Acids and Bases

Naming Binary Acids

- Start with the prefix “hydro”
- Use the root of the anion
- End with the suffix “ic”
- Use the word “acid”

- Example
  - HCl
    - Hydrochloric acid

Naming Oxyacids

- General formula: $H_aX_bO_c$
    - X is an element other than hydrogen or oxygen
- Replace the anion's suffix "ate" with "ic"

- Examples:
    - HNO_3
        - Nitric acid
    - H_2SO_4
        - Sulfuric acid

Strong Acids

- Acids that completely dissociate in water
- There are only six strong acids:
    - Hydrochloric acid (HCl)
    - Hydrobromic acid (HBr)
    - Hydroiodic acid (HI)
    - Sulfuric acid (H_2SO_4)
    - Nitric acid (HNO_3)
    - Perchloric acid ($HClO_4$)

Naming Bases

- The name of the metal is combined with the anion, hydroxide (OH^-)
- Example
  - $NaOH$
    - Sodium hydroxide
  - $Mg(OH)_2$
    - Magnesium hydroxide

Strong Base

- Bases that completely dissociate in water
- Strong bases include any ionic compound that contains the hydroxide ion
- Group 1 and 2 elements for strong bases when combined with OH^-

- When a strong acid and a strong base combine together they react completely.
- All of the hydrogen ions (from the acid) and all of the hydroxide ions (from the base) will react to form water.

- Write and equation for the neutralization reaction between H_2SO_4 and NaOH

- Predict the products and ensure that the equation is balanced
  - $H_2SO_4 + 2NaOH \rightarrow 2H_2O + Na_2SO_4$
- Use the solubility rules to confirm whether each product will be aqueous, solid, or liquid.
  - $H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow 2H_2O_{(aq)} + Na_2SO_{4(aq)}$
- Write a total ionic equation
  - $2H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$
- Write the net ionic equation
  - $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

Neutralization Reactions

- Write a balanced chemical equation for the reaction.
- Use the concentration and volume of the known acid or base to calculate the moles of the substance.
- Use the coefficients from the balanced equation to determine the moles of the unknown acid or base
- Calculate the required volume or concentration of the acid or base.

Arrhenius

- **Acids** are any substances that dissolve to produce hydrogen ions (H^+) when dissolve in water.
  - $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$
- **Bases** are any substances that dissolve to produce hydroxide ions (OH^-) when dissolved in water.
  - $NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

- However, this does not explain CO_2 (no hydrogen) and NH_3 (no hydroxide)
- Arrhenius explained this by saying that they reacted with the water first:
  - $CO_{2(g)} + H_2O_{(l)} \rightarrow H_2CO_{3(aq)} \rightarrow 2H^+_{(aq)} + HCO_3^-{}_{(aq)}$
  - $NH_{3(g)} + H_2O_{(l)} \rightarrow NH_4OH_{(aq)} \rightarrow NH_4^+{}_{(aq)} + OH^-_{(aq)}$
- Brønsted and Lowry independently proposed a new theory that relates acid-base theory to proton transfer.

Brønsted-Lowry

- **Acids** are substances that increase the hydronium (H_3O^+) ion concentration. Thus acids are proton donors.
  - $HNO_{3(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + NO_3^-{}_{(aq)}$
- **Bases** are substances that increase the hydroxide (OH-) ion concentration. Thus bases are proton acceptors.
  - $Ba(OH)_{2(aq)} \rightarrow Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$

- When any one of HCl, HNO_3, CH_3COOH, CO_2, or H_2SO_4 is added to water, the hydronium ion concentration is increased.
- Hence, they are acids.

- When any one of NaOH, $Ca(OH)_2$, CaO, MgO, or NH_3 is added to water, the hydroxide ion concentration is increased.
- Hence, they are considered bases.

Conjugate Acids and Bases

- In any acid base reaction, a conjugate acid and base pair are established.
- Conjugate acid-base pairs are compounds that differ by the presence of one proton, or H^+.
- All acids have a conjugate base, which is formed when their proton has been donated
- Likewise, all bases have a conjugate acid, formed after they have accepted a proton.

Example

$$HX_{(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+{}_{(aq)} + X^-{}_{(aq)}$$

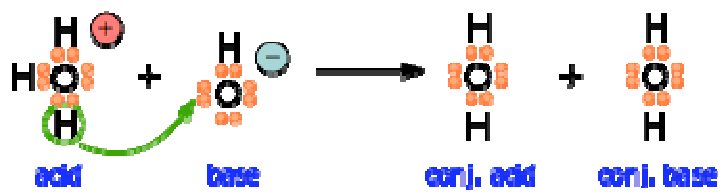
acid	base	conjugate acid	conjugate base

- Substances, such as water, which can act as both acids and bases are said to be amphoteric.
- Other examples of amphoteric substances are amino acids and proteins
  - Both have an amino group, NH_2 (base) and a carboxyl group, COOH (acid)

Lewis

- **Bases** are substances that can donate a pair of electrons.
- **Acids** are substances that can accept a pair of electrons.

