ACIDS & BASES

I. GENERAL DEFINITIONS OF ACIDS & BASES

A. ACIDS are molecular compounds that produce ions by chemical reaction with water.

Ionization Reaction:

$$HA_{(aq)} + H_2O_{(l)} \longrightarrow \underset{\text{hydronium ion}}{H_3O^+_{(aq)}} + A^-_{(aq)}$$

Simplified Ionization Reaction:

$$HA_{(aq)} \longrightarrow \underset{\substack{\text{hydrogen ion}\\(\text{proton})}}{H^+_{(aq)}} + A^-_{(aq)}$$

1. Strong Acids: react completely with water.

   The strong acids are: HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$ (these are not all the strong acids that exist)

2. Weak Acids: react very little with water.

B. BASES

1. Strong Bases (soluble metal hydroxides): are ionic compounds that dissociate into their ions when they dissolve in water. (The strong bases are . . . . .)

   Dissociation:

   $$MOH_{(s)} \longrightarrow M^+_{(aq)} + \underset{\text{hydroxide ion}}{OH^-_{(aq)}}$$

2. Weak Bases: these are molecular compounds that produce ions by reaction with water, however they react very little with water.

   Ionization Reaction:

   $$B_{(aq)} + H_2O_{(l)} \longrightarrow BH^+_{(aq)} + OH^-_{(aq)}$$

3. Insoluble Metal Hydroxides

C. More Definitions

1. Acidic Solution: aqueous solution in which $[H_3O^+] > [OH^-]$

2. Basic (alkaline) Solution: aqueous solution in which $[OH^-] > [H_3O^+]$

3. Neutral Solution: $[H_3O^+] = [OH^-]$

II. pH Scale

A. pH scale is used to designate relative acidity or basicity (alkalinity) of aqueous solutions.

B. Calculation of pH, pOH

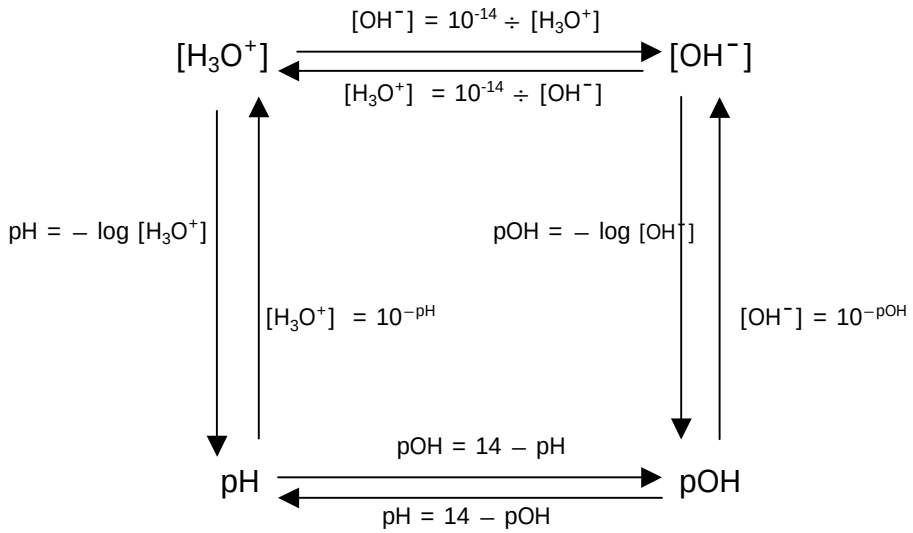
1. $pH = -\log [H_3O^+]$

2. $pOH = -\log [OH^-]$

	← ACIDIC →								← BASIC →						
$[H_3O^+]$	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}
pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pOH	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$[OH^-]$	10^{-14}	10^{-13}	10^{-12}	10^{-11}	10^{-10}	10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	10^0

NOTICE: $[H_3O^+] \times [OH^-] = 1.0 \times 10^{-14}$ and $pH + pOH = 14$

also, $[H_3O^+] = \text{antilog}(-pH)$ or 10^{-pH} and $[OH^-] = \text{antilog}(-pOH)$ or 10^{-pOH}



