Honors text: 4.3; 13.1-13.6; 14.1-14.3

NOTES – Acids, Bases & Salts

Arrhenius Theory of Acids & Bases:

-an acid contains hydrogen and ionizes in solutions to produce H+ ions:

$$HCl \rightarrow H^+(aq) + OH^-(aq)$$

-a base contains an -OH group and ionizes in solutions to produce OH^- ions:

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

Neutralization: the combination of H^+ with OH^- to form water

• Hydrogen ions (H^+) in solution form hydronium ions (H_3O^+)

Bronsted-Lowry Theory of Acids & Bases:

-an acid is a proton (H^+) donor

-a base is a proton (H^+) acceptor

BAD

LAA

Examples: ← Proton transfer

$$\underset{\text{acid}}{HCl(aq)} + \underset{\text{base}}{H_2O(l)} \rightarrow H_3O^+(aq) + Cl^-(aq)$$

Conjugate acid-base pairs differ by one proton (H+)

A conjugate acid is the particle formed when a base gains a proton.

A conjugate base is the particle that remains when an acid gives off a proton.

Examples: In the following reactions, label the conjugate acid-base pairs:

a) $\underset{\text{acid}}{H_3PO_4} + \underset{\text{base}}{NO_2^-} \leftrightarrow \underset{\text{conjugate acid}}{HNO_2} + \underset{\text{conjugate base}}{H_2PO_4^-}$

b) $\underset{\text{acid}}{CN^-} + \underset{\text{base}}{HCO_3^-} \leftrightarrow \underset{\text{conjugate acid}}{HCN} + \underset{\text{conjugate base}}{CO_3^{2-}}$

c) $\underset{\text{acid}}{HCN} + \underset{\text{base}}{SO_3^{2-}} \leftrightarrow \underset{\text{conjugate acid}}{HSO_3^-} + \underset{\text{conjugate base}}{CN^-}$

d) $\underset{\text{base}}{H_2O} + \underset{\text{acid}}{HF} \leftrightarrow \underset{\text{con base}}{F^-} + \underset{\text{con acid}}{H_3O^+}$

• notice that water can act as both an acid and a base according to the Bronsted Lowry theory (depending on what it is reacting with); it is said to be **AMPHOTERIC**.

Properties of Acids and Bases:

ACIDS:	BASES:
Have a sour taste	Have a bitter taste
Change the color of many indicators	Change the color of many indicators
Are corrosive (react with metals)	Have a slippery feeling
Neutralize bases	Neutralize acids
Conduct an electric current	Conduct an electric current

Strength of Acids and Bases:

-a strong acid dissociates completely in sol'n:

$HCl \rightarrow H^+(aq) + Cl^-(aq)$

-a weak acid dissociates only partly in sol'n:

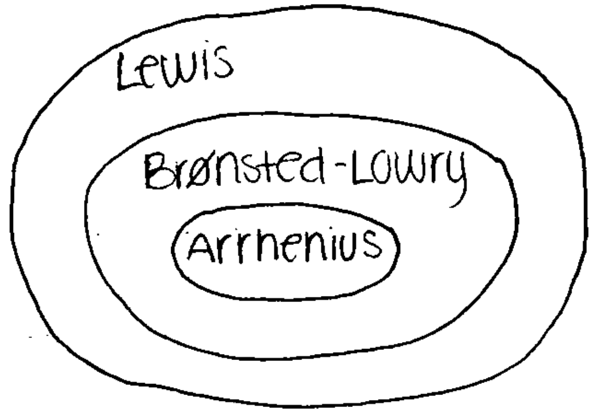
$HNO_2 \rightleftharpoons H^+(aq) + NO_2^-(aq)$

-a strong base dissociates completely in sol'n:

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

-a weak base dissociates only partly in sol'n:

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



The Lewis Theory of Acids & Bases

acid: electron pair acceptor.

base: electron pair donor.

