Chapter 15 - Acids and Bases

15-1 Properties of Acids and Bases

I. Acids

A. Properties of Acids

1. Aqueous solutions have a sour taste
2. Acids change the color of acid-base indicators
3. Some acids react with active metals to release hydrogen

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

4. Acids react with bases to produce salts and water

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

5. Acids conduct electric current

B. Acid Nomenclature (covered in Chapter 7)

1. Binary acids - acids that contain two different elements: hydrogen and one of the more-electronegative elements
   a. prefix "hydro-"
   b. Root of element name
   c. "-ic" ending
      example: HBr = hydrobromic acid
2. Oxyacids - compounds of hydrogen, oxygen, and a third element, usually a nonmetal
   a. no prefixes

Rules for Naming Oxyacids		
Description	*Rule*	*Example*
One more oxygen than the "ate" ion	"per" prefix "ic" suffix	Ion: ClO_4^- Formula: $HClO_4$ Name: perchloric acid
Contains the "ate" ion	"ic" suffix	Ion: ClO_3^- Formula: $HClO_3$ Name: chloric acid
Contains the "ite" ion	"ous" suffix	Ion: ClO_2^- Formula: $HClO_2$ Name:
One less oxygen than the "ite" ion	"hypo" prefix "ous" suffix	Ion: ClO Formula: HClO Name: hypochlorous acid

II. Some Common Industrial Acids

A. H_2SO_4 - Sulfuric Acid

1. Used in making fertilizer, paper, petroleum products, car batteries
2. Highest production chemical in the U.S.

B. HNO_3 - Nitric Acid

1. Unstable, volatile liquid in pure state
2. Yellowing caused by the formation of nitrogen dioxide gas
3. Used in making fertilizers, explosives, rubber, plastics, pharmaceuticals
4. Stains skin and other proteins yellow

C. H_3PO_4 - Phosphoric Acid
   1. Not a common laboratory acid
   2. Flavoring agent in sodas
   3. Used in making fertilizers and detergents

D. HCl - Hydrochloric Acid
   1. HCl in the stomach aids the digestion of proteins
   2. Used in pickling steel, recovering magnesium from sea water, cleaning masonry and correcting pool pH

E. Acetic Acid
   1. Acid component of vinegar
   2. Concentrated "glacial" acetic acid used in making chemicals for plastic manufacturing

III. Bases

A. Properties of Bases
   1. Aqueous solutions of bases have a bitter taste
   2. Bases change the color of acid-base indicators
   3. Dilute aqueous solutions of bases feel slippery
   4. Bases react with acids to produce salts and water
   5. Bases conduct electric current

IV. Arrhenius Acids and Bases

Svante Arrhenius, Swedish chemist (1859-1927)

A. Arrhenius Acid
   1. A chemical compound that increases the concentration of hydrogen ions, H^+, in aqueous solution

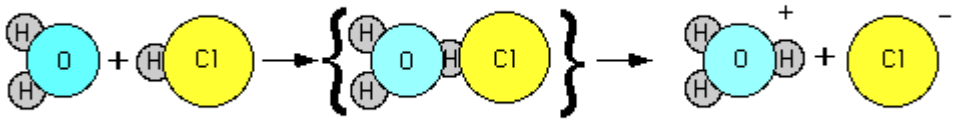
B. Arrhenius Base
   1. A substance that increases the concentration of hydroxide ions, OH-, in aqueous solution

C. Aqueous solutions of acids
   1. Acids are molecular compounds that ionize in solution

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$

$$H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$$

$$H_2O + HCl \rightarrow H_3O^+ + Cl^-$$

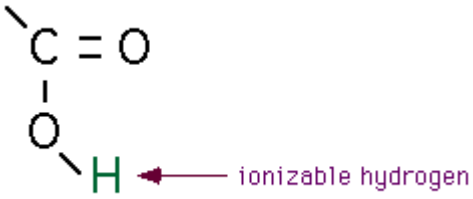


D. Strength of Acids
   1. Strong acids ionize completely in solution

2. Weak acids ionize only slightly and are weak electrolytes

Strong acids	*Weak acids*
H_2SO_4	HSO_4^-
$HClO_4$	H_3PO_4
HCl	HF
HNO_3	CH_3COOH
HBr	H_2CO_3
HI	H_2S
	HCN
	HCO_3^-

E. Organic Acids
   1. Covalent molecular substances containing a carboxyl group
      a. (-COOH)



   2. Weak acids (only slightly ionize)
   3. Examples
      a. Butyric acid - in rancid butter
      b. Lactic acid - in sour milk
      c. Citric acid - in citrus fruit
      d. Acetic acid - in vinegar

F. Aqueous Solutions of Bases
   1. Ionic bases dissociate to some extent when placed in water

$$NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$$

   2. Basic solutions are referred to as "alkaline"
   3. Molecular bases produce hydroxide ions through a reaction with water

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

G. Strength of Bases
   1. Strength of ionic bases is linked to solubility
      a. High solubility = strong base
      b. Low solubility = weak base
   2. Molecular bases tend to be weak regardless of solubility

