CHAPTER 19
Acids & Bases

19.1 Acid & Base
ACIDS
- tart or sour taste
- Electrolytes
- Strong acids are corrosive

Acid Facts...
- indicators will change color
- Blue litmus paper turns pink
- react with metals to form H_2
- react with OH^- to form water and a salt.
- Feel like water.

Common Reactions with Acids

$$Zn + HCl \rightarrow ZnCl_2 + H_2$$

$$NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O + CO_2$$

Definitions for Acids/Bases

- Dilute: small amount of solute 1-M
- Concentrated: large amount of solute 6-M
- Indicator: changes color to show the presence of acids or bases
- Corrosive: eat or wear away

Common Acids in Food
- Citric Acid: lemons, oranges
- Malic Acid: apples
- Acetic Acid: Vinegar, Catsup (Ketchup)
- Lactic Acid: sour milk
- Phosphoric Acid: soda pop
- Tartaric Acid: wine

Rule #1 for Naming Acids

- -ide
- hydro-(stem)-ic acid
- Ex. Hydrochloric acid

HCl: Hydrogen chloride

H_2S: Dihydrogen sulfide

HBr: Hydrogen bromide

HF: Hydrogen fluoride

Rule #2 for Naming Acids

- -ite
- (stem)-ous acid
- Ex. Sulfurous acid H_2SO_3

H_2SO_3: Dihydrogen sulfite

H_3PO_3: Trihydrogen phosphite

HNO_2: Hydrogen nitrite

Rule #3 for Naming Acids

- -ate
- (stem)-ic acid
- Ex. Nitric Acid HNO_3

H_2SO_4: Dihydrogen sulfate

H_3PO_4: Trihydrogen phosphate

HNO_3: Hydrogen nitrate

H_2CO_3: Dihydrogen carbonate

BASES

- react with acids to form water and a salt
- bitter taste
- Strong bases are corrosive
- Group 1A metals form stronger bases than Group 2A metals.

$K^+ + OH^- \longrightarrow$

$Na^+ + OH^- \longrightarrow$

$Mg^{2+} + OH^- \longrightarrow$

$Ca^{2+} + OH^- \longrightarrow$

Base Facts...

- feel slippery
- Alkaline solutions.
- electrolytes
- indicators change color
- Red litmus paper blue

Common Bases

- Household Ammonia
- Cleaners, Window Cleaner
- Lye and Drain Cleaner
- Sodium Hydroxide
- Milk of Magnesia (Laxative)
- Antacids (Tums, Rolaids, etc.)

Acid-Base Definitions

Type	Acid	Base
Arrhenius	H^+ producer	OH^- producer
Bronsted-Lowry	H^+ donor	H^+ acceptor
Lewis	Electron-pair acceptor	Electron-pair donor

Arrhenius Acids and Bases

- ACIDS: compounds containing hydrogen that ionize to yield hydrogen ions in aqueous solution
- BASES: compounds that ionize to yield hydroxide ions in aqueous solution OH^-

Arrhenius Acids

- **Monoprotic**: HNO_3
1 ionizable hydrogen
- **Diprotic**: H_2SO_4
2 ionizable hydrogen
- **Triprotic**: H_3PO_4
3 ionizable hydrogen

Ionization

H^+ NO_3^-

When dissolved

Bronsted-Lowry Acids and Bases

- **ACID: hydrogen-ion donor**
- **BASE: hydrogen-ion acceptor**
- **An acid and a base react to form a conjugate acid and a conjugate base.**

- Conjugate Acid: forms when a base gains a hydrogen
- Conjugate Base: forms when an acid donates a hydrogen
- Conjugate Acid-Base Pair

- $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
- $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

$$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$$

Lewis Acids & Bases

Lewis Acids: accept an electron pair

Lewis Bases: donate an electron pair

This expands Acid/Base definitions, by allowing us to classify acids and bases in the absence of H^+, H_3O^+, and OH^-.

Amphoteric

- Substances that either act as a base or an acid.
- Water is the best example.

- $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
- $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

Anhydrides

- Oxides that become acids or bases when reacting with water (CO_2 + CaO)
- Nonmetal oxides and water produce acids

$$CO_2 + H_2O \rightarrow H_2CO_3$$

- Metal oxides and water produce bases

$$CaO + H_2O \rightarrow Ca(OH)_2$$

19.2 STRENGTHS OF ACIDS AND BASES

- Strong acids completely ionize and weak acids only partly ionize.
- Strong acids are strong electrolytes and weak acids are weak electrolytes
- Table 19-1 on page 603

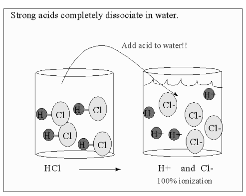
Complete vs. Partial Ionization

Strong Acids have maximum ionization and have no reverse reaction.

