Chapter 14

Outline

Main Ideas

I. Properties of Acids & Bases

Acids	Bases
taste sour	taste bitter
turn blue litmus paper red	turn red litmus paper blue
corrosive to metals	slippery feel
release H+ ions in water (Arrhenius definition)	release OH- ions in water (Arrhenius definition)
react with bases in neutralization relations	react with acids in neutralization reactions

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

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

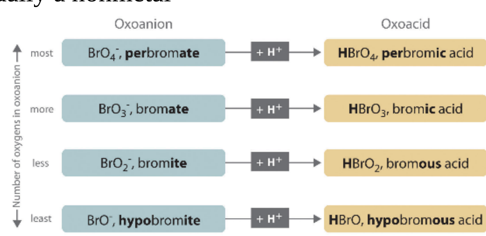
4. Acids react with bases to produce salts and water

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

5. Acids conduct electric current

B. Acid Nomenclature (covered in Chapter 7)

1. Since all acids contain hydrogen, the naming is based on the anion
   a. Binary acids - acids that contain two different elements: hydrogen and one of the more-electronegative elements
      i. *hydro*(anion root)*ic acid*
         example: HBr (Br^- brom<u>ide</u>) ⇒ hydrobromic acid
         - also applies to a few polyatomic anions that are not oxyanions, but have an *-ide* ending
           example: HCN (CN^- cyan<u>ide</u>) ⇒ hydrocyanic acid
   b. Oxyacids - compounds of hydrogen, oxygen, and a third element, usually a nonmetal
      i. acid names depend on anion ending
      ii. if anion ends with *-ate*, it is replaced with *-ic* in the acid name
          example: $HClO_3$ ($ClO3^-$ = chlor<u>ate</u>) ⇒ chloric acid
      iii. if anion ends in *-ite*, it is replaced with *-ous* in the acid name
          example: HClO (ClO^- = hypochlor<u>ite</u>) ⇒ hypochlorous acid



C. Some Common Industrial Acids

1. H_2SO_4 (Sulfuric Acid)
   a. Used in making fertilizer, paper, petroleum products, car batteries
   b. Highest production chemical in the U.S.
2. HNO_3 (Nitric Acid)
   a. Unstable, volatile liquid in pure state
   b. Yellowing caused by the formation of nitrogen dioxide gas
   c. Used in making fertilizers, explosives, rubber, plastics, pharmaceuticals
   d. Stains skin and other proteins yellow
3. H_3PO_4 (Phosphoric Acid)
   a. Not a common laboratory acid
   b. Flavoring agent in sodas
   c. Used in making fertilizers and detergents
4. HCl (Hydrochloric Acid)
   a. HCl in the stomach aids the digestion of proteins
   b. Used in pickling steel, recovering magnesium from sea water, cleaning masonry and correcting pool pH
5. $HC_2H_3O_2$ (Acetic Acid)
   a. Acid component of vinegar
   b. Concentrated "glacial" acetic acid used in making chemicals for plastic manufacturing

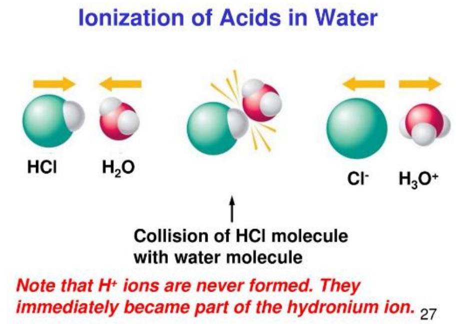
D. Bases

1. Properties of Bases
   a. Aqueous solutions of bases have a bitter taste
   b. Bases change the color of acid-base indicators
   c. Dilute aqueous solutions of bases feel slippery
   d. Bases react with acids to produce salts and water
   e. Bases conduct electric current

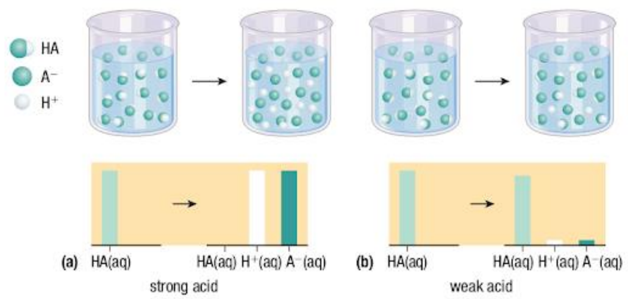
E. Arrhenius Acids and Bases
Svante Arrhenius, Swedish chemist (1859-1927)