15-2 Acid-Base Theories

I. Bronsted-Lowry Acids and Bases

A. Bronsted-Lowry Acid
   1. A molecule or ion that is a proton donor

B. Bronsted-Lowry Acid
   1. A molecule or ion that is a proton acceptor
   2. Hydroxide ion is the acceptor of ionic bases, not the ionic compound itself

C. Bronsted-Lowry Acid-Base Reaction
   1. A reaction in which protons are transferred from the acid to the base

II. Monoprotic and Polyprotic Acids

A. Monoprotic acids
   1. Acids that donate only one proton per molecule

HCl, HNO_3, $HClO_4$

B. Polyprotic acids
    1. Acids that can donate more than one proton per molecule
        a. Diprotic - two protons
            H_2SO_4, H_2CO_3
        b. Triprotic - three protons
            H_3PO_4

$H_3PO_4(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + H_2PO_4^-(aq)$
$H_2PO_4^-(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + HPO_4^{2-}(aq)$
$HPO_4^{2-}(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + PO_4^{3-}(aq)$

(Each successive proton is harder to remove than the previous one)

III. Lewis Acids and Bases
A. Lewis Acid
    1. An atom, ion, or molecule that accepts an electron pair to form a covalent bond
B. Lewis Base
    1. An atom, ion, or molecule that donates an electron pair to form a covalent bond
C. Lewis acid-base reaction
    1. The formation of one or more covalent bonds between an electron-pair donor and an electron-pair acceptor
    2. The Lewis definition can be applied to phases other than aqueous phase reactions

15-3 Acid-Base Reactions

I. Conjugate Acids and Bases
A. Conjugate Base
    2. The species that remains after an acid has given up a proton
        $H_3PO_4(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + H_2PO_4^-(aq)$
        acid — conjugate base
    3. The stronger an acid, the weaker its conjugate base
B. Conjugate Acid
    2. The species that is formed when a base gains a proton
        $H_3PO_4(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + H_2PO_4^-(aq)$
        base — conjugate acid
    3. The stronger a base, the weaker its conjugate acid
C. Proton-Transfer Reactions
    1. Proton-transfer rxns favor the production of the weaker acid and the weaker base

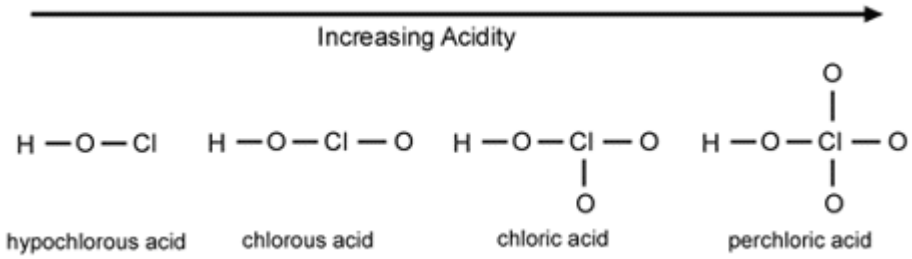
II. Amphoteric Compounds
A. Amphoteric
    1. Any species that can react as either an acid or a base
        a. Water as a base

$$H_3PO_4(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + H_2PO_4^-(aq)$$

b. Water as an acid

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

B. -OH in a Molecule (Hydroxyl group)
1. The -OH group in a molecule can be acidic or amphoteric
2. As the number of oxygens that are bonded around the atom with the -OH group increases, so does the acidity of the compound
   a. Oxygens pull electron density away from the hydrogen, making it appear more positive (and attractive to water and other bases)



15-3 Neutralization Reactions

III. Neutralization Reactions

A. Neutralization
1. The reaction of hydronium ions and hydroxide ions to form water molecules

B. Neutralization Rxns

$$KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(\ell)$$

1. Step 1: Dissociation of a base in water

$$KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$$

2. Step 2: Acid donates a proton to water

$$HNO_3(aq) + H_2O(l) \rightarrow H_3O^+(aq) + NO_3^-(aq)$$

3. Complete ionic equation

$$K^+(aq) + OH^-(aq) + H_3O^+(aq) + NO_3^-(aq) \rightarrow K^+(aq) + NO_3^-(aq) + 2H_2O(\ell)$$

4. Net ionic equation (eliminate spectator ions)

$$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(\ell)$$

II. Acid Rain

A. Formation of Acid Rain
1. Nonmetallic oxides enter the atmosphere as a result of coal burning, auto exhaust, other forms of air pollution

SO_2 SO_3 CO_2 NO NO_2

2. Nonmetallic oxides combine with water to form oxyacids

$$SO_3(g) + H_2O(\ell) \rightarrow H_2SO_4(aq)$$

B. Reactions of Acid Rain

1. Reaction with marble (metamorphic calcium carbonate)

$$CaCO_3(s) + 2H_3O^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + 3H_2O(\ell)$$