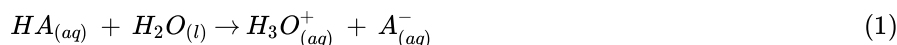


8.6 - Finding the Hydronium Ion Concentration and pH of Strong and Weak Acid Solutions

If we wish to find the hydronium ion concentration ($[H_3O^+]$) and the pH of a solution, we need to know both the strength of the acid (or base) and the concentration of the acid (or base). We will find that we need to treat strong acids (and bases) differently than weak acids (and bases) based on the extent to which they react with water.

Strong Acids

By definition, strong acids are those acids with a $K_a \geq 1$. using this definition, we assume that strong acids will react completely with water, so that every molecule of acid reacts with a molecule of water to produce a hydronium ion and the conjugate base. (This assumption is, of course, not possible because there must always be at least a few particles of each reactant and each product at equilibrium, but our assumption is a valid one when K_a gets to be quite a bit larger than 1.):



Based on our assumption, $[H_3O^+]_{eq} = [HA]_{initial}$, so we can carry out the following calculation:

$$pH = -\log([H_3O^+]_{eq}) = -\log([HA]_{initial}) \quad (2)$$

Example 1

What is the pH of a 0.175 M aqueous solution of HBr?

Solution

HBr is a strong acid ($K_a > 1$), so $[H_3O^+]_{eq} = [HBr]_{initial}$. Thus, $pH = -\log(0.175) = 0.757$

Exercise 1

What is the pH of a 0.0043 M aqueous solution of HNO_3 ?

Answer

HNO_3 is a strong acid ($K_a > 1$), so $[H_3O^+]_{eq} = [HNO_3]_{initial}$. Thus, $pH = -\log(0.0043) = 2.37$

Strong Bases

By definition, strong bases are those bases with a $K_b \geq 1$. using this definition, we assume that strong bases will react completely with water, so that every molecule of base reacts with a molecule of water to produce a hydroxide ion and the conjugate acid. (This assumption is, of course, not possible because there must always be at least a few particles of each reactant and each product at equilibrium, but our assumption is a valid one when K_b gets to be quite a bit larger than 1.):



Based on our assumption, $[OH^-]_{eq} = [B]_{initial}$, so we can carry out the following calculation:

$$pOH = -\log([OH^-]_{eq}) = -\log([B]_{initial}) \quad (4)$$

To find the pH, we then subtract the pOH from 14.

Example 2

What is the pH of a 0.175 M aqueous solution of $NaNH_2$?

Solution

NH_2^- is a strong base ($K_b > 1$), so $[OH^-]_{eq} = [NH_2^-]_{initial}$. Thus, $pOH = -\log(0.175) = 0.757$, and $pH = 14.000 - 0.757 = 13.243$

Exercise 2

What is the pH of a 0.0043 M aqueous solution of KOH?

Answer

KOH is a strong base ($K_b = 1$), so $[OH^-]_{eq} = [OH^-]_{initial}$. Thus, $pOH = -\log(0.0043) = 2.37$, and $pH = 14.00 - 2.37 = 11.63$

Weak Acids

If the acid you are working with is weak ($K_a < 1$), you must use a logic chart (ICE diagram) to determine the $[H_3O^+]$ because you cannot tell how much H_3O^+ will form in solution simply by looking at the initial $[HA]$.

Example 3

What is the pH of a 0.025 M aqueous solution of HClO?

Solution

ClO^- is a weak base with $K_b = 3.5 \times 10^{-8}$. The law of mass action for the reaction of $HClO$ with water is $3.5 \times 10^{-8} = \frac{[ClO^-][H_3O^+]}{[HClO]}$

The ICE diagram will look like this:

HClO	H ₂ O	\rightleftharpoons	ClO^-	H_3O^+
0.025	-		0	0
-n	-		+n	+n
0.025-n	-		n	n

Thus,

$$3.5 \times 10^{-8} = \frac{[n][n]}{[0.025 - n]} \quad (5)$$

which rearranges to

$$0 = n^2 + 3.5 \times 10^{-8}n - 8.75 \times 10^{-10} \quad (6)$$

using the quadratic formula, the answer can be found to be 2.96×10^{-5} M H_3O^+ . Thus the pH is $-\log(2.96 \times 10^{-5}) = 4.53$

Exercise 3

What is the pH of a 0.111 M aqueous solution of acetic acid? $K_a = 1.8 \times 10^{-5}$

Answer

pH = 2.85

Weak Bases

If the base you are working with is weak ($K_b < 1$), you must use a logic chart (ICE diagram) to determine the $[OH^-]$ because you cannot tell how much OH^- will form in solution simply by looking at the initial $[B]$.

Example 4

What is the pH of a 0.025 M aqueous solution of NaClO?

Solution

ClO^- is a weak base with $K_b = 2.9 \times 10^{-7}$. The law of mass action for the reaction of ClO^- with water is $2.9 \times 10^{-7} = \frac{[HClO][OH^-]}{[ClO^-]}$

The ICE diagram will look like this:

ClO^-	H_2O	\rightleftharpoons	HClO	OH^-
0.025	-		0	0
-n	-		+n	+n
0.025-n	-		n	n

Thus,

$$2.9 \times 10^{-7} = \frac{[n][n]}{[0.025 - n]} \quad (7)$$

which rearranges to

$$0 = n^2 + 2.9 \times 10^{-7}n - 7.25 \times 10^{-9} \quad (8)$$

using the quadratic formula, the answer can be found to be $2.68 \times 10^{-5} \text{ M OH}^-$. Thus the pOH is $-\log(2.68 \times 10^{-5}) = 4.57$, and the pH is $14.00 - 4.57 = 9.43$.

Exercise 4

What is the pH of a 0.045 M aqueous solution of sodium phosphate. $K_b = 2.8 \times 10^{-2}$

Answer

12.38

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