- **$HCl + H_2O \rightarrow H_3O^+ + Cl^-$**

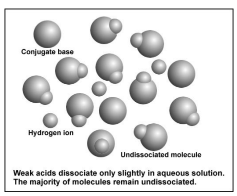
Weak Acids have partial ionization and stay at equilibrium

- **$HC_2H_3O_2(aq) + H_2O(l) \rightleftharpoons H_3O(aq) + C_2H_3O_2^-(aq)$**



Maximum Ionization

Strong Acid



Very Little Ionization

Weak Acid

Acid Strength & Bronsted-Lowry Model

What attracts the H^+ ion more, the base or the conjugate base?

$HX(aq) + H_2O(l) \rightarrow H_3O^+(aq) + X^-(aq)$

acid — base — Conugate Acid — Conugate Base

Water is pulling so strong on the H+ that the conjugate base cannot attract it enough to reverse

$HX(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + X^-(aq)$

acid — base — Conugate Acid — Conugate Base

The conjugate base is pulling so strong on the H+ that it allows the reaction to reverse and stay at equilibrium

Water is at Equilibrium

Remember your shifting rules!!!

$$H_2O \leftrightarrow H^+ + OH^-$$

- If H^+ ions are released, it causes a shift that will lower OH^- ions.
- **$HCl \rightarrow H^+ + Cl^-$**
- If OH^- ions are released, it causes a shift that will lower H^+ ions.
- **$NaOH \rightarrow Na^+ + OH^-$**

Hydrogen Ions and Acidity

- A water molecule that gains a hydrogen ion becomes a positively charged hydronium ion (H_3O^+)

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

What does strong mean?

- **Strong acids and bases ionize more than weak acids and bases.**
- **8.0 *M* phosphoric acid is not as dangerous as 1.0 *M* sulfuric acid.**
  - **Concentration and ionization are two different things.**
- **Ionization determines strength**
- **Concentration is used to compare the same acids with a different molarity.**

Strong Acids	Weak Acids
$HClO_4$	H_3PO_4
HCl	HF
HNO_3	$HC_2H_3O_2$
H_2SO_4	HCN
HI	H_2S
HBr	H_2CO_3

Acid Ionization Constant (K_a)

- The value of the equilibrium constant expression for the ionization of a weak acid. *(same as K_{eq}, but for an acid)*
- Indicates whether the reactants *(un-ionized molecules)* or products *(ions)* are favored at Equilibrium.
- Weak acids have the smallest Ka values.
- $HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$

$$K_a = \frac{[H_3O^+]x[CN^-]}{[HCN]}$$

Strengths of Bases

Strong Bases dissociate entirely and weak bases partially dissociate.

Metallic hydroxides are strong bases.

- $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

Weak Bases

What attracts the H^+ ion more, the base or the conjugate base?

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

base **acid** **Conugate Acid** **Conugate Base**

$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

base **acid** **Conugate Acid** **Conugate Base**

The conjugate base is pulling so strong on the H+ that it allows the reaction to reverse and stay at equilibrium

Base Ionization Constant (K_b)

- The value of the equilibrium constant expression for the ionization of a base. *(Same as K_{eq}, but for a base)*
- Indicates whether the reactants *(un-ionized molecules)* or products *(ions)* are favored at Equilibrium.
- Weak bases have the smallest K_b values.
- $CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

$$K_b = \frac{[CH_3NH_3^+]x[OH^-]}{[CH_3NH_2]}$$

19.3 What is pH?

- Ion-product constant for water = 1×10^{-14}
- **ACID:** H^+ greater than OH^-
- **BASE;** OH^- greater than H^+

- **$[OH^-]$ increases, then $[H^+]$ decreases!**
- **$[OH^-]$ decreases, then $[H^+]$ increases!**
- **$K_w = [H^+] \times [OH^-] = 1.0 \times 10^{-14}$ mol/L²**

- The reaction in which two water molecules react to give ions is the self-ionization of water.
- The self-ionization of water occurs to a very small extent.

