Ch 15 Acids and Bases

Reading: 645-673, 682-685

Learning Goals:

Definition of an Acid and Base (Ch 4)

-Bronsted

Acid: any substance capable of donating a proton (H^+)

Base: any substance capable of accepting a proton

Conjugate acid-base pairs:

Identify the conjugate acid-base pairs for the following reaction

Acid-Base properties of water

-we just saw that water can act as either an acid or a base depending on what it is reacted with

-water can also act as both an acid and a base with itself

Autoionization of Water

$$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$$

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Write the equilibrium constant (Kc)

For pure water at 25 °C:

$[H^+] = 1.0 \times 10^{-7}$ M
$[OH^-] = 1.0 \times 10^{-7}$ M

$Kw = [H^+][OH^-] = (1.0 \times 10^{-7})(1.0 \times 10^{-7}) = 1.0 \times 10^{-14}$

Examples: A solution has a $[H^+] = 1.0 \times 10^{-6}$ M, calculate $[OH^-]$

Calculate $[H^+]$, when $[OH^-] = 0.056$ M

Calculate $[OH^-]$, when $[H^+] = 2.5 \times 10^{-3}$ M

pH: measure of solution acidity

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

Acidic: $[H^+] > 1.0 \times 10^{-7}$, $pH < 7.00$
Basic: $[H^+] < 1.0 \times 10^{-7}$, $pH > 7.00$
Neutral: $[H^+] = 1.0 \times 10^{-7}$, $pH = 7.00$

Calculate the pH of a solution containing 0.056 M OH^-

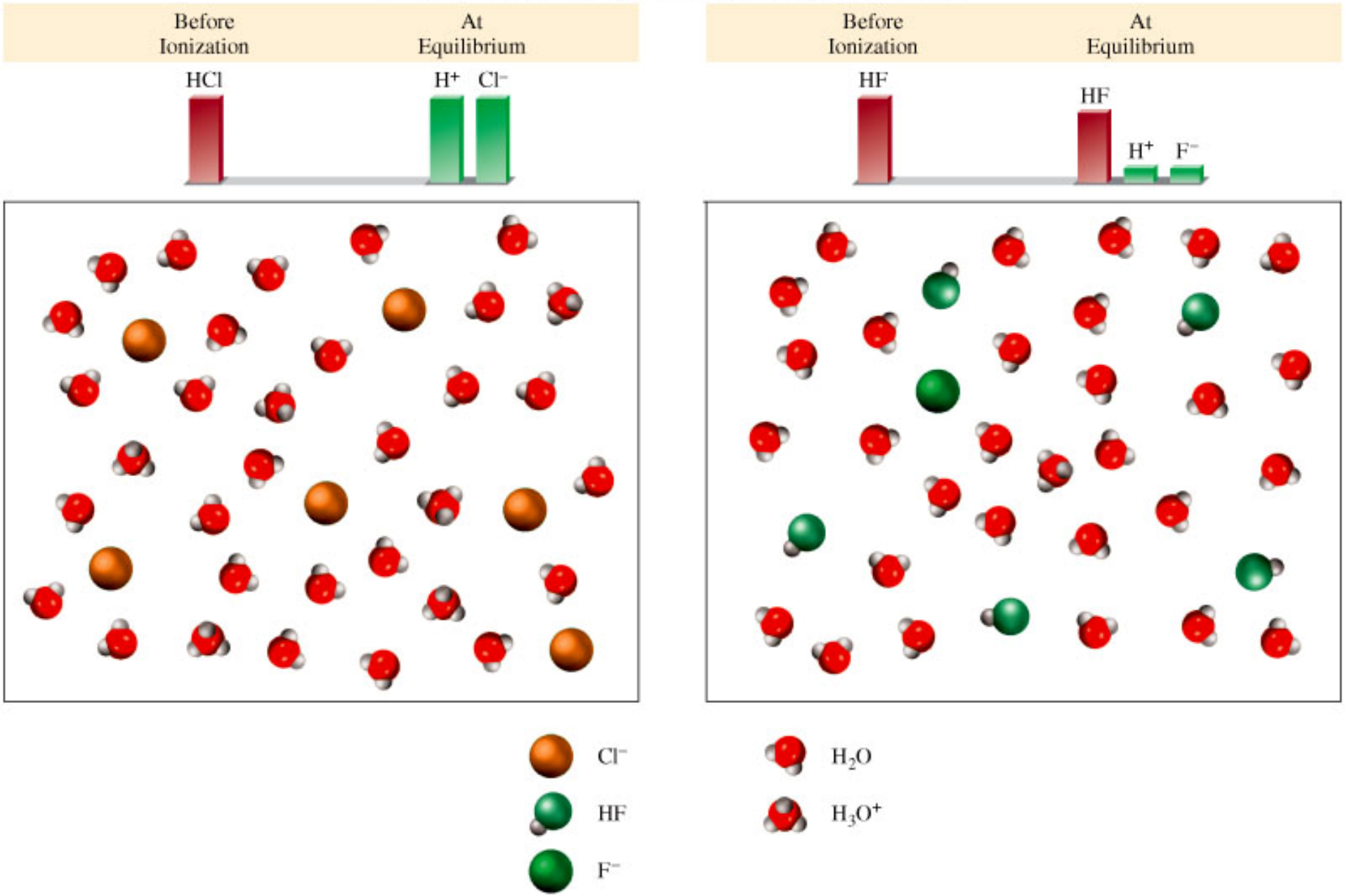
A solution has a pOH = 8.96, what is the $[H^+]$?

