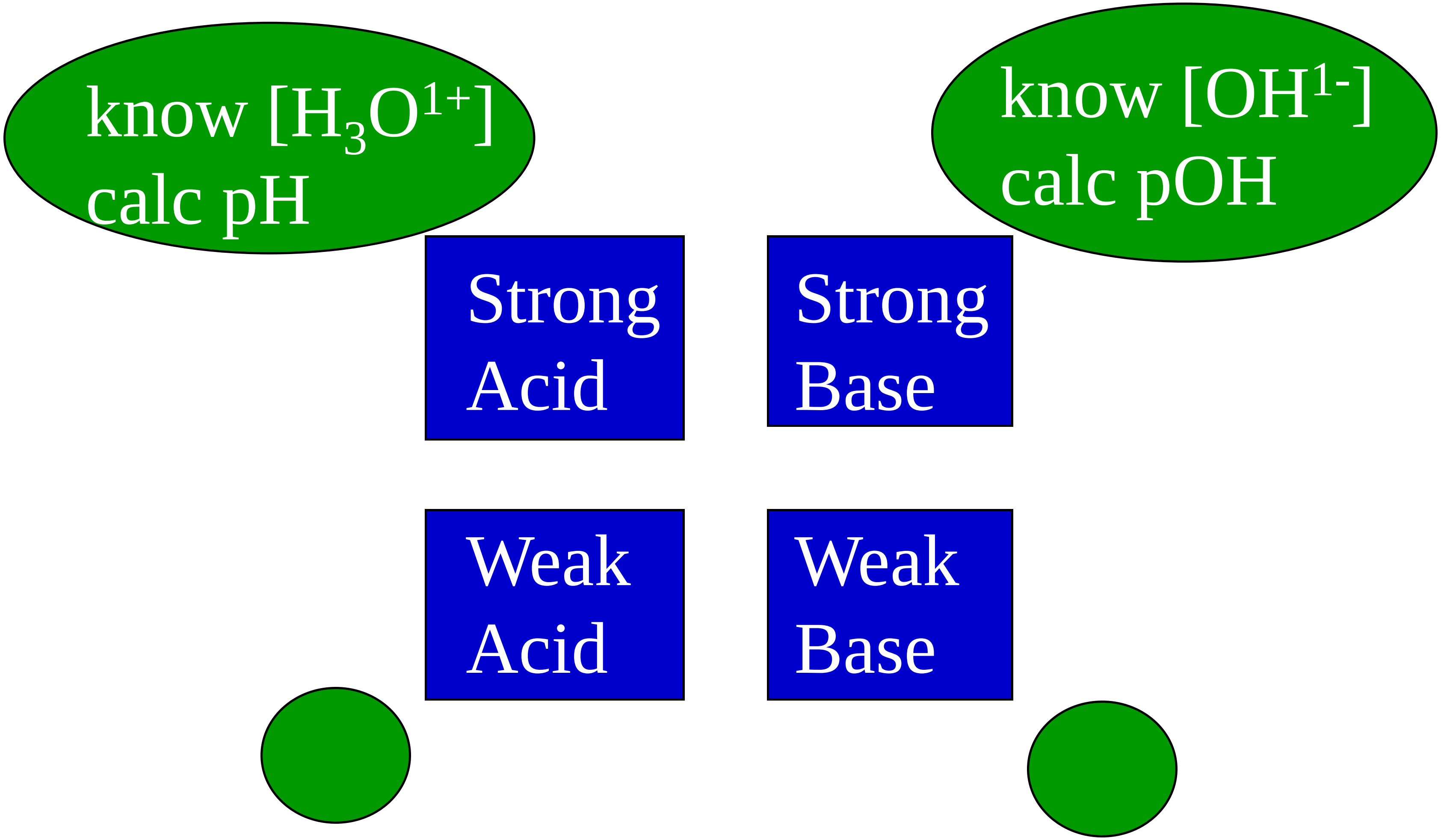
Chemistry 201

Weak Acids and Bases

NC State University


know [H_3O^{1+}]
calc pH
know [OH^{1-}]
calc pOH
Strong Acid
Strong Base
Weak Acid
Weak Base

pH of Weak Acids & Bases

- How do we find $[H_3O^{1+}]$?
- How do acid and base strengths relate?

Relationship of pK_a and pK_b

$$HA + H_2O \leftrightarrow A^- + H_3O^+ \qquad K_a = \frac{[A^-][H^+]}{[HA]}$$

$$A^- + H_2O \leftrightarrow HA + OH^- \qquad K_b = \frac{[HA][OH^-]}{[A^-]}$$

$$H_2O + H_2O \leftrightarrow OH^- + H_3O^+ \qquad K_w = [H^+][OH^-]$$

$$\left(\frac{[A^-][H^+]}{[HA]}\right)\left(\frac{[HA][OH^-]}{[A^-]}\right) = [H^+][OH^-]$$

$$K_a K_b = K_w$$

$$pK_a + pK_b = pK_w$$

Calculation of the pH of weak acids

For a generic weak acid dissociation in water to produce ions we can consider the general case,

$$HA \leftrightarrow A^{-} + H^{+}$$

in which the initial concentration of [HA] = C and $[A^{-}]$ = $[H^{+}]$ = 0. Then we make the following reaction table:

