

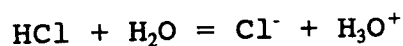
## CHAPTER 15

### ACID - BASE

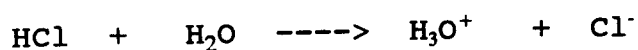
See Dewey Table 15.2 for the properties of acids and bases

#### ARRHENIUS THEORY:

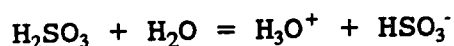
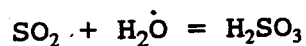
An ARRHENIUS ACID is a substance which when put in water produces  $\text{H}_3\text{O}^+$



1. Some acids produce the hydronium ion by giving a  $\text{H}^+$  ion to water

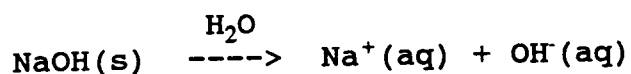


2. Nonmetal oxides react with water to produce a substance that contains hydrogen. This substance then reacts with water to give hydronium ions. Nonmetal oxides are called acid anhydrides

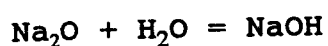


An ARRHENIUS BASE is a substance which when put in water produces  $\text{OH}^-$  *hydroxide*

1. Metal hydroxides produce the hydroxide ion by dissolving in the water

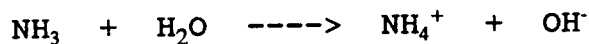


2. Metal oxides react with water to produce metal hydroxides  
Metal oxides are called Basic Anhydrides



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3. Some molecular substances react with water to give the OH<sup>-</sup>. Ammonia (bp=-33°C) produces the hydroxide ion by reacting with the water



Sometimes a soln of ammonia is called ammonium hydroxide. NH<sub>4</sub>OH does not exist, but is sometime used to represent a solution of ammonia NH<sub>3</sub>(aq) or NH<sub>3</sub> + H<sub>2</sub>O

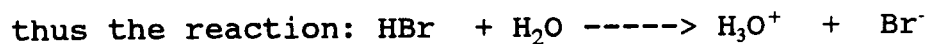
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A "STRONG ACID" reacts completely (ionizes) with water to produce H<sub>3</sub>O<sup>+</sup> ions

Strong Acids:



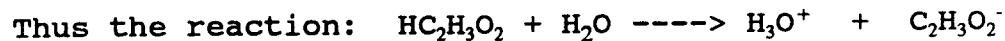
HBr is a strong acid



occurs completely (100%)

A "WEAK ACID" reacts partially with water

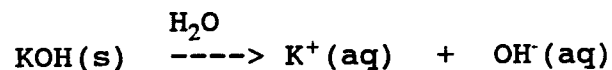
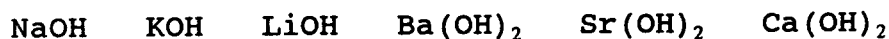
HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> is a weak acid



occurs partially (about 5%)

A "STRONG BASE" dissolves completely in water to produce hydroxide ions

Strong Bases



## CHAPTER 15

A "WEAK" base reacts partially with water to produce hydroxide ion

Ammonia is a weak base

thus the reaction:  $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$

occurs partially

or it dissolves partially in water to give hydroxide ion

$\text{Mg}(\text{OH})_2$  is a weak base

thus the rxn:

$\text{Mg}(\text{OH})_2 \xrightarrow{\text{H}_2\text{O}} \text{Mg}^{+2} + 2\text{OH}^-$

