Acid-Base Chemistry

- Acids and bases play an important role in our lives.
- Acids and bases are in a way opposites and neutralize each other.

Acid	Base
Sour taste.	Bitter Taste
Blue litmus turns red.	Red litmus turns blue.
pH < 7.0	pH > 7.0
	Slippery, soapy feel.

Chapter 15 – Study 15.1-15.5, 15.7-15.8 and 15.10 ONLY!

Arrhenius Acids and Bases

Arrhenius Acid: Substance that releases H^+ ions when dissolved in water.

Arrhenius Base: Substance that releases OH^- ions when dissolved in water.

$$HCl\ (aq) + NaOH\ (aq) \longrightarrow H_2O\ (l) + NaCl\ (aq)$$

_______ is the Arrenhius acid and _______ is the Arrhenius base.

Ionization is the process by which the molecules in a polar compound form cations and anions.

→ A molecule of HCl ionizes to H^+ and Cl^-

Dissociation is the process whereby the already existing ions in an ionic compound simply separate.

→ A formula unit of NaOH dissociates into Na^+ and OH^-

The strength of an Arrhenius acid is measured by the degree of *ionization* in solution.

Common Arrhenius Acids

Aqueous Acids	Percent Ionization	Acid Strength
hydrochloric acid, $HCl(aq)$	~100%	strong
nitric acid, $HNO_3(aq)$	~100%	strong
sulfuric acid, $H_2SO_4(aq)$	~100%	strong
acetic acid, $HC_2H_3O_2(aq)$	slightly	weak
carbonic acid, $H_2CO_3(aq)$	slightly	weak
hydrofluoric acid, $HF(aq)$	slightly	weak
phosphoric acid, $H_3PO_4(aq)$	slightly	weak

The strength of an Arrhenius base is measured by the degree of *dissociation* in solution.

Common Arrhenius Bases

Aqueous Bases	Percent Dissociation	Base Strength
barium hydroxide, $Ba(OH)_2(aq)$	~100%	strong
calcium hydroxide, $Ca(OH)_2(aq)$	~100%	strong
lithium hydroxide, $LiOH(aq)$	~100%	strong
potassium hydroxide, $KOH(aq)$	~100%	strong
sodium hydroxide, $NaOH(aq)$	~100%	strong
ammonium hydroxide, $NH_4OH(aq)$*	slightly	weak

*Ammonium hydroxide is prepared by dissolving ammonia gas in water. It is referred to as an aqueous ammonia solution, $NH_3(aq)$, or as ammonia water, $NH_3 \cdot H_2O$. The name "ammonium hydroxide" is somewhat misleading since there is no evidence for ammonium hydroxide molecules in solution. For simplicity, however, we will refer to an ammonia solution as ammonium hydroxide, $NH_4OH(aq)$.

For simplicity, chemists often use H^+ to designate a hydrogen ion in aqueous solution.

The solution actually contains ***hydronium ion***, H_3O^+.

It is formed when an aqueous hydrogen ion attaches to a water molecule.

$$HCl\ (aq) + H_2O\ (l) \longrightarrow H_3O^+\ (aq) + Cl^-\ (aq) \quad (\sim 100\ \%)$$

$$HC_2H_3O_2\ (aq) + H_2O\ (l) \longrightarrow H_3O^+\ (aq) + C_2H_3O_2^-\ (aq) \quad (\sim 1\ \%)$$

Similarly, with a strong base and weak base:

$$NaOH\ (aq) \longrightarrow Na^+\ (aq) + OH^-\ (aq) \quad (\sim 100\ \%)$$

$$NH_4OH\ (aq) \longrightarrow NH_4^+\ (aq) + OH^-\ (aq) \quad (\sim 1\ \%)$$

Brønsted-Lowry Acids and Bases

Brønsted-Lowry Acid: Substance that donates a proton (a.k.a. – H^+ donor).

Brønsted-Lowry Base: Substance that accepts a proton (a.k.a. – H^+ acceptor).

