

## Acids and Base

**Objective 1:** Define Acids and bases according to the *Brønsted-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
- $HSO_4^- + OH^- \leftrightarrow SO_4^{2-} + H_2O$ 
  - $HSO_4^-$  is BL Acid
  - $OH^-$  BL Base
  - $SO_4$  Conj Base
  - $H_2O$  Conj Acid

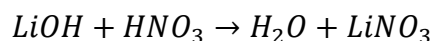
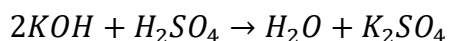
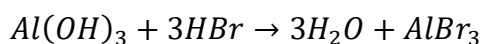
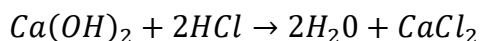
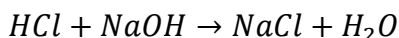
Acid	Conj Base
HCN	$H^+ + CN^-$
$HSO_4^-$	$H^+ + SO_4^{2-}$
HF	$H^+ + F^-$
$CH_3CH_2COOH$	$H^+ + CH_3CH_2COO^-$
$HC_3H_5O_2$	$H^+ + C_3H_5O_2^-$

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

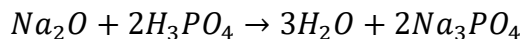
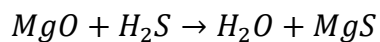
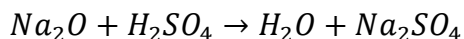
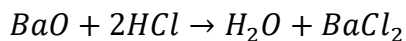
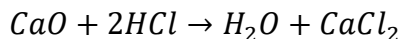
**Objective 3:** Outline the characteristics of acids and bases in aqueous solutions.

### ACIDS

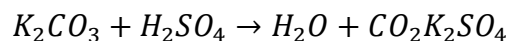
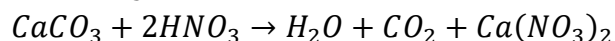
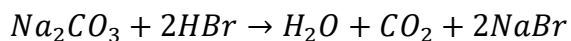
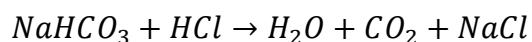
1. @ 25°C the pH of an acid solution is < 7
2. An acid will turn litmus red. Phenolphthalein is colorless and methyl orange
3. Acids taste sour
4. Acids react with Hydroxides in neutralization reactions to produce salts and water



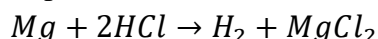
5. Acids react with metal oxides to form a Salt and  $H_2O$



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



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

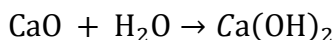


### BASES

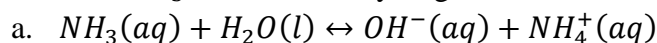
- Most bases are Metal Oxides, Hydroxides, Carbonates, Hydrogen Carbonates, and Amines (Primary, Secondary, or Tertiary)
- Solutions of Bases are called alkalis

### Properties of Bases

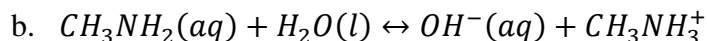
1. They feel Slippery
2. Taste Bitter
3. They form Aqueous Solutions @ 25°C with pH > 7
4. Bases will turn Litmus Blue, will also turn Phenolphthalein pink.
5. Metal Oxides react with Dihydrogen Monoxide to form Metal Hydroxides



6. Amines and  $NH_3$  react with Dihydrogen Monoxide to form  $OH^-$  and appropriate Cations



- i. BL Base:  $NH_3$
- ii. BL Acid:  $H_2O$
- iii. Conj Base:  $OH^-$
- iv. Conj Acid:  $NH_4^+$



- 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:
    - $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$
    - $HBr(aq) \rightarrow H^+(aq) + Br^-(aq)$
    - $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
    - $H_2SO_4 \rightarrow H^+ + HSO_4^-$
  - Weak:
    - $HSO_4^-(aq) \leftrightarrow H^+(aq) + SO_4^{2-}$
  - 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 form  $OH^-$
  - 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 @  $25^\circ C > 7$ 
    - $NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)**$
    - $F^-(aq) + H_2O(l) \leftrightarrow HF(aq) + OH^-(aq)**$

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

**Objective 5:** Calculate pH, pOH and  $K_w$

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

**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.
  - $S(s) + O_2(g) \rightarrow SO_2(g)$
  - $SO_2(g) + \frac{1}{2}O_2(g) \xrightarrow{\text{Sunlight Catalyst}} SO_3(g)$
  - $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$
  - $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
- $HNO_2$  and  $HNO_3$  are associated with electrical storms, bacterial action, and jet/internal combustion engines
  - $N_2(g) + O_2(g) \xrightarrow{\text{heat catalyst}} 2NO(g)$
  - $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
  - $2NO_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$  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:  $pH < 5.6$
  - $CO_2 + H_2O \leftrightarrow H_2CO_3(aq)$