Chapter 14

Acids and Bases

Chapter 14 Preview

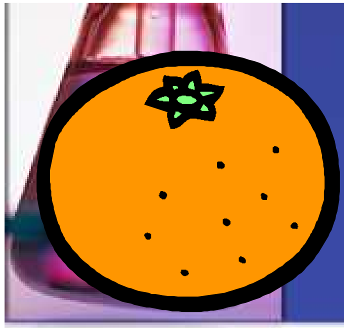
Acid and Bases

- Acid and bases
  - Nature and properties
- Acids
  - Strength, water as an acid or a base, pH calculations of strong and weak acids, Polyprotic acids…
- Bases
  - Properties, Acid-base properties of salts, effect of structure on acid-base properties, oxides
- Lewis Acid-base Model
- Strategy for solving Acid-Base problems

Introduction

Acid and bases chemistry are important in a wide variety of everyday applications:

- Deviation in the blood acidity may lead to serious illness and death
- Uncontrolled acidity of the water in the aquarium destroy the life of many kinds of fish
- Vast quantity of H_2SO_4 manufactured in the US every year to satisfy the fertilizers, polymers, steel,… industrial needs
- …..



14.1 The Nature of Acids and Bases

Acids: Have a sour taste. Vinegar owes its taste to acetic acid. Citrus fruits contain citric acid.

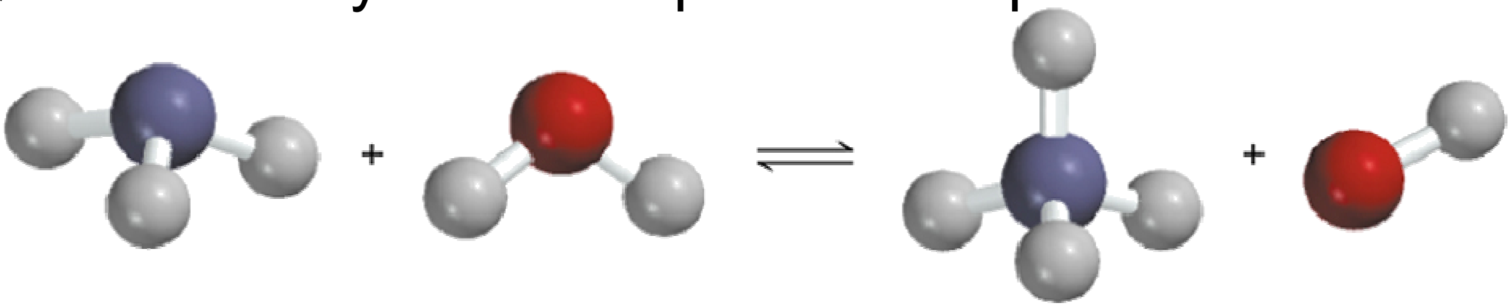
Bases: Have a bitter taste. Feel slippery. Many soaps contain bases.

Arrhenius acid is a substance that produces H^+ (H_3O^+) in water

Arrhenius base is a substance that produces OH^- in water

A Brønsted-Lowry acid is a proton donor

A Brønsted-Lowry base is a proton acceptor



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

base | acid | acid / conjugate acid | base / conjugate base

base | acid

14.2 Acid Dissociation Constant, K_a and Acid Strength

The general reaction of acid (HA) in water is:

$$HA\,(aq) + H_2O\,(l) \rightleftharpoons H_3O^+\,(aq) + A^-\,(aq) \qquad K_a = \frac{[H^+][A^-]}{[HA]}$$

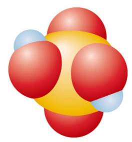
TABLE 14.1 Various Ways to Describe Acid Strength

Property	Strong Acid	Weak Acid
K_a value	K_a is large	K_a is small
Position of the dissociation (ionization) equilibrium	Far to the right	Far to the left
Equilibrium concentration of H^+ compared with original concentration of HA	$[H^+] \approx [HA]_0$	$[H^+] \ll [HA]_0$
Strength of conjugate base compared with that of water	A^- much weaker base than H_2O	A^- much stronger base than H_2O

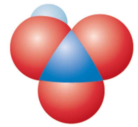
14.2 Acid Strength

- Common strong acids:

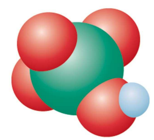
  Sulfuric, Hydrochloric, Nitric, …



Sulfuric acid (H_2SO_4)



Nitric acid (HNO_3)

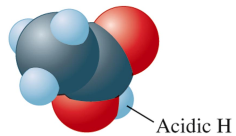


Perchloric acid ($HClO_4$)

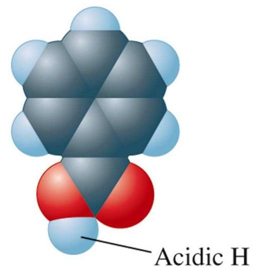
- Sulfuric acid is a Diprotic Acid, i.e., acid having two protons, virtually 100% ionized in water.
- Most acids are Oxyacids, H-O…
- Organic acids

  commonly contain Carboxyl

  and usually weak acids



Acetic acid (CH_3CO_2H)



Benzoic acid ($C_6H_5CO_2H$)