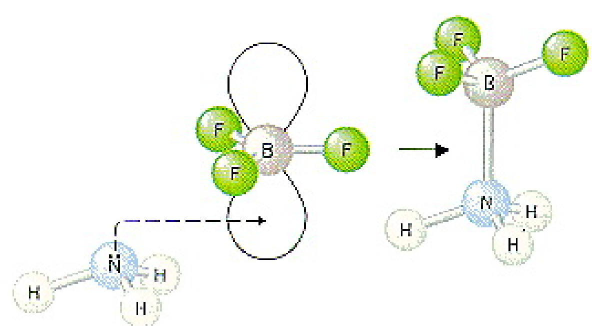
- Lewis argued that the H+ ion accepts a pair of electrons from the OH- ion to form a new covalent bond.
- Any substance that can act as an electron pair acceptor is a Lewis acid.



- The pair of electrons that went into the new covalent bond were donated by the OH^-.
- Any substance that can act as an electron pair donor is a Lewis base.

- The Lewis acid-base theory expands the number of substances that can be considered acids.
- Any compound that has one or more valence shell orbitals can now be considered an acid.

- The theory explains why BF_3 reacts instantly with NH_3
- The non-bonding electrons on the nitrogen in ammonia are donated into an empty orbital on the boron atom to form a covalent bond



Ion Product Constant of Water

- Pure water undergoes a small degree of ionization
- Only two molecules out of one billion will ionize

$$2H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$$

Dissociation Constant (K_w)

$$K_w = [\mathrm{H_3O^+}][\mathrm{OH^-}]$$

- In pure water, the $[H_3O^+]$ and $[OH^-]$ at 25^oC are experimentally measured as $1x10^{-7}$ mol/L

$$K_w = \left(1\times10^{-7}\right)\left(1\times10^{-7}\right)$$
$$K_w = 1\times10^{-14}$$

EVERY water solution is neutral, acidic, or basic

- A neutral solution occurs when the hydronium ion concentration is equal to the hydroxide ion concentration
- An acidic solution occurs when the hydronium ion concentration is greater than the hydroxide ion concentration
- A basic solution occurs when the hydronium ion concentration is less than the hydroxide ion concentration

pH

- Most concentrations of hydronium ions are very small (around 4×10^{-8} mol/L), so Soren P. Sorenson proposed the potency of hydrogen, or the pH scale

Calculating pH

- pH is calculated as follows:

$$\mathrm{pH} = -\log[\mathrm{H_3O^+}]$$

- Similarly, we can calculate a potency of hydroxide (pOH):

$$\mathrm{pOH} = -\log[\mathrm{OH^-}]$$

- Together: $\mathrm{pH} + \mathrm{pOH} = 14$

Indicators

- Indicators are weak organic acids that change color when the hydronium or hydroxide ion concentration is changed
- Indicators change color over a given pH range
- Le Châtelier’s Principle can be used to explain the color change

Color 1 $\rightarrow$ HIn; Color 2 $\rightarrow$ In^-

$$\underset{\text{(acid form)}}{HIn_{(aq)}} \leftrightarrow H^+_{(aq)} + \underset{\text{(base form)}}{In^-_{(aq)}}$$

- The presence of an acid increases H^+, causing a shift toward color 1
- The presence of a base decreases H^+, causing a shift toward color 2

- Change ranges are often about 2 pH units
  - quite a few are less
- The human eye responds more readily to some shades of color than others
- Some substances are more intensely colored than others are, even at the same concentration

Strengths of Acids and Bases

- Strong Acid
  - Completely dissociates into ions
- Strong Base
  - Completely dissociates into ions

Weak Acids

- Dissociate only slightly into ions

$$HA_{(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + A^-_{(aq)}$$

$$K_a = \frac{[\mathrm{H_3O^+}][\mathrm{A^-}]}{[\mathrm{HA}]}$$

- K_a is called the acid dissociation constant
- Example, HCN
  - $HCN_{(aq)}+H_2O_{(l)}\leftrightarrow H_3O^+_{(aq)}+CN^-_{(aq)}$ $K_a=6.2\times10^{-10}$

Weak Bases

- Dissociate only slightly into ions

$$BH_{(aq)} + H_2O_{(l)} \leftrightarrow BH_2^+{}_{(aq)} + OH^-{}_{(aq)}$$

$$K_b = \frac{[BH_2^+][OH^-]}{[BH]}$$

- K_b is called the base dissociation constant
- Example, NH_3
  - $NH_{3(aq)}+H_2O_{(l)}\leftrightarrow NH_4^+{}_{(aq)}+OH^-{}_{(aq)}$ $K_b=1.8\times10^{-5}$

Other Examples of Weak Bases

- $C_6H_5NH_2$ (aniline)
- CH_3NH_2 (methylamine)
- C_5H_5N (pyridine)

Is the solution acidic, basic, or neutral?

- A salt solution is not necessarily neutral
- When an acid combines with a base, a salt and water are produced
  - A strong acid and a strong base produce a neutral solution
  - A strong base plus a weak acid produce a slightly basic salt
  - A strong acid plus a weak base produce a slightly acidid salt

- A salt can react with water (called salt hydrolysis)
  - The anions of the dissociated salt may accept hydrogen ions from the water producing a basic solution
  - The cations of the dissociated salt may donate hydrogen ions from the water producing an acidic solution