$K_w = [H^+] \times [OH^-] = 1.0 \times 10^{-14}$ mol/L²

$$[H^+] = \frac{1.0 \times 10^{-14}\ \text{mol/L}^2}{[OH^-]}$$

$$[OH^-] = \frac{1.0 \times 10^{-14}\ \text{mol/L}^2}{[H^+]}$$

- **Finding the $[OH^-]$ of a solution.**
- **The $[H^+]$ is 1.0×10^{-5} mol/L.**
- **$K_w = [H^+] \times [OH^-]$**
- **Acid = $[H^+]$ greater than 1.0×10^{-7}**
- **Base = $[H^+]$ less than 1.0×10^{-7}**
- **Neutral = $[H^+]$ equal to 1.0×10^{-7}**

The pH Scale

- **pH = 0**
  - > Many H+ ions
  - > Few or no OH^- ions
- **pH = 14**
  - > Many OH^- ions
  - > Few or no H^+ ions
- **pH = 7**
  - > Number of "**H^+ ions**" and "**OH^- ions**" are equal

What is a logarithm?

log 100 = 2 (This means $10^2 = 100$)

log 50 = 1.699 (This means $10^{1.699} = 50$)

log 0.5 = -.301 (This means $10^{-.301} = 0.5$)

Calculating Logarithms

- 5.6
- 3.2
- 0.00056
- 2.5×10^{-6}

Calculating Antilogarithms

- 3.26
- -6.9
- 0.56
- 4.8

The pH Concept

- The pH of a solution is the negative logarithm of the $[H^+]$ concentration
- **pH = - log (H^+)**
- The $[H^+]$ concentration is the antilogarithm of the negative pH.
- **[H+] = antilog (- pH)**

Calculating pH from $[H^+]$ concentration

- **Always find the $[H^+]$ concentration first**

What is the pH for the following?

1. **$[H^+] = 1.0 \times 10^{-10}$ mol/L**
2. **$[H^+]$ = .0000001 *M***
3. **$[OH^-] = 1.0 \times 10^{-12}$ mol/L** ***(Two ways)***
4. **$[OH^-]$ = .0001 M**
5. **$[OH^-] = 1.0 \times 10^{-7}$**
6. **$[H+] = 6.73 \times 10^{-11}$ M**

Calculating $[H^+]$ concentration from pH

- **Take antilog of negative pH.**

What is the $[H^+]$ for the following pH?

1. **4.0**
2. **6.0**
3. **12.0**
4. **8.0**
5. **7.0**
6. **11.65**

Measuring pH

- Indicators: use color
- Usually a piece of paper
- Litmus paper does not give the strength.
- pH meters: accurate and fast measurements

H^+ Concentration	OH^- Concentration	pH	pOH
6.23×10^{-2}			
	3.67×10^{-4}		
		9.4	
			11.5

Which is the strongest acid?

Hint: always use pH to determine strength!!!

- $[H^+] = 1.0 \times 10^{-5}$ M
- $[OH^-] = 1.0 \times 10^{-12}$ M
- $[H^+] = 1.0 \times 10^{-11}$ M
- $[OH^-] = 1.0 \times 10^{-4}$ M

Which is the strongest base?

Hint: always use pH to determine strength!!!

- $[H^+] = 1.0 \times 10^{-3}$ M
- $[OH^-] = 1.0 \times 10^{-7}$ M
- $[H^+] = 1.0 \times 10^{-13}$ M
- $[OH^-] = 1.0 \times 10^{-11}$ M

What is the Hydrogen ion concentration if 3.5×10^{-3} *M* acid ionizes at 13.0%?

What is the pH & pOH?

What is the Hydroxide ion concentration if 4.7×10^{-2} *M* base ionizes at 8.0%?

What is the pH & pOH?

Calculating the pH of Strong Acids

Strong acids ionize at 100%

What is the Hydrogen ion concentration if you have 2.0-*M* HCl?

What is the pH & pOH?

Calculating the pH of Strong Bases

Strong bases ionize at 100%

What is the Hydroxide ion concentration if you have 2.0 *M* NaOH?

What is the pH & pOH?

Calculating the pH of Strong Bases

Strong bases ionize at 100%, and can ionize more if there are more OH^- present.

What is the Hydroxide ion concentration if you have 2.3×10^{-3} *M* $Ca(OH)_2$?

What is the pH & pOH?

