Percent Ionization

Percent Ionization: percentage of acid molecules that dissociate (ionize) when dissolved in water

➔ Another way to measure acid strength!

$$\% \textbf{ Ionization} = \frac{molarity\ of\ ionized\ acid}{initial\ molarity\ of\ acid} \times 100 = \frac{[H_3O^+]_{equil}}{[HA]_0} \times 100$$

(@ equilibrium; [HA]₀ (or i); not on F.C.!)

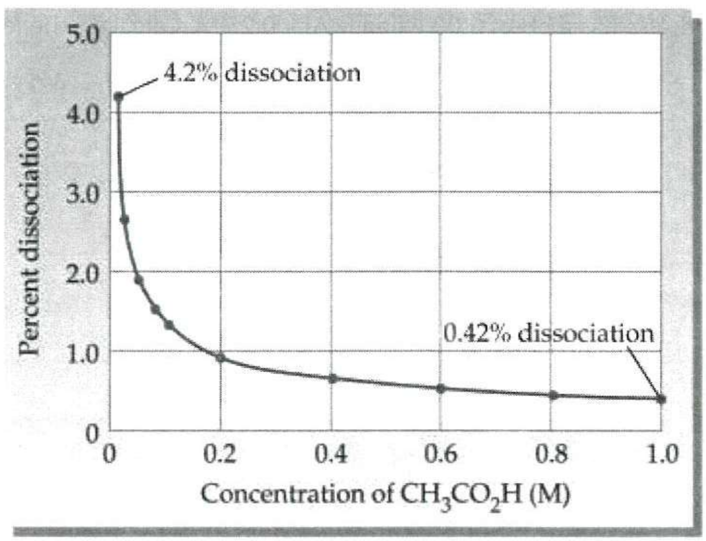
$$HA(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + A^-(aq)$$

Effect of Dilution on Percent Ionization

- Diluting an acid will increase the percent ionization.
- A more concentrated acid will decrease the percent ionization.

$\downarrow [HA] = \uparrow$ % Ion. ($\uparrow$ pH)
($\downarrow [HA] = \downarrow [H^+]$)

Why? $Q = \frac{[H_3O^+]\downarrow [A^-]\downarrow}{[HA]\downarrow}$
⇒ K > Q
⇒ Shift right ($\uparrow$ % ionization) to re-establish equilibrium!



*pH and % Ion. have same results when [HA] is diluted!

*Hint: if % Ion. is < 5%, it's safe to make "x negligible" approximation

In summary: we now know 5 ways to compare acid strength!

Various Ways to Describe Acid Strength		
Property	**Strong Acid**	**Weak Acid**
Ionization constant (K_a) value	K_a is large	K_a is small
Percent Ionization	% Ionization = 100%	% Ionization << 100%
Position of the dissociation (ionization) equilibrium	Far to the right (favors products)	Far to the left (favors reactants)
Equilibrium concentration of H^+ when compared to original [HA]	$[H^+] \approx [HA]_0$	$[H^+] << [HA]_0$
Strength of conjugate base compared with that of water (K_b value of conjugate base)	A^- much weaker base than H_2O K_b (conjugate base) is small/weak	A^- much stronger base than H_2O K_b (conjugate base) is large/strong

pH Calculations with Weak Acids and Bases: Yummy RICE!

Unlike strong acids and bases, weak acids and bases do NOT dissociate completely, so calculation of pH or pOH for these solutions requires the ability to calculate delicious equilibrium concentrations of [H_3O^+] and [OH^-], using RICE tables and K_a or K_b values. pH (weak acid) ≠ −log [weak acid] !!!

Example 1: Calculate the pH of a 0.10 M solution of acetic acid, $HC_2H_3O_2$. The K_a of acetic acid is 1.8 x 10^{-5}.

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons C_2H_3O^-_{2(aq)} + H_3O^+_{(aq)}$$

$HC_2H_3O_2$		$C_2H_3O_2^-$	H_3O^+
0.10		∅	∅
−x		+x	+x
0.10 − x		x	x

$K_a \ll 1$, x negligible — almost always true for weak acids/bases!

weak acid pattern: $K_a = \frac{x^2}{[HA]_i}$ (only if x is negligible)

$$K_a = \frac{[H_3O^+][C_2H_3O_2^-]}{[HC_2H_3O_2]} = \frac{x^2}{0.10 - x} \approx \frac{x^2}{0.10} = 1.8E-5$$

$$x = [H_3O^+] = \sqrt{(0.10)(1.8E-5)} = 0.0013416$$

$$pH = -\log[H_3O^+] = -\log(0.0013416) = 2.87$$

(2 s.f. → 2 s.f.)

Example 2: A 0.200 M weak acid solution (HA) has a pH of 4.25. Find the ionization constant for the acid.

$$[H_3O^+] = 10^{-pH} = 10^{-4.25} = 5.6234E-5\ M = x$$

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$$

HA		H_3O^+	A^-
0.200		∅	∅
−x		+x	+x
0.200 − x		x	x

weak acid ⇒ $K_a \ll 1$, x negligible

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{x^2}{0.200 - x} \approx \frac{x^2}{0.200} = \frac{(5.6234E-5)^2}{0.200}$$

$$= 1.6 \times 10^{-8}$$

Example 3: Determine the [OH⁻] and pH of a 0.100 M NH_3 solution. The K_b of NH_3 is 1.76 x 10^{-5}.

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

NH_3		NH_4^+	OH^-
0.100		∅	∅
−x		+x	+x
0.100 − x		x	x

$K_b << 1$, x negligible

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = \frac{x^2}{0.100 - x} \approx \frac{x^2}{0.100} = 1.76E-5$$

$$\Rightarrow x = [OH^-] = \sqrt{(0.100)(1.76E-5)} = \boxed{1.33 \times 10^{-3} M}$$

$$pOH = -\log[OH^-] = -\log(1.33E-3) = 2.877$$

$$\Rightarrow pH = 14 - 2.877 = \boxed{11.123}$$

Example 4: Calculate the percent ionization of a 2.5 M HNO_2 solution (K_a = 4.0 x 10^{-4}).

$$HNO_{2(aq)} + H_2O_{(l)} \rightleftharpoons NO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

$$K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]} = \frac{x^2}{2.5 - x} \approx \frac{x^2}{2.5} = 4.0E-4$$

$K_a << 1$, x negligible

$$x = [H_3O^+] = \sqrt{(2.5)(4.0E-4)} = 0.032 M$$

$$\% \text{ Ion} = \frac{[H_3O^+]_{eq}}{[HNO_2]_i} \times 100 = \frac{0.032}{2.5} \times 100 = \boxed{1.3\%}$$