- In some acids, H is not attached to oxygen (HX), X is halogen

14.2 Acid Strength

TABLE 14.2 Values of K_a for Some Common Monoprotic Acids

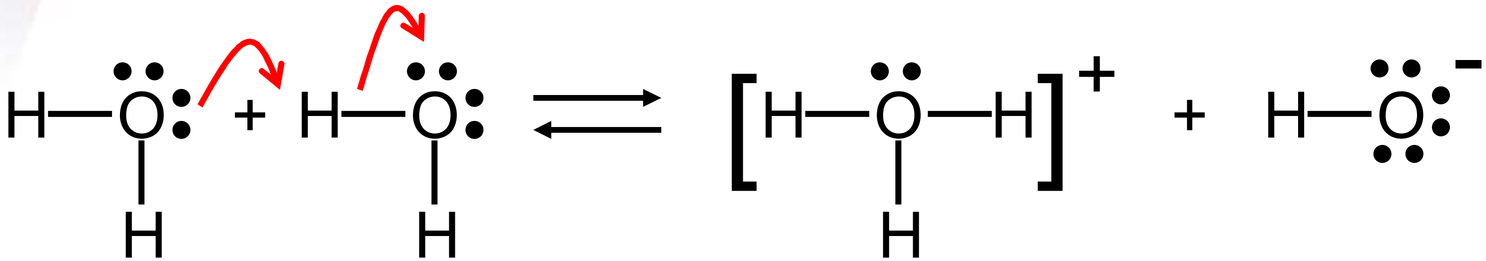
Formula	Name	Value of K_a*
HSO_4^-	Hydrogen sulfate ion	1.2×10^{-2}
$HClO_2$	Chlorous acid	1.2×10^{-2}
$HC_2H_2ClO_2$	Monochloracetic acid	1.35×10^{-3}
HF	Hydrofluoric acid	7.2×10^{-4}
HNO_2	Nitrous acid	4.0×10^{-4}
$HC_2H_3O_2$	Acetic acid	1.8×10^{-5}
$[Al(H_2O)_6]^{3+}$	Hydrated aluminum(III) ion	1.4×10^{-5}
HOCl	Hypochlorous acid	3.5×10^{-8}
HCN	Hydrocyanic acid	6.2×10^{-10}
NH_4^+	Ammonium ion	5.6×10^{-10}
HOC_6H_5	Phenol	1.6×10^{-10}

↑ Increasing acid strength

*The units of K_a are customarily omitted.

Acid-Base Properties of Water

autoionization of water: $H_2O\ (l) \rightleftharpoons H^+\ (aq) + OH^-\ (aq)$



Water is the most common **amphoteric substance**, i.e., it can behave either as an acid or as a base.

base — conjugate acid

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

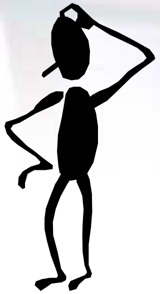
acid — conjugate base

$$K_c = \frac{[H^+][OH^-]}{[H_2O]^2} \qquad [H_2O] = \text{constant}$$

$$K_c[H_2O] = K_w = [H^+][OH^-]$$

The ***ion-product constant*** (***K_w***) is the product of the molar concentrations of H^+ and OH^- ions **at a particular temperature.**

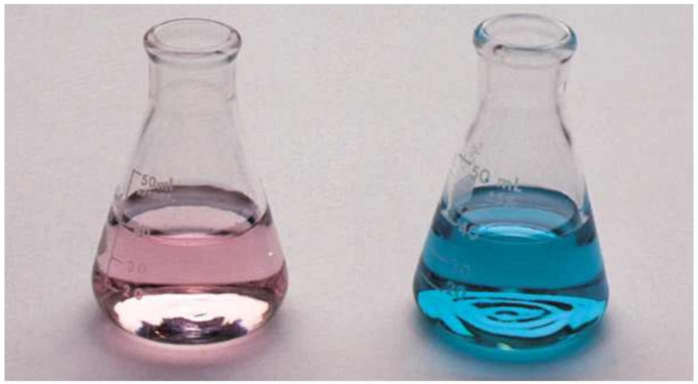
Exercise



What is the concentration of OH^- ions in a HCl solution whose hydrogen ion concentration is 1.3 *M*?

$$K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$$

$$[H^+] = 1.3\ M$$



$$[OH^-] = \frac{K_w}{[H^+]} = \frac{1 \times 10^{-14}}{1.3} = 7.7 \times 10^{-15}\ M$$

14.3 The pH Scale

$[H^+]$ is quite small, therefore pH scale will provides a convenient way to represent solution acidity.

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

pH ↑ $[H^+]$ ↓

Solution Is		**At 25⁰C**
neutral	$[H^+] = [OH^-]$	$[H^+] = 1 \times 10^{-7}$
acidic	$[H^+] > [OH^-]$	$[H^+] > 1 \times 10^{-7}$
basic	$[H^+] < [OH^-]$	$[H^+] < 1 \times 10^{-7}$

Similarly, log scale can be used for others, e.g.

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

$$-\log [H^+] - \log [OH^-] = 14.00$$

$$pH + pOH = 14.00$$

The pHs of Some Common Fluids

Sample	pH Value
Gastric juice in the stomach	1.0–2.0
Lemon juice	2.4
Vinegar	3.0
Grapefruit juice	3.2
Orange juice	3.5
Urine	4.8–7.5
Water exposed to air*	5.5
Saliva	6.4–6.9
Milk	6.5
Pure water	7.0
Blood	7.35–7.45
Tears	7.4
Milk of magnesia	10.6
Household ammonia	11.5

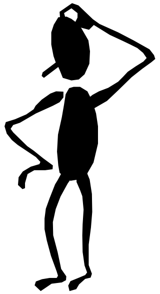
* Water exposed to air for a long period of time absorbs atmospheric CO_2 to form carbonic acid, H_2CO_3.

Exercise

The pH of rainwater collected in a certain region of the northeastern United States on a particular day was 4.82. What is the H^+ ion concentration of the rainwater?

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

$$[H^+] = 10^{-pH} = 10^{-4.82} = 1.5 \times 10^{-5}\ M$$



The OH^- ion concentration of a blood sample is 2.5×10^{-7} *M*. What is the pH of the blood?

$$pH + pOH = 14.00$$

$$pOH = -\log [OH^-] = -\log (2.5 \times 10^{-7}) = 6.60$$

$$pH = 14.00 - pOH = 14.00 - 6.60 = 7.40$$

Strong and Weak Acids

Strong Acids are strong electrolytes

$$HCl\ (aq) + H_2O\ (l) \longrightarrow H_3O^+\ (aq) + Cl^-\ (aq)$$

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

$$HClO_4\ (aq) + H_2O\ (l) \longrightarrow H_3O^+\ (aq) + ClO_4^-\ (aq)$$

$$H_2SO_4\ (aq) + H_2O\ (l) \longrightarrow H_3O^+\ (aq) + HSO_4^-\ (aq)$$

Weak Acids are weak electrolytes

$$HF\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + F^-\ (aq)$$

$$HNO_2\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + NO_2^-\ (aq)$$

$$HSO_4^-\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + SO_4^{2-}\ (aq)$$

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

Strong and Weak Bases

Strong Bases are strong electrolytes

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

$$KOH\ (s) \xrightarrow{H_2O} K^+\ (aq) + OH^-\ (aq)$$

$$Ba(OH)_2\ (s) \xrightarrow{H_2O} Ba^{2+}\ (aq) + 2OH^-\ (aq)$$

Weak Bases are weak electrolytes

$$F^-\ (aq) + H_2O\ (l) \rightleftharpoons OH^-\ (aq) + HF\ (aq)$$

$$NO_2^-\ (aq) + H_2O\ (l) \rightleftharpoons OH^-\ (aq) + HNO_2\ (aq)$$

Conjugate acid-base pairs:

- The conjugate base of a strong acid has no measurable strength.
- H_3O^+ is the strongest acid that can exist in aqueous solution.
- The OH^- ion is the strongest base that can exist in aqeous solution.