19.4 NEUTRALIZATION REACTIONS

- **A reaction in which an acid and a base react in aqueous solution to produce a salt and water.**

$$H_2SO_4 + 2NaOH \longrightarrow 2H_2O + Na_2SO_4$$

- Neutralization reactions are also considered salt production reactions.
- After neutralizing the acid and base, heating the solution will produce salt.

Acid-Base Reactions: produce salt and water

$HCl + KOH \longrightarrow$

$H_2SO_4 + Ca(OH)_2 \longrightarrow$

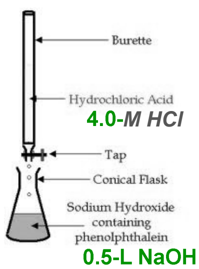
$H_3PO_4 + Al(OH)_3 \longrightarrow$

Steps in aNeutralization Reactions

- Titration
- Equivalence Point
- Standard Solution
- End Point
- Titration curves

TITRATION

- The addition of a known amount of solution of known concentration to determine the concentration of another solution.



$HCl + NaOH \rightarrow H_2O + NaCl$

Performing a Titration

- Standard Solution
- The solution of known concentration

-Remember: concentration = molarity

- ex.) .50-*M* HCl

Equivalence Point

- The number of moles of hydrogen ions must equal the number of moles of hydroxide ions.
- Use stoichiometry!
- **Mathematically neutral!!!!** $OH^- = H^+$
- Sometimes, the indicator does not change at the equivalence point.

End Point

- The point at which the indicator changes color.
- Not always equal to equivalence point
- Sometimes, the pH change is so drastic that it takes the indicator extra time to change.
- AKA...point of neutralization.

Phenophtalein

- Universal indicator for acid-base neutralization reactions.
- Pink in a base
- Colorless in an acid

Example #1

How many moles of H_2SO_4 would you require to neutralize 0.50 mol of NaOH? *(Regular stoichiometry)*

Moles neutralizes Moles

- **Write a balanced equation.**

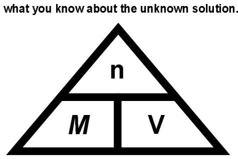
  $H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

- **Find the ratio of H_2SO_4 to NaOH.**
- **Solve the problem.**

Neutralization Reactions

1. Determine the number of moles in the known solution.
2. Using stoichiometry, determine the moles of unknown solution needed.
3. Answer the question using what you know about the unknown solution.

Easy way to solve for the missing component of the unknown solution.



Example #2 - A

How much 1.0-*M* H_2SO_4 is needed to neutralize 1.0-L of 2.0-*M* NaOH?

$H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

H_2SO_4	NaOH
M:	*M*:
V:	V:
n:	n:

Example #2 - B

How much 2.0-*M* H_2SO_4 is needed to neutralize 1.0-L of 2.0-*M* NaOH?

$H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

H_2SO_4	NaOH
M:	*M*:
V:	V:
n:	n:

Example #2 - C

How much 5.0-*M* H_2SO_4 is needed to neutralize 1.0-L of 2.0-*M* NaOH?

$H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

H_2SO_4	NaOH
M:	*M*:
V:	V:
n:	n:

Example #3 – A

If 1.0-Lof H_2SO_4 neutralizes 1.0-L of 2.0-*M* NaOH, what is the concentration of H_2SO_4?

$H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

H_2SO_4	NaOH
M:	*M*:
V:	V:
n:	n:

Example #3 – B

If 2.0-Lof H_2SO_4 neutralizes 1.0-L of 2.0-*M* NaOH, what is the concentration of H_2SO_4?

$H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

H_2SO_4	NaOH
M:	*M*:
V:	V:
n:	n:

Example #3 – C

If 4.0-Lof H_2SO_4 neutralizes 1.0-L of 2.0-*M* NaOH, what is the concentration of H_2SO_4?

$H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

H_2SO_4	NaOH
M:	*M*:
V:	V:
n:	n:

Example #4

A 25-mL solution of H_2SO_4 is neutralized by 18 mL of 1.0 *M* NaOH using phenolphthalein as an indicator. What is the concentration of the H_2SO_4 solution?

$H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$

H_2SO_4	NaOH
M:	*M*:
V:	V:
n:	n:

Buffers

- A solution of weak acid and conjugate base or weak base and conjugate acid.
- Able to resist drastic changes in pH better than pure water
- Why is some aspirin buffered?

Buffer Capacity

The point at which a buffer can no longer resist change in pH. Dependent on the amount of acid or base that is added.