Why is H^+ called a proton?

$$HCl\ (aq) + NaOH\ (aq) \longrightarrow H_2O\ (l) + NaCl\ (aq)$$

proton donor — proton acceptor

$$HCl\ (aq) + NH_3\ (aq) \longrightarrow NH_4Cl\ (aq)$$

proton donor — proton acceptor

$$HCl\ (aq) + H_2O\ (l) \longrightarrow H_3O^+\ (aq) + Cl^-\ (aq)$$

proton donor — proton acceptor

Determine the Brønsted-Lowry Acid and Brønsted-Lowry Base

H_2O (l) + HNO_3 (aq) ⟶ H_3O^+ (aq) + NO_3^- (aq)

$HC_2H_3O_2$ (aq) + H_2O (l) ⟶ H_3O^+ (aq) + $C_2H_3O_2^-$ (aq)

NO_2^- (aq) + $HClO_4$ (aq) ⟶ HNO_2 (aq) + ClO_4^- (aq)

NH_3 (aq) + H_2O (l) ⟶ OH^- (aq) + NH_4^+ (aq)

Water

H_2O (l) + H_2O (l) ⟶ H_3O^+ (aq) + OH^- (aq)

proton donor — proton acceptor

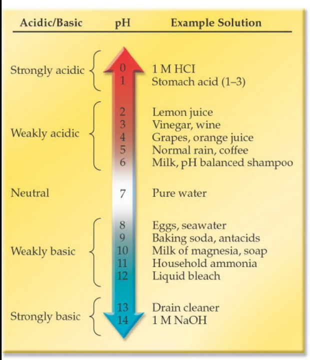
"Amphoteric"

Even though pure water is considered as a nonconductor, an extremely sensitive detector will show that slight ionization occurs.

H_2O (l) ⇌ H_3O^+ (aq) + OH^- (aq)

pH Scale

A pH value expresses the acidity or basicity of a solution.



pH between 0 and 2 is *strongly* acidic

pH between 2 and 7 is *weakly* acidic

pH = 7 is considered *neutral*

pH between 7 and 12 is *weakly* basic

pH between 12 and 14 is *strongly* basic

Indicate whether each of the following solutions is considered strongly acidic, Weakly acidic, neutral, weakly basic, or strongly basic.

1. Gastric juice, pH 1.5
2. Oven cleaner, pH 13.5
3. Orange juice, pH 4.5
4. Eggs, pH 7.5
5. Deionized water, pH 7.0
6. Carbonated soda, pH 4.0

pH and pOH Calculations

Rather than express hydrogen and hydroxide ion concentrations in very small numbers with negative exponents, a base-10 logarithm is applied.

$pH = -\log [H^+]$ $pOH = -\log [OH^-]$

$[H^+] = 10^{(-pH)}$ $[OH^-] = 10^{(-pOH)}$

$pH + pOH = 14.00$

$[H^+] = [OH^-] = 1 \times 10^{-7}$ Neutral solution, pH = 7

$[H^+] > [OH^-]$ Acidic solution, pH < 7

$[H^+] < [OH^-]$ Basic solution, pH > 7

K_w is the equilibrium constant for water

$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$

Determine the pH of the following solutions:

a. $[H^+]$ = 0.001 M pH = ________
b. $[H^+]$ = 0.00001 M pH = ________
c. $[H^+]$ = 0.0000001 M pH = ________
d. $[H^+]$ = 0.01 M pH = ________

Converting between pH and pOH: pH + pOH = 14.00

pOH = 2.65	pH = _______	acidic	basic	neutral
pOH = 7.61	pH = _______	acidic	basic	neutral
pOH = 10.53	pH = _______	acidic	basic	neutral
pOH = 6.91	pH = _______	acidic	basic	neutral

Titration

Standard Solution
An acid or base solution where the concentration is known, generally to 3 sig figs

Used to analyze properties of substances, such as neutralizing power of commercial antacids, tartness of wine, etc.

pH Indicator
Solutions that are pH sensitive and change color

titration
The gradual addition of standard solution to another solution of unknown concentration until the reaction between the two is complete, as signaled by an indicator changing color.

endpoint
When one reactant has completely reacted with the other reactant, as evidenced by an indicator changing color.