Molecule	HA	A^{-}	H^{+}
Initial	C	0	0
Change	-x	x	x
Equilibrium	C-x	x	x

Using the K_a to obtain x = $[H^+]$

We can substitute these values into K_a,

$$K_a = \frac{x^2}{C - x}$$

This can be formulated as a general quadratic equation.

$$K_a C - K_a x - x^2 = 0$$

Note that we do not necessarily need to use the quadratic Formula. If C >> x then we can use an approximation

$$x \approx \sqrt{CK_a}$$

Which is justified on the next slide.

Justification of approximate solution

The general case has a solution

$$x = \frac{K_a \pm \sqrt{{K_a}^2 + 4CK_a}}{-2}$$

If the concentration C of the acid is sufficiently large, then we can neglect x relative to x, i.e. C >> x. In this case,

$$K_a \approx \frac{x^2}{C}$$

and

$$x \approx \sqrt{CK_a}$$

pH of Weak Acids

What is the pH of a 0.20 M solution of $HC_2H_3O_2$? ($pK_a = 4.74$)

pH of Weak Acids

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Solution: Set A = $HC_2H_3O_2$

$$HA \rightarrow H^+ + A^-$$

Step 1: Solve for $K_a = 1.82 \times 10^{-5}$
Step 2: Make a reaction table

Molecule	HA	A^-	H^+
Initial	0.2	0	0
Difference	-x	x	x
Equilibrium	0.2-x	x	x

pH of Weak Acids

What is the pH of a 0.20 M solution of $HC_2H_3O_2$? ($pK_a = 4.74$)

Step 3: Solve for x

$$K_a = \frac{[A^-][H^+]}{[HA]} = \frac{x^2}{0.2 - x}$$

$$K_a(0.2 - x) - x^2 = 0 \qquad K_a 0.2 - K_a x - x^2 = 0$$

$$x = \frac{K_a \pm \sqrt{K_a{}^2 + 4(0.2)K_a}}{-2}$$

$$x = \frac{1.82x10^{-5} \pm \sqrt{(1.82x10^{-5})^2 + 0.8(1.82x10^{-5})}}{-2}$$

$$x = 0.00189$$

pH of Weak Acids

What is the pH of a 0.20 M solution of $HC_2H_3O_2$? (pK_a = 4.74)

Step 3. Calculate pH

$$pH = -log_{10}(0.00189) = 2.72$$

We could have used the approximate method for this acid since x = 0.00189 and C = 0.2. According to the approximate method.

$$x \approx \sqrt{CK_a} = \sqrt{(0.2)\left(1.82\ x\ 10^{-5}\right)} = 0.00190$$

The difference from the exact method is less than 1%.

know $[H_3O^{1+}]$
calc pH

know $[OH^{1-}]$
calc pOH

Strong Acid

Strong Base

rxn table
use K_a
get $[H_3O^{1+}]$
calc pH

Weak Acid

Weak Base

pH of Weak Bases

What is the pH of a 0.10 M solution of NaF? (pK_a = 3.14 for HF)

Solution: Write down the conjugate base reaction

$$F^- + H_2O \leftrightarrow HF + OH^-$$

Step 1: Solve for K_b

$$K_b = 10^{-pKb} = 10^{-10.86} = 1.38x10^{-11}$$

$$pKb = pKw - pKa$$
$$pKb = 14 - 3.14 = 10.86$$

pH of Weak Bases

NaF problem(contd) (pK_a = 3.14 for HF)

Step 2: Make a reaction table

Molecule	F^-	HF	OH^-
Initial	0.1	0	0
Difference	-x	x	x
Equilibrium	0.1-x	x	x

Step 3: Solve for x

$$K_b 0.1 - K_b x - x^2 = 0$$

$$x = \frac{K_b \pm \sqrt{K_b{}^2 + 4(0.1)K_b}}{-2}$$

$$x = 1.17x10^{-6}$$

$$x = \frac{1.38x10^{-11} \pm \sqrt{(1.38x10^{-11})^2 + 0.4(1.38x10^{-11})}}{-2}$$

pH of Weak Bases

NaF problem(contd) (pK_a = 3.14 for HF)

Step 4: Solve for pOH

$$pOH = -log_{10}(1.17x10^{-6}) = 5.93$$

Step 5: Convert to pH

$$pH + pOH = pK_w$$

$$pH = pK_w - pOH$$

$$pH = 14 - 5.93 = 8.07$$

pH of Weak Bases

NaF problem(contd) (pK_a = 3.14 for HF)

Here again we could have used the approximate method and saved a lot of work.

$$x \approx \sqrt{CK_b} = \sqrt{(0.1)\left(1.38\ x\ 10^{-11}\right)} = 1.17\ x\ 10^{-6}$$

Since Kb is so small in this case the difference is less than one part in 1000.

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Strong Base

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