Acids and Base

Objective 1: Define Acids and bases according to the *Bronsted-Lowry and Lewis Theories*

- ***Brønsted-Lowry Acids*: Substances that donate H^+(protons) in aqueous solution**
- ***Brønsted-Lowry Bases:* Substances that accept H^+ (protons) in aqueous solution**
- *''Lewis Acid*: Substance that accepts an e^- pair''
- *''Lewis Base*: Substance that donates an e^- pair''
- Lewis Acids and Bases mustn't include Hydrogen
- **= Big in General Chem
- ''= Big in O-Chem

Examples of Lewis bases:

- NH_3 (lone pair on the N is readily donated)
- BF_3 (Actually a Lewis Acid but reacts with NH_3 to form NH_3BF_3)
- CN^- and the unbonded pair on the C is readily donated (due to Carbon having a lower electronegativity than Nitrogen so it more readily shares electrons)
- $Fe^{3+} + 6NH_3 \rightarrow [Fe(NH_3)_6]^{3+}$ Where Fe^{3+} is a Lewis Acid and NH_3 a Lewis Base
- Metal Ions with charges of 2^+ or more, are Lewis Acids

Objective 2: Deduce the formula of the conjugate acid (or base) of any Brønsted-Lowry Base or Acid

- Example: $HCO_2H + H_2O \leftrightarrow HCO_2^- + H_3O^+$!! $H_3O^+$is called Hydronium!!
  - HCO_2H is the B.L. Adic
  - H_2O is the B.L. Base
  - $HCO_2{}^-$ is conj Base
  - H_3O^+ is conj acid
- Example: $NH_3 + H_2S \leftrightarrow NH_4^+ + HS^-$
  - NH_3 is BL Base
  - H_2S is BL Acid
  - NH_4^+ is conj Acid
  - HS^- is Conj Base
- $HSO_4^- + OH^- \leftrightarrow SO_4^{2-} + H_2O$
  - HSO4- is BL Acid
  - OH- BL Base
  - SO4 Conj Base
  - H2O Conj Acid

Acid	Conj Base
HCN	H^+ + CN^-
HSO_4^-	H^+ + $SO_4{}^{2-}$
HF	$H^+ + F^-$
CH_3CH_2COOH	$H^+ + CH_3CH_2COO^-$
$HC_3H_5O_2$	$H^+C_3H_5O_2^-$

Base	Conj Acid
$NH_3 + H^+$	NH_4^+
$HCO_3^- + H^+$	H_2CO_3
$Br^- + H^+$	HBr

Objective 3: Outline the characteristics of acids and bases in aqueous solutions.

ACIDS

1. @ 25℃ the pH of an acid solution is < 7
2. An acid will turn litmus red. Phenolphthalein is colorless and methyl orange
3. Acids taste sour
4. Acids react with Hydroxides in neutralization reactions to produce salts and water

$$HCl + NaOH \rightarrow NaCl + H_2O$$

$$Ca(OH)_2 + 2HCl \rightarrow 2H_20 + CaCl_2$$

$$Al(OH)_3 + 3HBr \rightarrow 3H_2O + AlBr_3$$

$$2KOH + H_2SO_4 \rightarrow H_2O + K_2SO_4$$

$$LiOH + HNO_3 \rightarrow H_2O + LiNO_3$$

5. Acids react with metal oxides to form a Salt and H_2O

$$CaO + 2HCl \rightarrow H_2O + CaCl_2$$
$$BaO + 2HCl \rightarrow H_2O + BaCl_2$$
$$Na_2O + H_2SO_4 \rightarrow H_2O + Na_2SO_4$$
$$MgO + H_2S \rightarrow H_2O + MgS$$
$$Na_2O + 2H_3PO_4 \rightarrow 3H_2O + 2Na_3PO_4$$