Sample Titration Equation

If 15.00 mL of 0.5500 M NaOH is used to titrate 10.00 mL of nitric acid To the end point, what is the molarity of the nitric acid?

$NaOH\ (aq) + HNO_3\ (aq) \longrightarrow H_2O\ (l) + NaNO_3\ (aq)$

0.5500 M ??

$0.01500\ L\ NaOH \times \left(\frac{0.5500\ mol\ NaOH}{1\ L\ NaOH}\right) \times \left(\frac{1\ mol\ HNO_3}{1\ mol\ NaOH}\right) = 0.008250\ mol\ HNO_3$

$Molarity = \frac{mol\ solute}{L\ solution} = \frac{0.008250\ mol\ HNO_3\ (aq)}{0.01000\ L\ HNO_3\ (aq)} = \boxed{0.8250\ M\ HNO_3\ (aq)}$

Electrolytes & Ionic Equations

Strong Electrolyte -
Strong/good conductor of electricity

Example: soluble salts (soluble ionic compounds) that dissolve completely in water. Also strong acids/bases.

$NaCl\ (aq) \longrightarrow Na^+\ (aq) + Cl^-\ (aq)$

- *many* ions are present to conduct electricity

Weak Electrolyte -
Weak/poor conductor of electricity

Example: insoluble salts (insoluble ionic compounds) that DO NOT dissolve completely in water. Also weak acids/bases.

$HC_2H_3O_2\ (aq) \rightleftharpoons H^+\ (aq) + C_2H_3O_2^-\ (aq)$

- *very* few ions are present to conduct electricity

nonelectrolyte -
Substances that can NOT conduct electricity

Example: molecular liquids, solids, gases. These molecules are molecular (two or more nonmetals covalently bound to eachother) so they do not form ions.

$C_6H_{12}O_6$ (sugar) C_2H_5OH (ethanol) CO_2 (g)

- Dissolve any one of these in water and ***NO*** ions are present to conduct electricity!

Example:

Write the formula of the species in solution when water is added to the following ionic solids to make a solution.

a. $CaBr_2$
b. $Fe(NO_3)_3$
c. K_2SO_4
d. $Mg(C_2H_3O_2)_2$
e. $Zn(NO_3)_2$
f. $Sr(OH)_2$
g. Na_3PO_4

Example:

Use your solubility rules to determine if the following compounds are a strong or weak electrolyte.

a. $PbSO_4$	strong electrolyte	weak electrolyte
b. $NaOH$	strong electrolyte	weak electrolyte
c. NH_4Cl	strong electrolyte	weak electrolyte
d. $Zn(OH)_2$	strong electrolyte	weak electrolyte
e. K_2CrO_4	strong electrolyte	weak electrolyte
f. $Al(NO_3)_3$	strong electrolyte	weak electrolyte

Example:

Show the species present in solution when those same compounds are placed in water.

a. $PbSO_4 \xrightarrow{H_2O}$

b. $NaOH \xrightarrow{H_2O}$

c. $NH_4Cl \xrightarrow{H_2O}$

d. $Zn(OH)_2 \xrightarrow{H_2O}$

e. $K_2CrO_4 \xrightarrow{H_2O}$

f. $Al(NO_3)_3 \xrightarrow{H_2O}$

g. $Al_2(SO_4)_3 \xrightarrow{H_2O}$

h. $Ca_3(PO_4)_2 \xrightarrow{H_2O}$

Example:

For the weak electrolytes below, write N/A. For the strong electrolytes, indicate the number of moles of ions produced when **1 mole** of each compound dissolves in water.

a. $PbSO_4$ ________ moles of ions

b. $NaOH$ ________ moles of ions

c. NH_4Cl ________ moles of ions

d. $Zn(OH)_2$ ________ moles of ions

e. K_2CrO_4 ________ moles of ions

f. $Al(NO_3)_3$ ________ moles of ions

g. $Al_2(SO_4)_3$ ________ moles of ions

h. $Ca_3(PO_4)_2$ ________ moles of ions