Relative Strengths of Conjugate Acid-Base Pairs

		Acid	Conjugate Base	
Acid strength increases ↑	Strong acids	$HClO_4$ (perchloric acid)	ClO_4^- (perchlorate ion)	Base strength increases ↓
	Strong acids	HI (hydroiodic acid)	I^- (iodide ion)	
	Strong acids	HBr (hydrobromic acid)	Br^- (bromide ion)	
	Strong acids	HCl (hydrochloric acid)	Cl^- (chloride ion)	
	Strong acids	H_2SO_4 (sulfuric acid)	HSO_4^- (hydrogen sulfate ion)	
	Strong acids	HNO_3 (nitric acid)	NO_3^- (nitrate ion)	
		H_3O^+ (hydronium ion)	H_2O (water)	
	Weak acids	HSO_4^- (hydrogen sulfate ion)	SO_4^{2-} (sulfate ion)	
	Weak acids	HF (hydrofluoric acid)	F^- (fluoride ion)	
	Weak acids	HNO_2 (nitrous acid)	NO_2^- (nitrite ion)	
	Weak acids	HCOOH (formic acid)	$HCOO^-$ (formate ion)	
	Weak acids	CH_3COOH (acetic acid)	CH_3COO^- (acetate ion)	
	Weak acids	NH_4^+ (ammonium ion)	NH_3 (ammonia)	
	Weak acids	HCN (hydrocyanic acid)	CN^- (cyanide ion)	
	Weak acids	H_2O (water)	OH^- (hydroxide ion)	
	Weak acids	NH_3 (ammonia)	NH_2^- (amide ion)	

Acid-Base Problem General Strategies

- ***Think chemistry***

  Focus on the solution components and their reactions

- ***Be systematic***

  Acid-base problems require a step-by step approach

- ***Be flexible***

  Treat each problem as separate entity and do not try to force a given problem into another solved problem

- ***Be patient***

  The complete solution cannot be seen immediately

- ***Be confident***

  Understand and think; don’t just memorize

Exercise: Strong Acids and Base

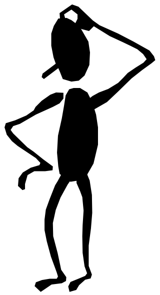
What is the pH of a 2×10^{-3} *M* HNO_3 solution?

Start 0.002 *M* 0.0 *M* 0.0 *M*

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

End 0.0 *M* 0.002 *M* 0.002 *M*

$$pH = -\log[H^+] = -\log[H_3O^+] = -\log(0.002) = 2.7$$



What is the pH of a 1.8×10^{-2} *M* $Ba(OH)_2$ solution?

$Ba(OH)_2$ is a strong base – 100% dissociation.

Start 0.018 *M* 0.0 *M* 0.0 *M*

$$Ba(OH)_2\,(s) \longrightarrow Ba^{2+}\,(aq) + 2OH^-\,(aq)$$

End 0.0 *M* 0.018 *M* 0.036 *M*

$$pH = 14.00 - pOH = 14.00 + \log(0.036) = 12.56$$

Exercise: Weak Acid

What is the pH of a 0.5 *M* HF solution (at 25^0C)?

$$HF\ (aq) \rightleftharpoons H^+\ (aq) + F^-\ (aq) \qquad K_a = \frac{[H^+][F^-]}{[HF]} = 7.1 \times 10^{-4}$$

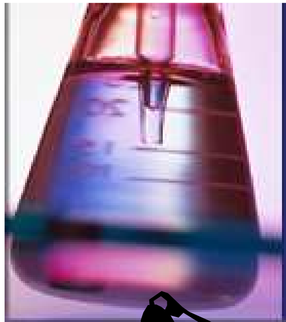
	$HF\ (aq) \rightleftharpoons$	$H^+\ (aq)$ +	$F^-\ (aq)$
Initial (*M*)	0.50	0.00	0.00
Change (*M*)	$-x$	$+x$	$+x$
Equilibrium (*M*)	$0.50 - x$	x	x

$$K_a = \frac{x^2}{0.50 - x} = 7.1 \times 10^{-4} \qquad K_a << 1 \qquad 0.50 - x \approx 0.50$$

$$K_a \approx \frac{x^2}{0.50} = 7.1 \times 10^{-4} \qquad x^2 = 3.55 \times 10^{-4} \qquad x = 0.019\ M$$

$[H^+] = [F^-] = 0.019\ M$ $\qquad$ $pH = -\log [H^+] = 1.72$

$[HF] = 0.50 - x = 0.48\ M$



Approximation

When can I use the approximation?

$K_a << 1 \quad 0.50 - x \approx 0.50$

When x is less than 5% of the value from which it is subtracted.

$x = 0.019 \quad \frac{0.019\ M}{0.50\ M} \times 100\% = 3.8\%$

Less than 5%

Approximation ok.

What is the pH of a 0.05 *M* HF solution (at 25⁰C)?

$K_a \approx \frac{x^2}{0.05} = 7.1 \times 10^{-4} \quad x = 0.006\ M$

$\frac{0.006\ M}{0.05\ M} \times 100\% = 12\%$

More than 5%

Approximation **not** ok.

Must solve for x exactly using quadratic equation or method of successive approximation.

