Chem 40S Notes:
Indicators
What makes an acid/base strong?

Strong acids and bases

What makes an acid or base strong?

- ***Complete*** dissociation into separate ions.
    - $HCl \rightarrow H^+ + Cl^-$
- Meaning that all of HCl will be dissociated into its separate ions
- Strong acids are also strong electrolytes, which means they are good conductors.

- Another example, Sulfuric acid are found in our car batteries.

Weak acids and bases

<u>What makes an acid or base weak?</u>

- Weak electrolytes are weak acid/base as well.
- They do not dissociate completely in solution and as a result do not have many ions to carry out the electrical charge.

https://www.youtube.com/watch?v=a21kuzQW7AE

How do we determine the quantitative aspects of dissociation?

- Equilibrium ionization concentration constants

Ionization constants

We can determine the amount of the ions present at equilibrium by using the Equilibrium Law Expression

Recall,

$$aA + bB \leftrightarrow cC + dD$$

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Water's Ionization constant

Water can be ionized into 2 forms:

1) Hydronium ion $H_3O^+_{(aq)}$

$$H_2O_{(l)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$$

or

2) "Proton" H^+

$$H_2O_{(l)} \rightarrow H^+_{(aq)} + OH^-_{(aq)}$$

Therefore,

It can be

$K_w = [H_3O^+][OH^-]$ or $[H^+][OH^-]$

$K_w = 1.0 \times 10^{-14}$

The K_w is water's equilibrium ionization constant. Since the K_w is a small number, water doesn't readily dissociate into the ions!

Acid's Ionization constants, K_a

What about equilibrium constant for acid? K_a?

K_a – is the equilibrium constant for acids. The higher the constant the more ions are dissociated.

Strong acid:

Hydrochloric acid

$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

$$Ka = \frac{[H+][Cl-]}{[HCl]} = 1.3 \times 10^6$$

Weak Acid: Formic Acid

$HCHO_{2\,(aq)} \leftrightarrow H^+_{(aq)} + CHO_2^-{}_{(aq)}$

$$Ka = \frac{[H+][CHO_2^-]}{[HCHO_2]} = 1.8 \times 10^{-4}$$

The higher the equilibrium constant of acid, the stronger the acid since there will be MORE of H+!
COOL!

Base's Ionization constant, K_b

Equilibrium constant for Base, K_b

Same as acid but the higher the constant, the more "OH-", the stronger the base.

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

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = 1.8 \times 10^{-5}$$

The *higher* the equilibrium constant of base, the stronger the base since there will be MORE of OH-!

Calculating Concentrations of acids and bases

Calculating concentrations of acids [H+] and bases [OH-] contains 2 major categories.

The 1st is with strong acids and bases – because of their complete dissociation, direct stoichiometry can be used.

The 2nd is with weak acids and bases – because of the incomplete dissociation, algebra is used.

Strong acid and base calculations

Calculating Concentrations

1st Type. Concentrations of [H+] and [OH-] for strong acids and bases.

1. Calculate the hydrogen ion concentration in a 0.050 M solution of hydrochloric acid.
   HCl is a strong acid → Complete dissociation

   $$HCl_{(aq)} \rightarrow H^{+}_{(aq)} + Cl^{-}_{(aq)}$$

   Use molar ratios.

   $1\ HCl : 1H^{+} : 1Cl^{-}$

   0.050M HCl will give 0.050M of H^{+}

Calculating Concentrations

1st Type. Concentrations of [H+] and [OH-] for strong acids and bases.

2. Calculate the hydroxide ion concentration in a 0.010 M solution of barium hydroxide, $Ba(OH)_2$. Barium hydroxide is a strong base.

$$Ba(OH)_{2\,(aq)} \rightarrow Ba^{2+}_{(aq)} + 2\ OH^-_{(aq)}$$

Since 2 moles of OH^- are produced for every 1 mole of $Ba(OH)_2$, the concentration of OH^- will be twice the concentration of $Ba(OH)_2$.

Or [OH-] = 2 x 0.010M = 0.02M

Calculating Concentrations

2nd Type. Finding concentrations when dissolved in Water or in solution. Because the acid is a strong acid, the ions dissociates completely.

If 2.5 moles of hydrochloric acid is dissolved in 5.0 L of water, what is the concentration of the hydroxide ions? Assume the volume remains unchanged.