C. Calculation of Theoretical pH, pOH, $[H_3O^+]$, and $[OH^-]$ of Solutions of Strong Acids and Bases

1. Calculate the theoretical pH of:

   a. 0.01 M HNO_3

   b. 0.0250 M HCl

2. Calculate the theoretical pOH of:

   a. 0.0010 M NaOH

   b. 0.055 M KOH

3. If the pH is 3.26, what is the $[H_3O^+]$?

4. If the pOH is 7.88, what is the $[OH^-]$?

5. If the pH is 5.92, what is the $[OH^-]$?

6. If the pOH is 11.43, what is the $[H_3O^+]$?

7. If the $[H_3O^+]$ is 9.92×10^{-5}, what is the pOH?

8. If the $[OH^-]$ is 4.07×10^{-10}, what is the pH?

D. Calculation of Theoretical pH of Aqueous Solutions of *Weak* Acids and Bases

III. ACID BASE THEORIES

A. ARRHENIUS THEORY OF ACIDS AND BASES (1887)

1. Arrhenius Acid: a substance that produces H^+ in water solution

2. Arrhenius Base: a substance that produces OH^- in water solution

3. Neutralization reaction between acids & bases:

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$$

4. Limitations of Arrhenius theory:

B. BRÖNSTED-LOWRY THEORY OF ACIDS AND BASES (1923)

1. Brönsted Acid: a substance that can donate a proton.

2. Brönsted Base: a substance that can accept a proton.

3. Conjugate Acid-Base Pairs

In terms of the Brönsted-Lowry concept, ionization of an acid or of a molecular base is a reversible reaction involving two acid-base pairs.

a. Examples

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

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

b. Members of a conjugate acid-base pair differ by one H^+

c. Write equations for the ionization reactions of the following:

(1) $C_2H_5NH_2$, a base

(2) HNO_2, an acid

d. Practice – writing symbols/formulas for conjugates

(1) What is the conjugate base of:

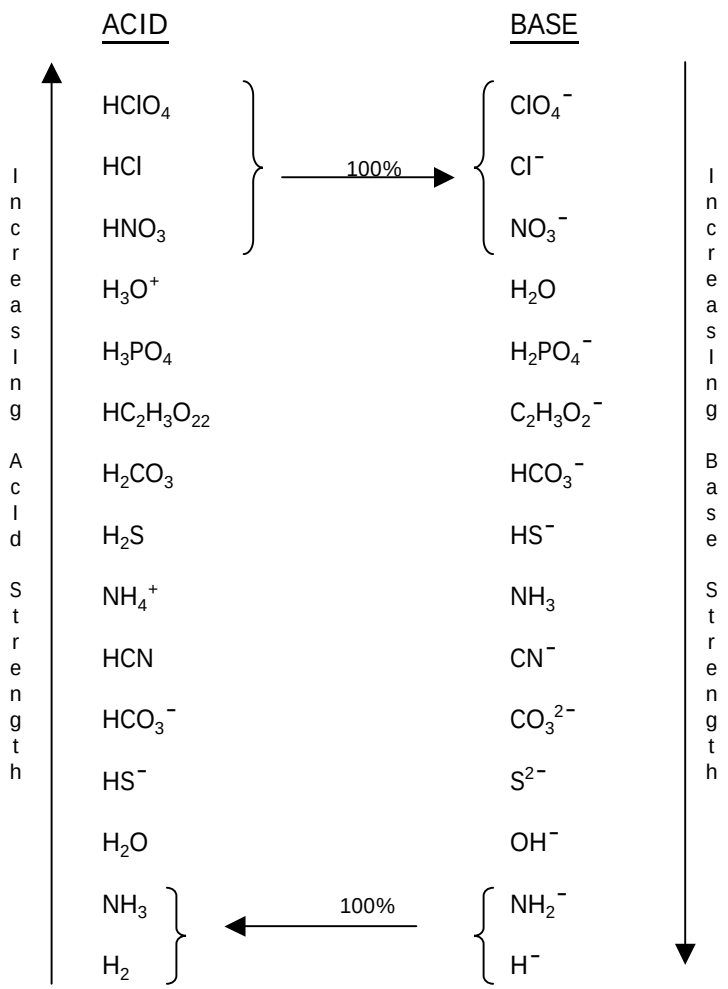
H_2O	NH_4^+	HS^-
NH_3	H_3O^+	$HClO_4$
H_3PO_4	H_2SO_4	

(2) What is the conjugate acid of:

H_2O	NH_2CONH_2	Cl^-
NH_3	C_5H_5N	N_2H_4
OH^-	PO_4^{3-}	HCO_3^-

d. Note: water is amphoteric (amphiprotic) - it can act as both an acid and a base

4. Relative Strengths of Conjugate Acid Base Pairs



The stronger the acid, the weaker its conjugate base. The stronger the base, the weaker its conjugate acid.

a. Example

$$HCl_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$$

b. Example

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

c. Equilibrium always favors formation of the weaker acid and base.

d. Molecular structure and acid strength. (see text)

C. LEWIS ACID BASE THEORY

1. Lewis base: a species that has an unshared electron pair with which it can form a covalent bond with another species. An electron pair donor.

2. Lewis Acid: a species that can form a covalent bond by accepting an electron pair from another species. An electron pair acceptor

3. Lewis Acid-Base Reaction

$$BF_3 + NH_3 \longrightarrow F_3BNH_3$$

$$HCl + NH_3 \longrightarrow NH_4^+ + Cl^-$$

Formation of complex ions:

$$Al^{3+} + 6\ H_2O \longrightarrow Al(H_20)_6^{3+}$$