Solving **weak acid** ionization problems:

1. Identify the major species that can affect the pH.
   - In most cases, you can ignore the autoionization of water.
   - Ignore $[OH^-]$ because it is determined by $[H^+]$.
2. Use ICE to express the equilibrium concentrations in terms of single unknown *x*.
3. Write K_a in terms of equilibrium concentrations. Solve for *x* by the approximation method. If approximation is not valid, solve for *x* exactly.
4. Calculate concentrations of all species and/or pH of the solution.

Acid Mixtures

- pH of weak acid mixtures

  The pH of solutions containing different weak acids, will depend on the $[H^+]$ of higher strength

Exercise 14.9

Calculate the pH of solution that contains 1.00 M HCN ($K_a = 6.2 \times 10^{-10}$) and 5.00 M HNO_2 ($K_a = 4.0 \times 10^{-4}$). What is the concentration CN^--ion in this solution?

Solution:

$$[H^+] = 4.5 \times 10^{-2} \quad \text{and pH} = 1.35$$

$$[CN^-] = 1.4 \times 10^{-8}$$

% of Dissociation

The percent dissociation is defined as follows:

$$\textbf{\textit{percent dissociation}} = \frac{\text{Ionized acid at equilibrium}}{\text{Initial concentration of acid}} \times 100\%$$

For a monoprotic acid HA

$$\text{Percent ionization} = \frac{[H^+]}{[HA]_0} \times 100\% \qquad [HA]_0 = \text{initial concentration}$$

The percent dissociation increases as the acid becomes more dilute

Exercise 14.10:

% dissociation of 1.00 M AcOH = 0.42%
% dissociation of 0.10 M AcOH = 1.3%

14.6 Bases

Weak Bases are weak electrolytes

Weak Bases and Base Ionization Constants

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

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

K_b is the ***base ionization constant***

Solve weak base problems like weak acids ***except*** solve for [OH-] instead of [H^+].

QUESTION

Calculate the pH of a 0.02 M solution of KOH.

1) 1.7
2) 2.0
3) 12.0
4) 12.3
5) cannot calculate answer unless a volume is given

KOH is a strong base; [OH] = 0.02 M.

pH = 14.0 – pOH = 14.0 – {-log [OH]} = 14.0 – {-log 0.02}

pH = 14.0 – 1.7 = 12.3

14.7 Polyprotic Acids

- They always dissociate in a stepwise manner

Phosphoric acid is triprotic acid that dissociate as follows:

$$H_3PO_{4(s)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)} \qquad K_{a1} = 7.5\times10^{-3}$$
$$H_2PO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + HPO_4^{2-}{}_{(aq)} \qquad K_{a2} = 6.2\times10^{-8}$$
$$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)} \qquad K_{a3} = 2.14\times10^{-13}$$

Only the first dissociation constant step is important in determining the pH.

- Sulfuric acid is strong acid in its first dissociation and a weak acid in its second dissociation, thus:

$[H^+]$ = Acid concentration = $[HSO_4^-]$ and use ICE for $[SO_4^{2-}]$

Review QUESTION

Ascorbic acid, also known as vitamin C, has two hydrogen atoms that ionize from the acid. $K_{a_1} = 7.9 \times 10^{-5}$; $K_{a_2} = 1.6 \times 10^{-12}$. What would be the pH, and $C_6H_6O_6^{2-}$ concentration of a 0.10 M solution of $H_2C_6H_6O_6$?

1. 2.56; $[C_6H_6O_6^{2-}] = 0.050$ M
2. 2.56; $[C_6H_6O_6^{2-}] = 1.6 \times 10^{-12}$ M
3. 1.00; $[C_6H_6O_6^{2-}] = 1.6 \times 10^{-12}$ M
4. 5.10; $[C_6H_6O_6^{2-}] = 0.050$ M

Choice 2: In a diprotic acid with two small, widely separated K_a values

- The pH of a solution can be obtained from the use of K_{a1} and molarity.
- The concentration of the dianion can be closely approximated by assuming very little dissociation of the second acidic hydrogen, so that K_{a_2} is very close to the molarity.

14.8 Acid-Base Properties of Salts

Neutral Solutions:

Salts containing an alkali metal or alkaline earth metal ion (except Be^{2+}) **and** the conjugate base of a **strong** acid (*e.g.* Cl^-, Br^-, and NO_3^-).

$$NaCl\ (s) \xrightarrow{H_2O} Na^+\ (aq) + Cl^-\ (aq)$$

Basic Solutions:

Salts derived from a strong base **and** a **weak** acid.

$$NaCH_3COOH\ (s) \xrightarrow{H_2O} Na^+\ (aq) + CH_3COO^-\ (aq)$$

$$CH_3COO^-\ (aq) + H_2O\ (l) \rightleftharpoons CH_3COOH\ (aq) + OH^-\ (aq)$$

14.8 Acid-base salts

Acid Solutions:

Salts derived from a strong acid and a weak base.

$$NH_4Cl\ (s) \xrightarrow{H_2O} NH_4^+\ (aq) + Cl^-\ (aq)$$

$$NH_4^+\ (aq) \rightleftharpoons NH_3\ (aq) + H^+\ (aq)$$

Salts with small, highly charged metal cations (*e.g.* Al^{3+}, Cr^{3+}, and Be^{2+}) and the conjugate base of a strong acid.

$$Al(H_2O)_6^{3+}(aq) \rightleftharpoons Al(OH)(H_2O)_5^{2+}(aq) + H^+\ (aq)$$

Conjugate Acid-Base Pairs

Ionization Constants of Conjugate Acid-Base Pairs

$$\cancel{HA}\,(aq) \rightleftharpoons H^+\,(aq) + \cancel{A^-}\,(aq) \qquad K_a$$

$$\cancel{A^-}\,(aq) + H_2O\,(l) \rightleftharpoons OH^-\,(aq) + \cancel{HA}\,(aq) \qquad K_b$$

$$H_2O\,(l) \rightleftharpoons H^+\,(aq) + OH^-\,(aq) \qquad K_w$$

$$\boxed{K_aK_b = K_w}$$

<u>Weak Acid and Its Conjugate Base</u>

$$K_a = \frac{K_w}{K_b} \qquad\qquad K_b = \frac{K_w}{K_a}$$

14.8 Acid-base salts

Solutions in which both the cation and the anion hydrolyze:

- K_b for the anion > K_a for the cation, solution will be basic
- K_b for the anion < K_a for the cation, solution will be acidic
- K_b for the anion ≈ K_a for the cation, solution will be neutral

Acid-Base Properties of Salts

Type of Salt	Examples	Ions That Undergo Hydrolysis	pH of Solution
Cation from strong base; anion from strong acid	NaCl, KI, KNO_3, RbBr, $BaCl_2$	None	≈ 7
Cation from strong base; anion from weak acid	CH_3COONa, KNO_2	Anion	> 7
Cation from weak base; anion from strong acid	NH_4Cl, NH_4NO_3	Cation	< 7
Cation from weak base; anion from weak acid	NH_4NO_2, CH_3COONH_4, NH_4CN	Anion and cation	< 7 if $K_b < K_a$
			≈ 7 if $K_b \approx K_a$
			> 7 if $K_b > K_a$
Small, highly charged cation; anion from strong acid	$AlCl_3$, $Fe(NO_3)_3$	Hydrated cation	< 7

Review QUESTION

Choice 3: The ranking is based on production of H^+ from the salt ions interacting with water.
The K_a of the aluminum's reaction is larger than the K_a for NH_4^+. NaCl is neutral and the acetate ion undergoes a reaction that produces $OH^–$

$NaCl$; NH_4NO_3; $Ca(C_2H_3O_2)_2$; $AlCl_3$

K_b for $NH_3 = 1.8 \times 10^{–5}$;
K_a for $HC_2H_3O_2 = 1.8 \times 10^{–5}$;
K_a for $Al(H_2O)^{3+} = 1.4 \times 10^{–5}$

1. $NaCl$; NH_4NO_3; $Ca(C_2H_3O_2)_2$; $AlCl_3$
2. $AlCl_3$; $NaCl$; NH_4NO_3; $Ca(C_2H_3O_2)_2$
3. $AlCl_3$; NH_4NO_3; $NaCl$; $Ca(C_2H_3O_2)_2$
4. NH_4NO_3; $AlCl_3$; $NaCl$; $Ca(C_2H_3O_2)_2$

103. Sodium azide (NaN_3) is sometimes added to water to kill bacteria. Calculate the concentration of all the species in 0.0100 M solution of (NaN_3). Ka of HN_3 = 1.9 x 10^{-5}

$NaN_3 \rightarrow Na^+ + N_3^-$; Azide, N_3^-, is a weak base since it is the conjugate base of a weak acid. All conjugate bases of weak acids are weak bases ($K_w < K_b < 1$). Ignore Na^+.

$$N_3^- + H_2O \rightleftharpoons HN_3 + OH^- \qquad K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.9 \times 10^{-5}} = 5.3 \times 10^{-10}$$

	N_3^-		HN_3	OH^-
Initial	0.010 *M*		0	~0
Change	$-x$	$\rightarrow$	$+x$	$+x$
Equil.	$0.010 - x$		x	x

$$K_b = 5.3 \times 10^{-10} = \frac{[HN_3][OH^-]}{[N_3^-]} = \frac{x^2}{0.010 - x} \approx \frac{x^2}{0.010} \quad (\text{assuming } x \ll 0.010)$$

$$x = [OH^-] = 2.3 \times 10^{-6}\ M;\ [H^+] = \frac{1.0 \times 10^{-14}}{2.3 \times 10^{-6}} = 4.3 \times 10^{-9}\ M \quad \text{Assumptions good.}$$

$[HN_3] = [OH^-] = 2.3 \times 10^{-6}\ M$; $[Na^+] = 0.010\ M$; $[N_3^-] = 0.010 ! 2.3 \times 10^{-6} = 0.010\ M$

Review QUESTION

The K_a value for monochloroacetic acid is 1.35×10^{-3} at 25°C. Neutralizing the acid with KOH would produce the salt potassium chloroaceate. What would be the pH of a 0.110 M solution of the salt at 25°C?

1. 7.956
2. 13.041
3. 6.044
4. 12.086

Choice 1: The salt, in water, will dissociate and provide the opportunity for the cation and anion to interact with water. Since the anion is from a weak acid (note the K_a) it can regain H^+ from water thus producing OH^- ions. The K_b for this reaction is obtained through K_w/K_a. Then the $[OH^-]$ can be obtained from the K_b and molarity. This is then converted to pH.

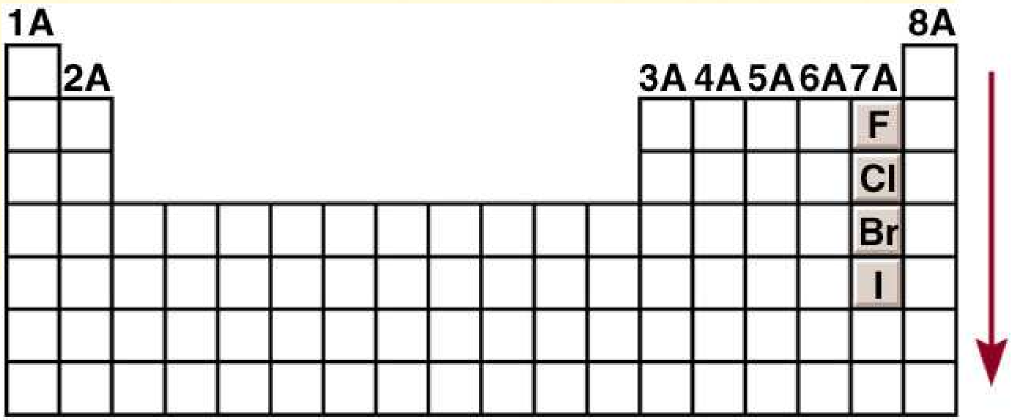
14.9 Molecular Structure and Acid Strength