6. Acids react with Carbonates and Hydrogen Carbonates to make Water, Carbon Dioxide, and a salt.

$$NaHCO_3 + HCl \rightarrow H_2O + CO_2 + NaCl$$
$$Na_2CO_3 + 2HBr \rightarrow H_2O + CO_2 + 2NaBr$$
$$CaCO_3 + 2HNO_3 \rightarrow H_2O + CO_2 + Ca(NO_3)_2$$
$$K_2CO_3 + H_2SO_4 \rightarrow H_2O + CO_2K_2SO_4$$

7. Acids react with active metals to produce a salt and H_2(Except HNO_3)

$$Mg + 2HCl \rightarrow H_2 + MgCl_2$$

<u>BASES</u>

- Most bases are Metal Oxides, Hydroxides, Carbonates, Hydrogen Carbonates, and Amines (Primary, Secondary, or Tertiary)
- Solutions of Bases are called alkalis

Properties of Bases

1. They feel Slippery
2. Taste Bitter
3. They form Aqueous Solutions @ 25℃ with pH>7
4. Bases will turn Litmus Blue, will also turn Phenolphthalein pink.
5. Metal Oxides react with Dihydrogen Monoxide to form Metal Hydroxides

   $\mathrm{CaO} + \mathrm{H_2O} \rightarrow Ca(\mathrm{OH})_2$

6. Amines and NH_3 react with Dihydrogen Monoxide to form OH^- and appropriate Cations
   a. $NH_3(aq) + H_2O(l) \leftrightarrow OH^-(aq) + NH_4^+(aq)$
      i. BL Base: NH_3
      ii. BL Acid: H_2O
      iii. Conj Base: OH^-
      iv. Conj Acid: NH_4^+
   b. $CH_3NH_2(aq) + H_2O(l) \leftrightarrow OH^-(aq) + CH_3NH_3^+$
      i. Hydrogen Ions must be shown with Nitrogen not Carbon
      ii. BL Base: CH_3NH_2
      iii. BL Acid: H_2O
      iv. Conj Base: OH^-
      v. Conj Acid: $CH_3NH_3^+$

Objective 4: Distinguish between strong and weak acids, strong acids completely in H_2O

- $HCl \rightarrow H^+(aq) + Cl^-(aq)$
- Strong Acids: HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$
- Weak Acids Ionize reversibly. The equilibrium favors the reactants
  - $CH_3COOH(aq) \leftrightarrow CH_3COO^-(aq) + H^+(aq)$ K_a is very small
  - $K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$
- Solutions of strong acids are excellent electrical conductors. Weak acids are weak electrical conductors.

- Acids (strong)
    - Are good electrical conductors
    - Reaction with H_2O to form H_3O^+ and the anions of the Acids
        - (acids are the only molecular compounds to ionize in water)
    - Ionization of Acids is shown 2 ways: Strong and Weak
    - Strong:
        - $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$
        - $\mathrm{HBr}(aq) \rightarrow H^+(aq) + \mathrm{Br}^-(aq)$
        - $HNO_3(aq) \rightarrow H^+(aq) + NO_3(aq)$
        - $H_2SO_4 \rightarrow H^+ + HSO_4^-$
    - Weak:
        - $\mathrm{H}SO_4^-(aq) \leftrightarrow H^+(aq) + SO_4^{2-}$
    - Strong (with Dihydrogen Monoxide)
        - $HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$
        - $HBr(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Br^-(aq)$
        - $HNO_3(aq) + H_2O(l) \rightarrow H_3O^+(aq) + NO_3^-(aq)$
    - Weak (with Dihydrogen Monoxide)
        - $HSO_4^-(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + SO_4^{2-}(aq)$
- Acids (weak)
    - Ionize very sparingly with H_2O
    - Equilibrium Arrow is used
    - Equilibrium Constant is usually much less than 1 (favors reactants)($K_a \ll 1$)
    - They are poor conductors of Electricity (not insulators)
- Bases (strong)
    - Dissociate completely in water to form metal cations and OH^- to limits of solubility (@ least 0.1 M)
    - Do not react with H_2O
    - Excellent electrical conductors
    - Strong Bases: LiOH, NaOH, KOH, $Ca(OH)_2$, $Ba(OH)_2$, $Sr(OH)_2$
        - $LiOH(aq) \rightarrow Li^+(aq) + OH^-(aq)$
        - $Ca(OH)_2(aq) \rightarrow Ca^{2-} + 2OH^-$
- Bases (weak)
    - React with H_2O to from OH^-
    - Only a small fraction of the base molecules react
    - Equilibrium Arrow is used for ionization reactions
    - Equilibrium Constant is much less than 1 (favors reactants) ($K_b \ll 1$)
    - Conduct electricity poorly
    - pH @ 25℃ > 7
        - $NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$**
        - $F^-(aq) + H_2O(l) \leftrightarrow HF(aq) + OH^-(aq)$**

