

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.
  - $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$
- 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

## What makes an acid or base weak?

- 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,



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

# Water's Ionization constant

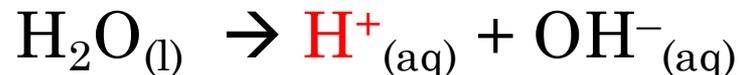
Water can be ionized into 2 forms:

1) Hydronium ion  $\text{H}_3\text{O}^+_{(\text{aq})}$



or

2) "Proton"  $\text{H}^+$



Therefore,

It can be

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] \text{ or } [\text{H}^+][\text{OH}^-]$$

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

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!

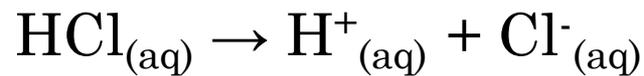
# Acid's Ionization constants, $K_a$

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



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

## Weak Acid: Formic Acid



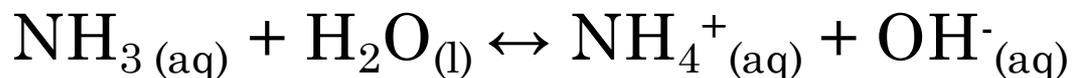
$$K_a = \frac{[\text{H}^+][\text{CHO}_2^-]}{[\text{HCHO}_2]} = 1.8 \times 10^{-4}$$

The higher the equilibrium constant of acid, the stronger the acid since there will be MORE of  $\text{H}^+$ !  
**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.



$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = 1.8 \times 10^{-5}$$

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

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

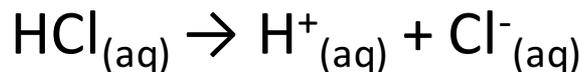
# Strong acid and base calculations

# Calculating Concentrations

1<sup>st</sup> Type. Concentrations of [H<sup>+</sup>] and [OH<sup>-</sup>] 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



Use molar ratios.



0.050M HCl will give 0.050M of H<sup>+</sup>

# Calculating Concentrations

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

2. Calculate the hydroxide ion concentration in a 0.010 M solution of barium hydroxide, Ba(OH)<sub>2</sub>. Barium hydroxide is a strong base.



Since 2 moles of OH<sup>-</sup> are produced for every 1 mole of Ba(OH)<sub>2</sub>, the concentration of OH<sup>-</sup> will be twice the concentration of Ba(OH)<sub>2</sub>.

Or [OH<sup>-</sup>] = 2 x 0.010M = 0.02M

# Calculating Concentrations

2<sup>nd</sup> 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,  $2.5\text{ moles}/5.0\text{L} = 0.5\text{M}$  of HCl.
2. Since HCl is a strong acid, it dissociates completely to

$$[\text{H}^+] = 0.5\text{M}$$

Use the  $K_w = [\text{H}^+][\text{OH}^-]$  and solve for  $[\text{OH}^-]$

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

# Calculating Concentrations

2<sup>nd</sup> 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?

1. Find moles of NaOH  $\text{moles} = 0.40 \text{ g} \left( \frac{1 \text{ mol}}{40.0 \text{ g}} \right) = 0.010 \text{ moles of NaOH}$
2. Change into concentration by dividing by 1.0L
3.  $[\text{NaOH}] = [\text{OH}^-] = 0.010 \text{ mol/L}$
4. Use  $K_w$  to find  $[\text{H}_3\text{O}^+]$

Answer:  $1.0 \times 10^{-12} [\text{H}_3\text{O}^+]$

# Calculating Concentrations

3<sup>rd</sup> 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,  $\text{HC}_2\text{H}_3\text{O}_2$ .

$K_a$  for acetic acid, a weak acid, is  $1.8 \times 10^{-5}$ .

Steps:

1. Write the balance equation out.
2. Use  $K_a$  or  $K_b$  to solve for  $[\text{H}^+]$  or  $[\text{OH}^-]$
3. Might need to use “x” for unknown

# Calculating Concentrations

3<sup>rd</sup> Type. Finding concentrations of WEAK acids or bases

Balance equation:

Acetic acid dissociates into  $\text{H}^+$  and  $\text{C}_2\text{H}_3\text{O}_2^-$ .



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  $[\text{H}^+]$  or  $[\text{OH}^-]$

# Calculating Concentrations

3<sup>rd</sup> Type. Finding concentrations of WEAK acids or bases

Balance equation:



Use your  $K_a$  to solve for  $\text{H}^+$

$$K_a = \frac{[\text{H}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]}$$

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

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

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

Steps:

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

# Calculating Concentrations

2<sup>nd</sup> ex:

Calculate the hydroxide ion concentration,  $[\text{OH}^-]$ , in a 0.025 M solution of analine,  $\text{C}_6\text{H}_5\text{NH}_2$ , 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  $[\text{H}^+]$  or  $[\text{OH}^-]$

# Calculating Concentrations

Calculate the hydroxide ion concentration,  $[\text{OH}^-]$ , in a 0.025 M solution of analine,  $\text{C}_6\text{H}_5\text{NH}_2$ , a weak base with  $K_b = 4.3 \times 10^{-10}$



$$K_b = 4.3 \times 10^{-10}$$

$$K_b = \frac{[\text{C}_6\text{H}_5\text{NH}^+][\text{OH}^-]}{[\text{C}_6\text{H}_5\text{NH}_2]}$$

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

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

Steps:

1. Write the balance equation out.
2. Use  $K_a$  or  $K_b$  equation to solve for  $[\text{H}^+]$  or  $[\text{OH}^-]$

# Indicators

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

## 1) Litmus and pH paper

- 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 its 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

- Limitations:

- 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