$$H{-}X \longrightarrow H^+ + X^-$$

The stronger the bond → The weaker the acid

Bond Energies for Hydrogen Halides and Acid Strengths for Hydrohalic Acids

Bond	Bond Energy (kJ/mol)	Acid Strength
H—F		
H—Cl		
H—Br		
H—I		



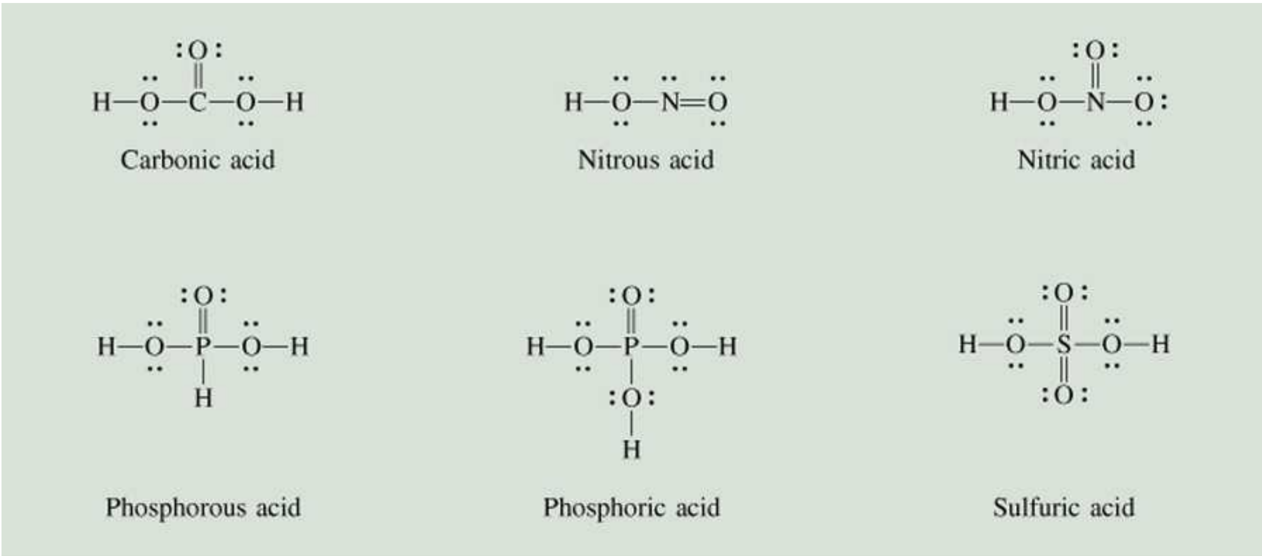
HF << HCl < HBr < HI

14.9 Molecular Structure and Acid Strength

$$\gt Z - \overset{\delta^-}{O} - \overset{\delta^+}{H} \longrightarrow \gt Z - O^- + H^+$$

<u>The O-H bond will be more polar and easier to break if:</u>

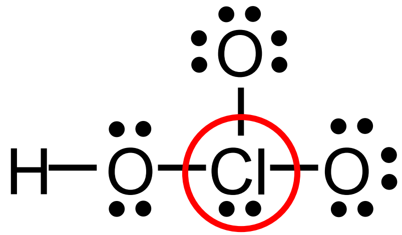
- Z is very electronegative or
- Z is in a high oxidation state

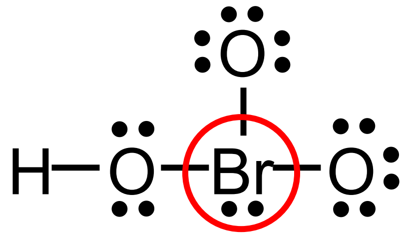


14.9 Molecular Structure and Acid Strength

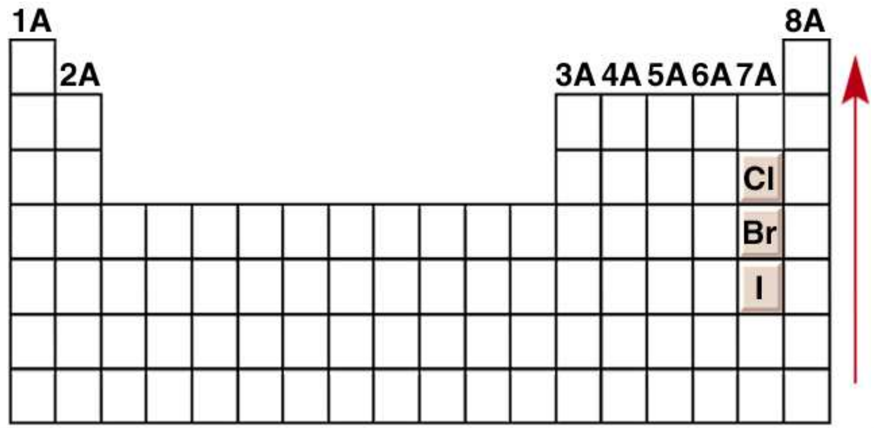
1. Oxoacids having different central atoms (Z) that **are from the same group** and that have the **same oxidation number**.