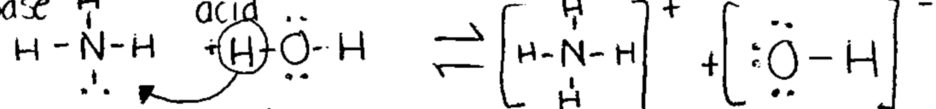
neutralization: the formation of a coordinate covalent bond in which both electrons originated on the same (donor) atom

Examples:

-ionization of NH_3:

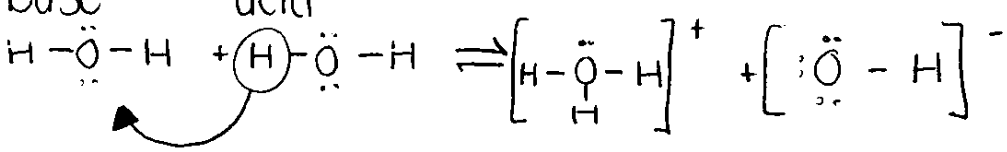
$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

base acid



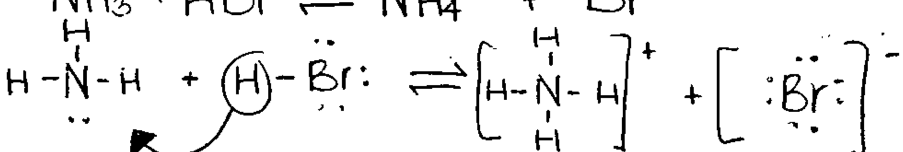
-auto-ionization of water: $H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$

base acid



-reaction of NH_3 with HBr (is a Lewis AND a Bronsted-Lowry acid-base reaction):

$NH_3 + HBr \rightleftharpoons NH_4^+ + Br^-$



base acid

Acid-Base Reactions - Arrhenius

Neutralization reactions: reactions between acids and metal hydroxide bases which produce a salt & water.

H^+ ions and OH^- ions combine to form water molecules:

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

Example: the reaction of **HCl** and **NaOH** (there are 3 ways to write the chem. eq.):

1) balanced formula unit equation:

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

2) total ionic equation:

$$H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)$$

3) net ionic equation:

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

Example: Write the 3 types of equations for the reaction of hydrobromic acid, HBr, with potassium hydroxide, KOH.

1) $HBr(aq) + KOH(aq) \rightarrow H_2O(l) + KBr(aq)$

2) $H^+(aq) + Br^-(aq) + K^+(aq) + OH^-(aq) \rightarrow H_2O(l) + K^+(aq) + Br^-(aq)$

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

Example: Write the 3 types of equations for the reaction of calcium hydroxide, $Ca(OH)_2$, with nitric acid, HNO_3.

1) $Ca(OH)_2(aq) + 2HNO_3(aq) \rightarrow 2H_2O(l) + Ca(NO_3)_2(aq)$

2) $Ca^{+2}(aq) + 2OH^-(aq) + 2H^+(aq) + 2NO_3^-(aq) \rightarrow 2H_2O(l) + Ca^{2+} + 2NO_3^-(aq)$

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

Notes: pH and pOH

- Experiments have shown that pure water ionizes very slightly:

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

- Measurements show that:

$$[H_3O^+] = [OH^-] = 1 \times 10^{-7} M$$

- Pure water contains equal concentrations of H_3O^+ and OH^-, so it is neutral.

- ***pH is a measure of the concentration of hydronium ions in a solution:***

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

or

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

* The number of decimal places in the log is equal to the number of significant figures in the original number

Example: What is the pH of a solution where $[H_3O^+] = 1 \times 10^{-7}M$?

$$pH = -\log[1 \times 10^{-7} M]$$

$$pH = 7.0$$

- ***When an acid is added to water, the [H_3O^+] increases, and the pH decreases.***

Example: What is the pH of a solution where [H_3O^+] = 1 x 10^{-5}M?

$pH = -\log[1 \times 10^{-5}]$

$pH = 5.0$

- ***When a base is added to a solution, the [H_3O^+] decreases, and the pH increases.***

Example: What is the pH of a solution where [H_3O^+] = 1 x 10^{-10} M?

$pH = -\log[1 \times 10^{-10}]$

$pH = 10.0$

The pH scale:

0 — 7 — 14

acid neutral base

- ***pOH is a measure of the concentration of hydroxide ions in solutions:***

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

Example: What is the pOH of a solution where [OH^-] = 1 x 10^{-5}M?