Strength of Acids and Bases

-strength refers to the amount of ionization (H^+ or OH^- produced)

Strong Acids or Bases: completely ionize in water

Weak Acids or Bases: partially ionize in water



Properties of Acid-Base Pairs:

1) A strong acid produces a weak conjugate base

2) H_3O^+ is the strongest acid

3) OH^- is the strongest base

Calculating solution pH: strong acid or base

Calculate the pH of a solution made from 0.020 M $Ba(OH)_2$

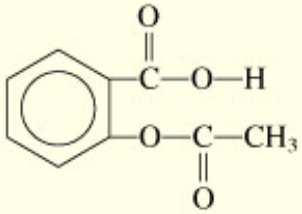
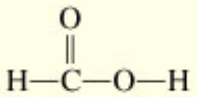
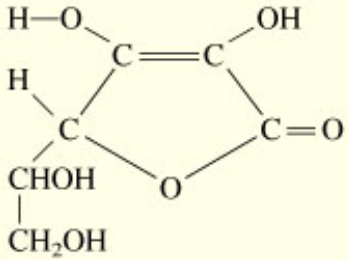
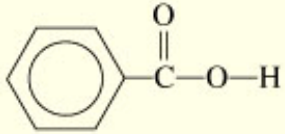
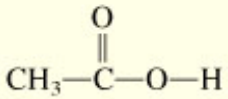
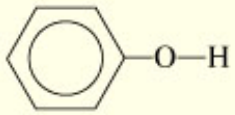
Calculating solution pH: weak acid or base

For weak acids or bases, we need to know how much of the acid or base is ionized (how much H^+ or OH^- is in solution).

To determine this, we can use an equilibrium constant:

$$HA\ (aq) \leftrightarrow H^+\ (aq) + A^-\ (aq)$$

TABLE 15.3 Ionization Constants of Some Weak Acids and Their Conjugate Bases at 25°C

Name of Acid	Formula	Structure	K_a	Conjugate Base	K_b
Hydrofluoric acid	HF	H—F	7.1×10^{-4}	F^-	1.4×10^{-11}
Nitrous acid	HNO_2	O=N—O—H	4.5×10^{-4}	NO_2^-	2.2×10^{-11}
Acetylsalicylic acid (aspirin)	$C_9H_8O_4$		3.0×10^{-4}	$C_9H_7O_4^-$	3.3×10^{-11}
Formic acid	HCOOH		1.7×10^{-4}	$HCOO^-$	5.9×10^{-11}
Ascorbic acid*	$C_6H_8O_6$		8.0×10^{-5}	$C_6H_7O_6^-$	1.3×10^{-10}
Benzoic acid	C_6H_5COOH		6.5×10^{-5}	$C_6H_5COO^-$	1.5×10^{-10}
Acetic acid	CH_3COOH		1.8×10^{-5}	CH_3COO^-	5.6×10^{-10}
Hydrocyanic acid	HCN	H—C≡N	4.9×10^{-10}	CN^-	2.0×10^{-5}
Phenol	C_6H_5OH		1.3×10^{-10}	$C_6H_5O^-$	7.7×10^{-5}

