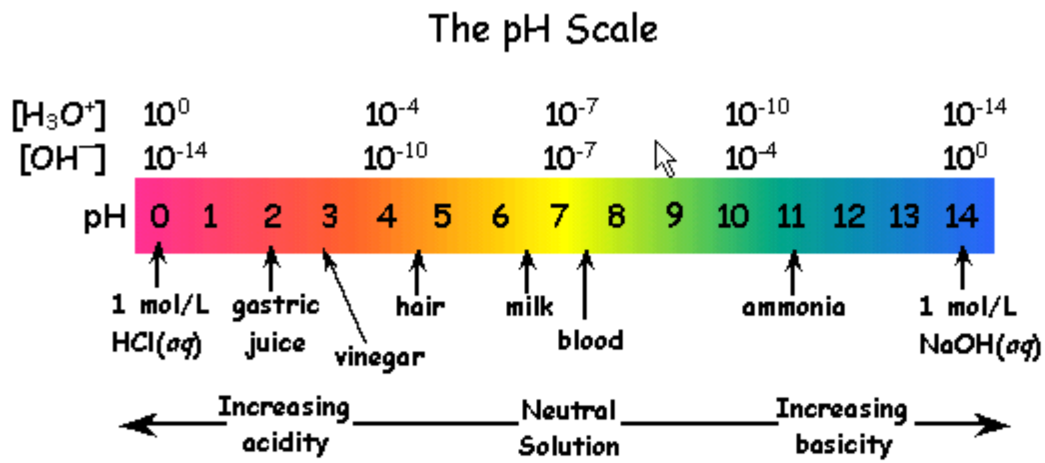
Try the examples shown on the right.

Based on the pH, you can tell if the substance is a strong/weak acid/base.



Acids
pH < 7
The lower the pH, the stronger the acid

Bases
pH > 7
The higher the pH, the stronger the base

Neutral solutions
pH = 7

	[H+]	**pH**
1.		3.0
2.	11	10.6
3.	9	8.3
4.	4	3.2
5.	7	7.0

Calculating pH

- Calculate the pH of a 0.01M HNO_3 solution?
  1. Begin finding pH by first finding $[H^+]$.
  2. You should recognize HNO_3 as a strong acid.

Based on the balanced equation shown below we see that there is a 1:1 ratio between HNO_3 and H^+,

so $[HNO_3] = [H^+]$:

$[H^+] = 0.01$

$$
\begin{aligned}
pH &= -\log [H^+] \\
&= -\log (0.01) \\
&= -(-2.0) \\
&= 2.0
\end{aligned}
$$

answer

What about pOH?

What if I want the pH? Can I get that from pOH?

To answer that: what is [H+] and [OH-] in neutral water at 25C?

$[H^+] = 1.0 \times 10^{-7}$

$[OH^-] = 1.0 \times 10^{-7}$

Then $K_w = [H^+]\,[OH^-]$

$[1.0 \times 10^{-7}]\,[1.0 \times 10^{-7}]$

This equals to = 1.0×10^{-14} and that is 14 if we combined both concentrations.

So if we have pOH, we can find pH.

$$14 = 3.4 + pH$$

$$pH = 14 – 3.4$$

$$= 10.6$$

Going backwards…

If you are given the pH, how can you find the [H+]?

Inverse function of log… or the anti-log function or 10^x.

[H$^+$] = antilog (-pH)

Don't forget the negative!

On your calculators, try pressing [2nd] and the [log] or [shift] then [log]

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

Answer: 5.0 x 10^{-9}M

Type 1 – Going backwards

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?

Type 2 – Finding K_a of a weak acid (x)

A 0.24M solution of the weak acid, H_2CO_3, has a pH of 3.49. Determine K_a for H_2CO_3 (carbonic acid).

Use ICE Table and form your equilibrium expression

Type 3 - Finding the hydroxide concentration [OH-] from a hydrogen concentration [H+]

Example 3. The pH of a solution is 10.30, what is the hydroxide ion concentration?

Type 4– Finding [H+] from pH
Example. We have a solution with a pH = 8.3. What is $[H^+]$?

pH = -log [H]
-antilog = [H+]

Challenging Example

- Example type – Finding pH from a weak base
- Find the pH of a 0.01 M solution of ammonia.
- Ammonia is a weak base with $K_b = 1.8 \times 10^{-5}$