Acid strength increases with increasing electronegativity of Z





Cl is more electronegative than Br

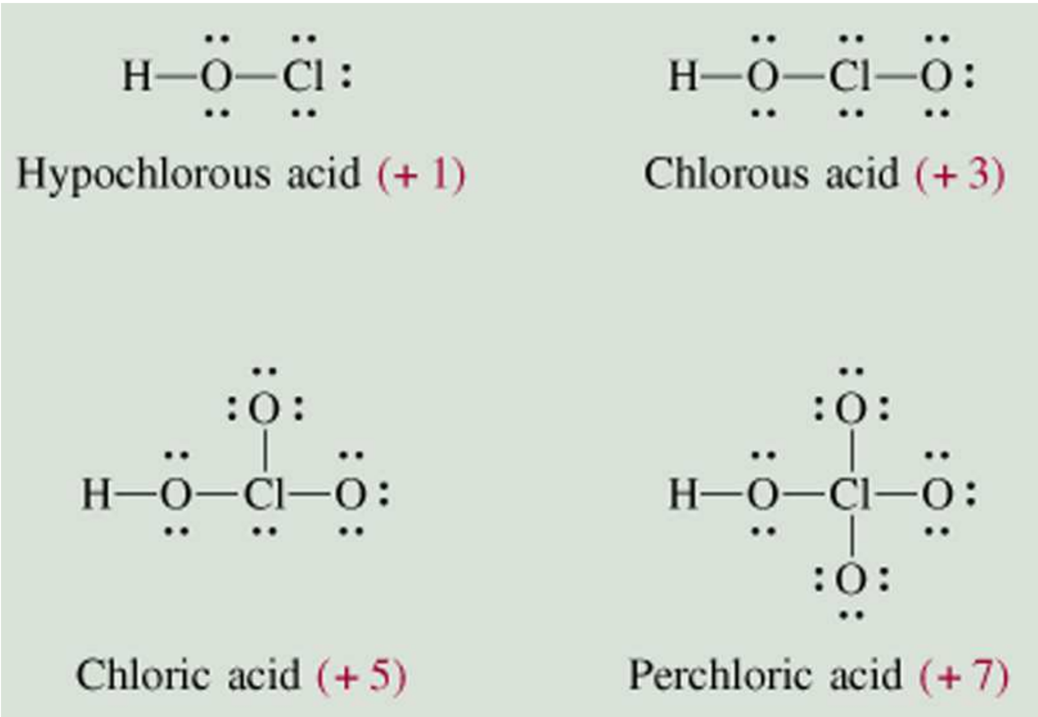


$HClO_3 > HBrO_3$

14.9 Molecular Structure and Acid Strength

2. Oxoacids having the same central atom (Z) but different numbers of attached groups.

Acid strength increases as the oxidation number of Z increases.



Hypochlorous acid (+ 1)

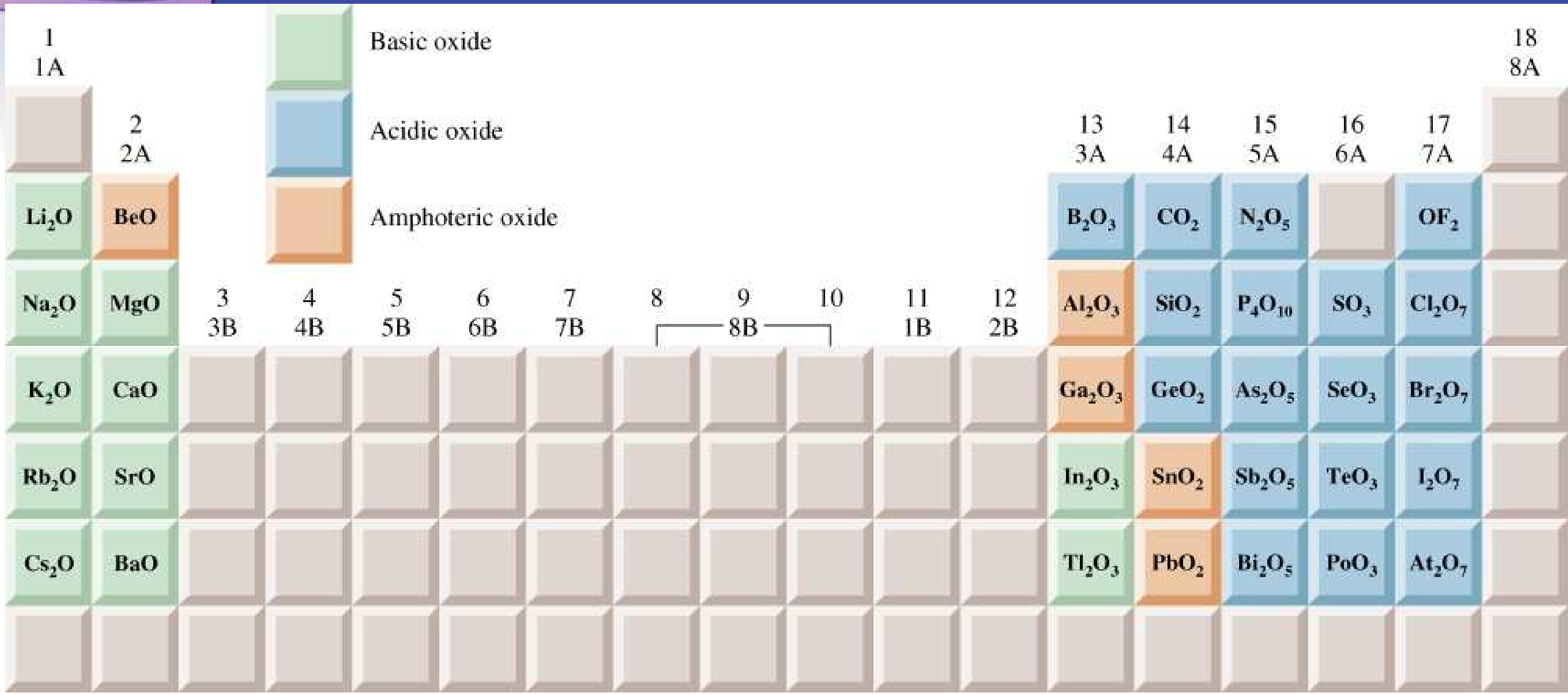
Chlorous acid (+ 3)

Chloric acid (+ 5)

Perchloric acid (+ 7)

$HClO_4 > HClO_3 > HClO_2 > HClO$

14.10 Oxides of the Representative Elements In Their Highest Oxidation States



$$CO_2\ (g) + H_2O\ (l) \rightleftharpoons H_2CO_3\ (aq)$$

$$N_2O_5\ (g) + H_2O\ (l) \rightleftharpoons 2HNO_3\ (aq)$$

Review QUESTION

Some CO_2 gas is bubbled into water. Which of the following compounds would be suitable to now neutralize the CO_2 infused solution?

1. K_2O
2. NaCl
3. NH_4Br
4. $AlCl_3$

Choice 1: Nonmetal oxides, such as CO_2, produce acid solutions in water. So a compound with basic properties would be needed to neutralize the solution. Of the choices, K_2O (a metal oxide) is the only one with basic properties.