*For ascorbic acid it is the upper left hydroxyl group that is associated with this ionization constant.

Weak Acid equilibrium calculations: part 1

$$HF\ (aq) \leftrightarrow H^+\ (aq) + F^-\ (aq) \qquad Ka = 7.1 \times 10^{-4}$$

Calculate the pH of a 0.50 M HF solution.

HF problem (part 1) continued:

Checking our assumption that $x << 0.50$ M

-Assumption is only GOOD if $x < 5\%$ of 0.50 M

Weak Acid equilibrium calculations: part 2

$$HF\ (aq) \leftrightarrow H^+\ (aq) + F^-\ (aq) \qquad Ka = 7.1 \times 10^{-4}$$

Calculate the pH of a 0.050 M HF solution.

HF problem (part 2) continued:

What if our assumption is NOT good?

-go back to original Ka expression

Quadratic Formula: $ax^2 + bx + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

HF problem (part 2) continued:

Summary of steps for weak acid problems: pg 659 in book

1) identify the species that affect the pH of the solution

2) use ICE method and initial concentrations to determine equilibrium concentrations

3) use ionization constant (Ka) expression and value along with equilibrium concentrations to solve for x.

4) try to simplify using assumption that $x << [HA]$
-must be < 5% to be a GOOD assumption

5) use x to find $[H^+]$ and pH

Weak Acid example: calculate the pH of a 0.036 M nitrous acid solution. $HNO_2\ (aq) \leftrightarrow H^+\ (aq) + NO_2^-\ (aq)$ $Ka = 4.5 \times 10^{-4}$

example continued

Percent Ionization: another measure of acid strength

Note: this is the same way you check your assumption!!!

Weak Base Ionization Constants: same procedures we just did for weak acids

Weak base example: What is the pH of a 0.40 M ammonia solution, Kb = 1.8×10^{-5}

weak base example continued

Weak Acid and Weak Base Ionization Constants:

$(Ka)(Kb) = Kw$ $\qquad\qquad$ $Kw = 1.0 \times 10^{-14}$

Diprotic and Polyprotic Acids

-acids which are capable of donating more than one proton (H^+)

Carbonic Acid

Step 1: $H_2CO_3\ (aq) \leftrightarrow H^+\ (aq) + HCO_3^-\ (aq)$

Step 2: $HCO_3^-\ (aq) \leftrightarrow H^+\ (aq) + CO_3^{2-}\ (aq)$

Phosphoric Acid (H_3PO_4), write out the ionization steps and ionization constant (Ka) expressions.

Acid Strength vs Molecular Structure: what makes one acid stronger than another?

Consider this acid: $HX \leftrightarrow H^+ + X^-$

-the strength is measured by how much HX is ionized

Two main factors that influence ionization:

TABLE 15.6 Bond Enthalpies for Hydrogen Halides and Acid Strengths for Hydrohalic Acids

Bond	Bond Enthalpy (kJ/mol)	Acid Strength
H—F	568.2	weak
H—Cl	431.9	strong
H—Br	366.1	strong
H—I	298.3	strong

2)

Note: these are general trends and usually one of the factors dominates

Lets look at some examples.

Comparing Oxoacid Strength: an oxoacid contains a hydrogen attached to oxygen, which is attached to a central atom (Z).

The electronegativity and/or oxidation state of the central atom (Z) affects the strength of the acid

Examples: 1) oxoacids with same oxidation but different electronegativity

2) oxoacids with same electronegativity but different oxidation

Lewis Acids and Bases