1. Arrhenius Acid
   a. A chemical compound that increases the concentration of hydrogen ions, H^+, in aqueous solution
2. Arrhenius Base
   a. A substance that increases the concentration of hydroxide ions, OH-, in aqueous solution
3. Aqueous solutions of acids
   a. Acids are molecular compounds that ionize in solution

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$
$$H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$$
$$H_2O + HCl \rightarrow H_3O^+ + Cl^-$$



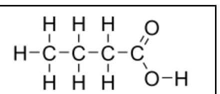
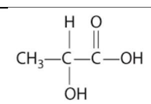
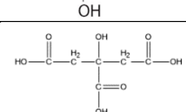
4. Strength of Acids
   a. Strong acids ionize completely in solution
   b. Weak acids ionize only slightly and are weak electrolytes

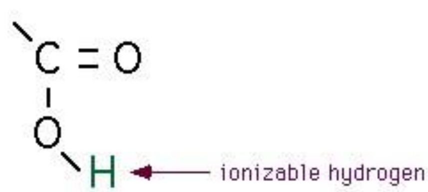


Strong Acids	Weak Acids
H_2SO_4	HSO_4^-
$HClO_4$	H_3PO_4
HCl	HF
HNO_3	CH_3COOH
HBr	H_2CO_3
HI	H_2S
$HClO_3$	HCN
	HCO_3^-

5. Organic Acids
   a. Most common organic acid = carboxylic acids
      i. Covalent molecular substances containing a carboxyl group (-COOH)
   b. Are weak acids (only slightly ionize)

examples:

Butyric acid - in rancid butter	
Lactic acid- in sour milk	
Citric acid - in citrus fruit	



6. Aqueous Solutions of Bases
   a. Ionic bases dissociate to some extent when placed in water.

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

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

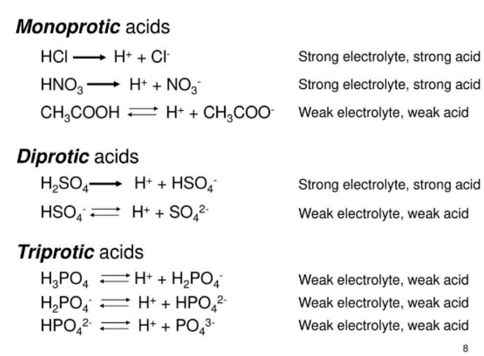
$$NH_3(g) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$$

7. Strength of Bases
   a. Strength of ionic bases relates to solubility
      i. High solubility = strong base
      ii. Low solubility = weak base
   b. Molecular bases tend to be weak regardless of solubility

II. <u>Acid-Base Theories</u>
   A. Brønsted-Lowry Acids and Bases
      1. Brønsted-Lowry Acid
         a. A molecule or ion that is a proton (H^+) donor
      2. Brønsted-Lowry Base
         a. A molecule or ion that is a proton (H^+) acceptor
         b. The hydroxide ion (OH^-) is the proton acceptor in ionic bases, not the ionic compound itself.
      3. Brønsted-Lowry Acid-Base Reaction
         a. A reaction in which protons are transferred from the acid to the base

   B. Monoprotic and Polyprotic Acids
      1. Monoprotic acids
         a. Acids that donate only one proton per molecule

$$H_1Cl,\ H_1NO_3,\ H_1ClO_4$$



      2. Polyprotic acids
         a. Acids that can donate more than one proton (H^+) per molecule
            i. In polyprotic acids, protons (H^+) are removed one at a time.
            ii. As each proton (H^+) is removed the anion exerts a greater force on the remaining protons(s).
               - Each successive acid formed is weaker than the preceding one.
         b. Diprotic - two protons

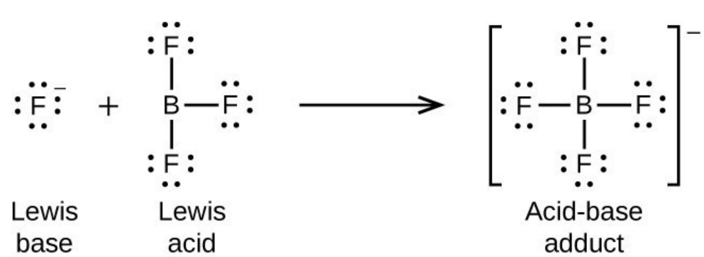
$$H_2SO_4,\ H_2CO_3$$

         c. Triprotic - three protons

$$H_3PO_4$$

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

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



III. Acid-Base Reactions
   A. Conjugate Acids and Bases
      1. Conjugate Base

a. The species that remains after an acid has given up a proton.