1. Find the concentration of HCl, 2.5moles/5.0L = 0.5M of HCl.
2. Since HCl is a strong acid, it dissociates completely to

   $[H^+] = 0.5M$

   Use the $K_w = [H+][OH-]$ and solve for [OH-]

$$[OH-] = \frac{Kw}{[H+]} = \frac{1.0 \times 10^{-14}}{0.50} = 2.0 \times 10^{-14} \text{ mol/l OH-}$$

Calculating Concentrations

2^{nd} Type. Finding concentrations when dissolved in Water or in solution.

Ex 2. 0.40 g of NaOH is dissolved in water to make a solution with a volume of 1.0 L. What is the hydronium ion concentration in this solution?

$$\text{moles} = 0.40\ \text{g}\left(\frac{1\ \text{mol}}{40.0\ \text{g}}\right) = 0.010\ \text{moles of NaOH}$$

1. Find moles of NaOH
2. Change into concentration by dividing by 1.0L
3. [NaOH] = [OH-] = 0.010mol/L
4. Use K_w to find $[H_3O^+]$

Answer: 1.0×10^{-12} $[H_3O^+]$

Calculating Concentrations

3rd Type. Finding concentrations of WEAK acids or bases. These are different because they do not dissociate completely!

Example 1.
Calculate the hydrogen ion concentration in a 0.10 M acetic acid solution, $HC_2H_3O_2$.
K_a for acetic acid, a weak acid, is 1.8×10^{-5}.

Steps:

1. Write the balance equation out.
2. Use K_a or K_b to solve for [H+] or [OH-]
3. Might need to use "x" for unknown

Calculating Concentrations

3rd Type. Finding concentrations of WEAK acids or bases

Balance equation:

Acetic acid dissociates into H^+ and $C_2H_3O_2$-.

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

Because this is a weak acid, the concentration of the products is not the same as the reactants.

But Concentration of products are the same.

Steps:

1. Write the balance equation out.
2. Use K_a or K_b to solve for [H+] or [OH-]

Calculating Concentrations

3rd Type. Finding concentrations of WEAK acids or bases

Balance equation:

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

Use your K_a to solve for H+

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

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

$$x = 1.3 \times 10^{-3}$$

$$\mathbf{[H^+] = 1.3 \times 10^{-3}}$$

Steps:

1. Write the balance equation out.
2. Use K_a or K_b to solve for [H+] or [OH-]
3. Use x for the product concentration

Calculating Concentrations

2nd ex:

Calculate the hydroxide ion concentration, $[OH^-]$, in a 0.025 M solution of analine, $C_6H_5NH_2$, a weak base with $K_b = 4.3 \times 10^{-10}$

Steps:

1. Write the balance equation out.
2. Use K_a or K_b to solve for [H+] or [OH-]

Calculating Concentrations

Calculate the hydroxide ion concentration, $[OH^-]$, in a 0.025 M solution of analine, $C_6H_5NH_2$, a weak base with $K_b = 4.3\times10^{-10}$

$$C_6H_5NH_2 + H_2O \rightarrow C_6H_5NH^+ + OH-$$

$Kb = 4.3 \text{ x } 10^{-10}$

$$K_b = \frac{[C_6H_5NH^+]\,[OH^-]}{[C_6H_5NH_2]}$$

$$4.3 \text{ x } 10^{-10} = \frac{(x)\;(x)}{0.025}$$

$$x = 3.3 \text{ x } 10^{-6} \text{ mol/L}$$

Steps:

1. Write the balance equation out.
2. Use K_a or K_b equation to solve for [H+] or [OH-]

Indicators

- There are many different types of indicators to indicate the acidity of a solution

  1) <u>Litmus and pH paper</u>

  - Litmus only tells us if the solution is acidic or basic

  - pH paper allows more precision because we can dip it in our solution and it will give us a color that can be matched to a color chart

2) Liquid Indicators

- a liquid indicator is a weak acid/base that undergoes dissociation in a known pH range

- in the range the acid/base is a different color from it's conjugate acid/base

3) pH meter or probe

- takes continuous readings of the pH changes

- values are usually precise to 0.01

- hospitals use these to test small (but very important) changes in pH of a patients' blood or bodily fluids

- <u>Limitations</u>:

  - litmus and pH paper are only approximations

  - pH probes are expensive

  - liquid indicator ranges are for substances at 25°C (at any other temperature, the color may be different or the indicator may change at a different pH)

  - also, any dissolved salts may also affect indicator color