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

$pOH = -\log[1 \times 10^{-5} M]$

$pOH = 5.0$

- **At every pH, the following relationships hold true:**

$[H^+] \cdot [OH^-] = 1 \times 10^{-14} M$ $\qquad pH + pOH = 14$

1) What is the pH of a solution where [H_3O^+] = 3.4 x 10^{-5}M?

$pH = -\log[3.4 \times 10^{-5}]$

$pH = 4.47$

2) The pH of a solution is measured to be 8.86. What is the [H_3O^+] in this solution?

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

$8.86 = -\log[H_3O^+]$

$-8.86 = \log[H_3O^+]$

$[H_3O^+] = \text{antilog}(-8.86)$

$[H_3O^+] = 10^{-8.86}$

$[H_3O^+] = 1.4 \times 10^{-9} M$

3) What is the pH of a solution where [H_3O^+] = 5.4 x 10^{-6}M?

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

$pH = -\log[5.4 \times 10^{-6} M]$

$pH = 5.27$

4) What is the [OH^-] and pOH for the solution in #3?

$[H_3O^+][OH^-] = 1 \times 10^{-14}$

$(5.4 \times 10^{-6})[OH^-] = 1 \times 10^{-14}$

$[OH^-] = 1.9 \times 10^{-9} M$

$pH + pOH = 14$

$pOH = 14 - 5.27 = 8.73$

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Acids & Bases: Titrations

• The amount of acid or base in a solution is determined by carrying out a neutralization reaction; an appropriate acid-base indicator (changes color in specific pH range) must be used to show when the neutralization is completed.

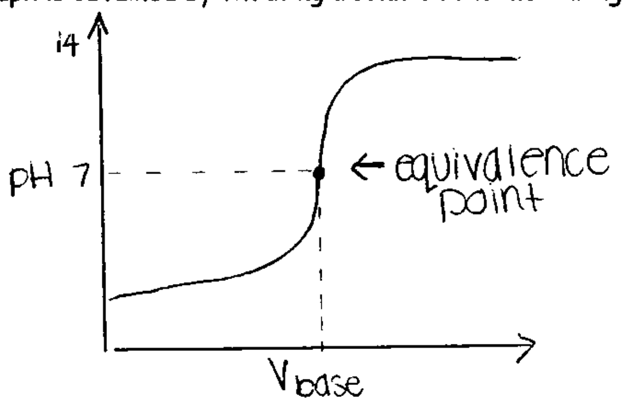
• This process is called a **TITRATION**: the addition of a known amount of solution to determine the volume or concentration of another solution.

3 steps:
1) add a measured amount of an acid of unknown concentration to a flask.
2) add an appropriate indicator to the flask (i.e. phenolphthalein)
3) Add measured amounts of a base of known concentration using a buret. Continue until the indicator shows that neutralization has occurred. This is called the end point of the titration.

Titration Curve: a graph showing how the pH changes as a function of the amount of added titrant in a titration.

Data for the graph is obtained by titrating a solution and measuring the pH after every drop of added titrant.

Sample titration curve:



****Equivalence point** = the point on the curve where the moles of acid equal the moles of base; the midpoint of the steepest part of the curve (the most abrupt change in pH) is a good approximation of the equivalence point.

Kowledge of the equivalence point can then be used to choose a suitable indicator for a given titration; the indicator must change color at a pH that corresponds to the equivalence point.

Calculations of Titrations:

$$N_aV_a = N_bV_b$$
(norm. acid)(vol. acid) = (norm. base)(vol. base)

Example: 30.0 mL of 0.0750 N HNO_3 required 22.5 mL of $Ca(OH)_2$ for neutralization. Calculate the normality and molarity of the $Ca(OH)_2$ solution.

$$2HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + 2H_2O$$

$N_aV_a = N_bV_b$

$(0.0750\ N)(30.0\ mL) = (N_b)(22.5\ mL)$

$N_b = \boxed{0.100\ N}$

$N = M \times (r.X)$

$0.100\ N = M \times (2)$

$M = \boxed{0.0500\ M}$