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

acid ... conjugate base

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

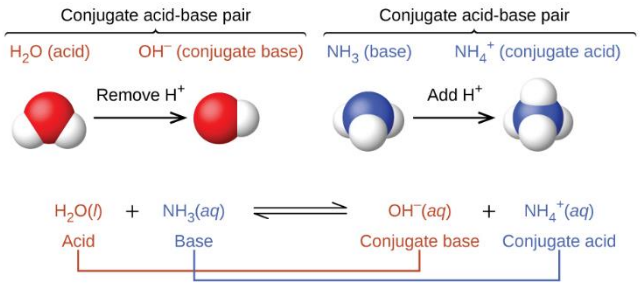
2. Conjugate Acid

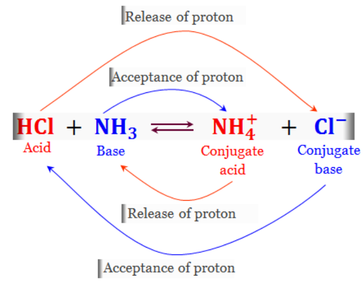
a. The species that is formed when a base gains a proton.

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

base ... conjugate acid

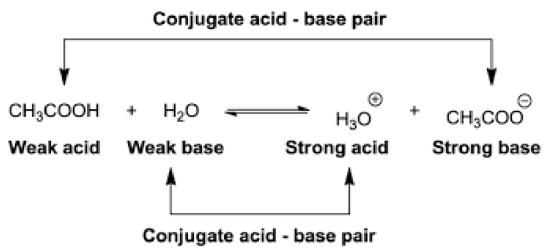
b. The stronger a base, the weaker its conjugate acid.





3. Proton-Transfer Reactions

a. Proton-transfer reactions favor the production of the weaker acid and the weaker base.



b. In the system above, the reaction would not proceed forward very effectively. Very little of the CH_3COOH would ionize (that's why it's a weak acid).

B. Amphoteric Compounds

1. Amphoteric = any species that can react as either an acid or a base

a. Water as a base

H^+

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

acid ... base ... conjugate base

b. Water as an acid

H^+

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

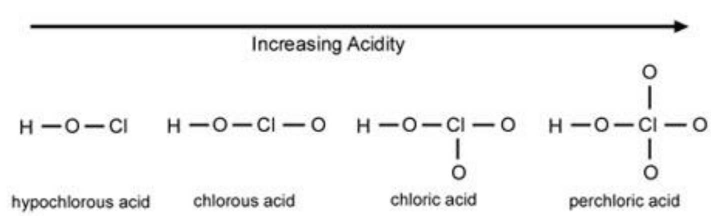
base ... base ... conjugate base

2. Hydroxyl groups (−OH)

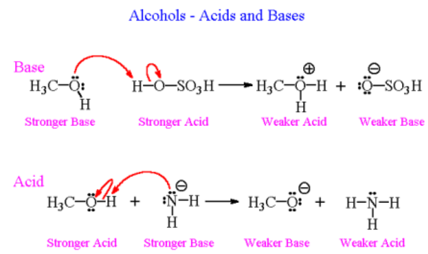
a. The −OH group in a molecule can be acidic or amphoteric.

i. As the number of oxygens that are bonded around the atom with the −OH group increases, so does the acidity of the compound.

ii. Oxygens pull electron density away from the hydrogen, making it appear more positive (and attractive to water and other bases).



iii. In alcohols, the –OH group is amphoteric and may donate or accept protons (H+) depending on what other molecules are present.



C. Neutralization Reactions

1. Neutralization = the reaction of hydronium ions (H_3O^+) and hydroxide ions (OH^-) to form water molecules.
2. Neutralization Rxns

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

Step 1: Dissociation of a base in water to produce hydroxide.

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

Step 2: Acid donates a proton to water to form hydronium.

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

Complete ionic equation.

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

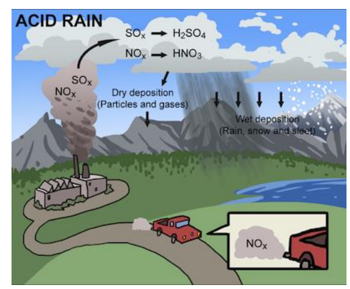
Net ionic equation (eliminate spectator ions)

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

D. Acid Rain

1. Formation of Acid Rain
   a. Nonmetallic oxides (SO_2, SO_3, CO_2, NO, NO_2) enter the atmosphere as a result of coal burning, auto exhaust, other forms of air pollution.
   b. Nonmetallic oxides combine with water to form oxyacids.

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



2. Reactions of Acid Rain
   a. Reaction with marble (metamorphic calcium carbonate) erodes the stone.

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