- $CH_3COO^-(aq) + H_2O(l) \leftrightarrow CH_3COOH(aq) + OH^-(aq)$**
- $HS^-(aq) + H_2O(l) \leftrightarrow H_2S(aq) + OH^-(aq)$**
- ** = Atom and Charge must be balanced
- H_2O must be shown

Objective 5: Calculate pH, pOH and K_w

- $pH = -\log[H^+]$
- $Examples$:
  - $0.0051 \frac{mol}{L} \rightarrow -\log[0.0051] = pH = 2.29$
  - 0.0125 mol L^{-1} H^+ pH=1.903
- $pOH = -\log[OH^-]$
  - $0.015 \frac{mol}{L} KOH \rightarrow -\log[0.015] \rightarrow pOH = 1.82$
- $pH + pOH = 14.00$ @ 25℃
  - 14.00-1.82 = 12.18 is the pH
  - pK_w is the negative log of the equilibrium constant
- K_w@25℃ $= 1.0 \times 10^{-14} = [H^+] \cdot [OH^-]$
  - $\frac{1.0\times10^{-14}}{[H^+]} = [OH^-]$
  - $\frac{1.0\times10^{-14}}{[OH^-]} = [H^+]$
- $H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$
  - $H_2O \leftrightarrow H^+ + OH^-$
  - $Reactants\ are\ heavily\ favored$
- Example: A 0.10 mol/L solution of a weak acid. The pH is 4.26. What is the % Ionization?
  - $10^{-4.26} = [H^+] = 5.5 \times 10^{-5} \frac{mol}{L}$
  - $\frac{5.5\times10^{-5}}{0.10} \times 100 = 0.055\%$

Objective 6: Predict the direction and magnitude of the change in $[H^+]$ when pH changes by an integer value.

PH VALUE	H^+ Concentration
pH = 1.00	$[H^+] = 1.0 \times 10^{-1} M$
pH = 2.00	$[H^+] = 1.0 \times 10^{-2}$M
pH = 3.00	$[H^+] = 1.0 \times 10^{-3}$ M
pH = 14.00	$[H^+] = 1.0 \times 10^{-14}$ M

- Ex Quest: The pH of a Solution increases from 2.00 to 5.00. By what factor has the $[H^+]$ changed and in what direction?
  - Went up in pH by 3.00
  - $10^3 = 1000$

- $[H^+]$ decreased by factor of 100

Objective 7: Know some facts about Acid Deposition in the environment.

- Acids: H_2SO_3 and H_2SO_4 are the results of volcanic activity and the burning of fossil fuels.
  - $S(s) + O_2(g) \rightarrow SO_2(g)$
  - $SO_2(g) + \frac{1}{2}O_2(g) \rightarrow (Sunlight\ Catalyst) \rightarrow SO_3(g)$
  - $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$
  - $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
- HNO_2 and HNO_3 are associated with electrical storms, bacterial action, and jet/internal combustion engines
  - $N_2(g) + O_2(g) \rightarrow (heat\ catalyst) \rightarrow 2NO(g)$
  - $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
  - $2NO_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$ OR
    $4NO_2(g) + O_2(g) + H_2O(l) \rightarrow 4HNO_3(aq)$
- pH of unpolluted rain: 5.65 due to CO_2
  - Acid Rain: pH<5.6
  - $CO_2 + H_2O \leftrightarrow H_2CO_3(aq)$