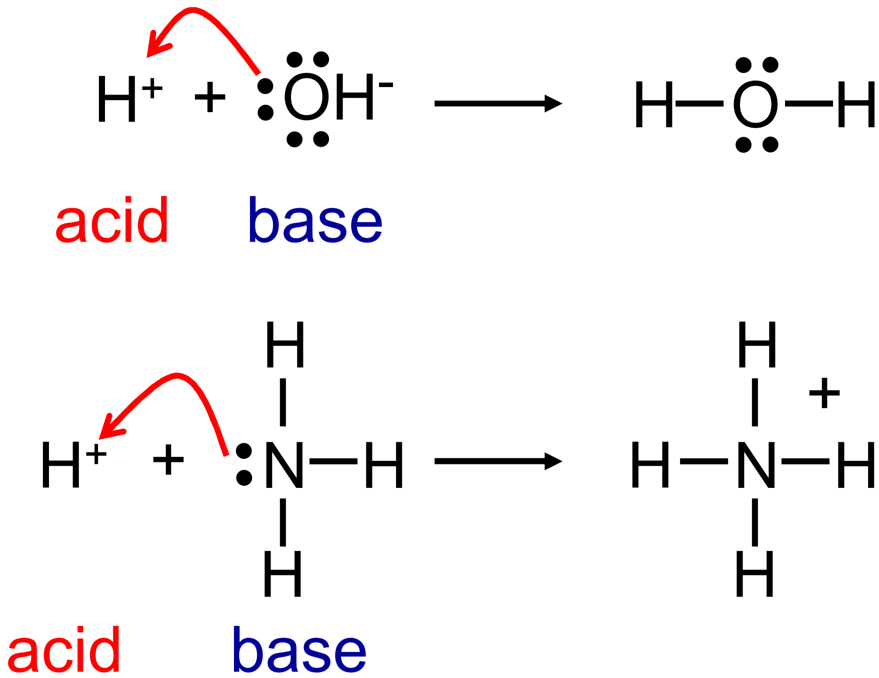
Definition of An Acid

Arrhenius acid is a substance that produces H^+ (H_3O^+) in water

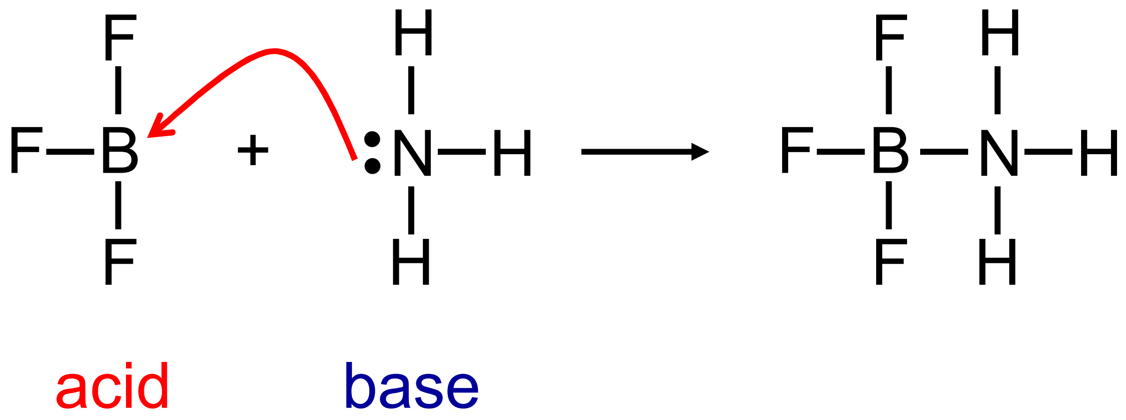
A ***Brønsted acid*** is a proton donor

A ***Lewis acid*** is a substance that can accept a pair of electrons

A ***Lewis base*** is a substance that can donate a pair of electrons



14.11 Lewis Acids and Bases



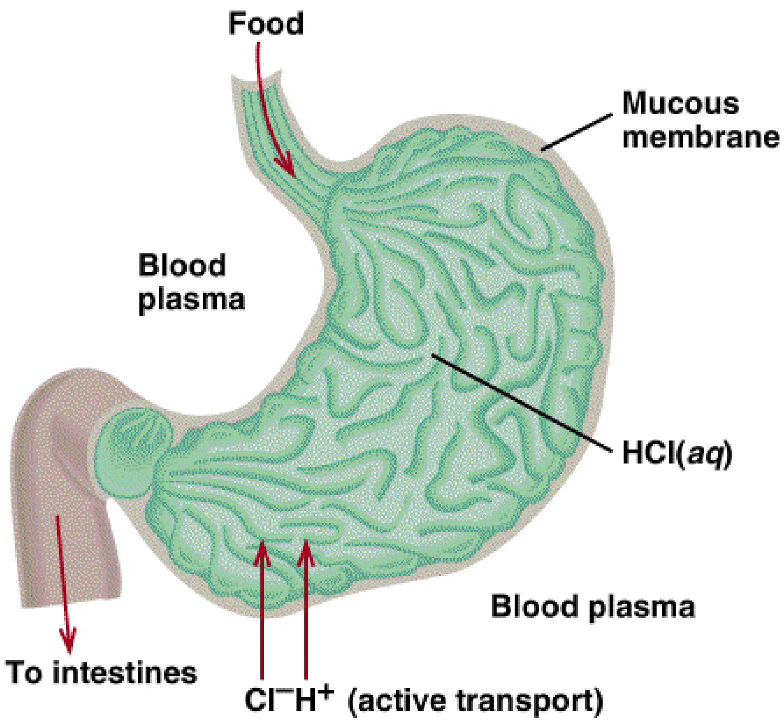
No protons donated or accepted!

Chemistry In Action: Antacids and the Stomach pH Balance

Some Common Commercial Antacid Preparations

Commercial Name	Active Ingredients
Alka-2	Calcium carbonate
Alka-Seltzer	Aspirin, sodium bicarbonate, citric acid
Bufferin	Aspirin, magnesium carbonate, aluminum glycinate
Buffered aspirin	Aspirin, magnesium carbonate, aluminum hydroxide-glycine
Milk of magnesia	Magnesium hydroxide
Rolaids	Dihydroxy aluminum sodium carbonate
Tums	Calcium carbonate

$$NaHCO_3\,(aq) + HCl\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l) + CO_2\,(g)$$



$$Mg(OH)_2\,(s) + 2HCl\,(aq) \longrightarrow MgCl_2\,(aq) + 2H_2O\,(l)$$