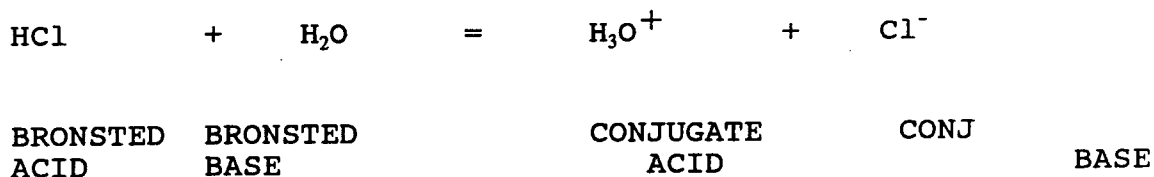
occurs partially

## CHAPTER 15

### BRONSTED THEORY

A BRONSTED ACID is a substance that donates a hydrogen ion (proton)

A BRONSTED BASE is a substance that accepts a hydrogen ion



A Bronsted acid must contain a hydrogen atom

A Bronsted base must contain a nonbonding electron pair (lone pair)

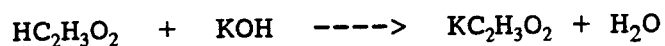
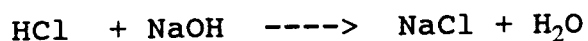
An AMPHOTERIC substance can act both as an acid and as a base

H<sub>2</sub>O and HSO<sub>4</sub><sup>-</sup> are amphoteric

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## WHEN AN ACID REACTS WITH A BASE

As long as either the acid or the base is strong  
the rxn will occur completely



MONOPROTIC - give up one hydrogen ion - HCl

DIPROTIC - give up two hydrogen ions - H<sub>2</sub>SO<sub>4</sub>

TRIPROTIC - give up three hydrogen ions - H<sub>3</sub>PO<sub>4</sub>

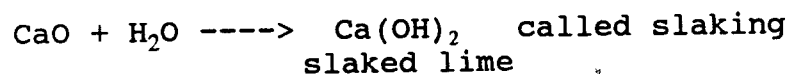
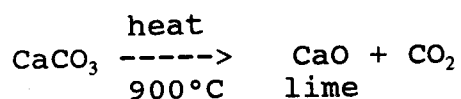
## WRITING IONIC EQUATIONS

Write all soluble salts and strong acids in the ionic form and  
all others in the molecular form

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CaCO<sub>3</sub> - limestone , marble

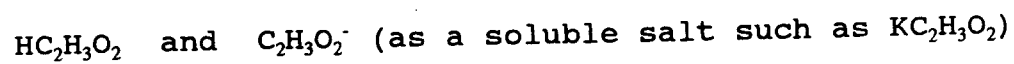
Seashells and chalk are almost entirely CaCO<sub>3</sub>  
antacids and mild abrasive in toothpaste and  
household cleansers



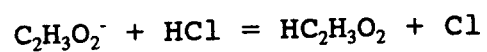
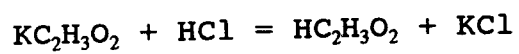
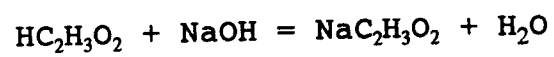
This is the first rxn when water is added to cement

## BUFFERS

Buffers are composed of a "WEAK" Bronsted Acid and its Conj Base



Buffers resist change in acidity (pH)



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Give the conj base of:

HF

HI

HCN

$\text{H}_3\text{O}^+$

$\text{HC}_2\text{H}_3\text{O}_2$

Give the conj acid of:

$\text{OH}^-$

$\text{I}^-$

$\text{H}_2\text{O}$

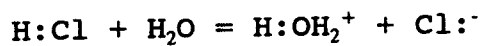
$\text{C}_2\text{H}_3\text{O}_2^-$

1. Bronsted Acids

- a. Contain hydrogen
- b. are uncharged (0), anions (-) or cations (+)

2. Bronsted Bases

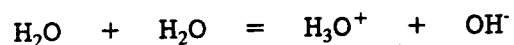
- a. are uncharged or anions (-)
- b. Must contain a lone pair of electrons



3. In the Bronsted Theory each acid is considered monoprotic
4. A substance that shows up on both sides is AMPHOTERIC and can act as an acid and a base
5. A substance must contain a hydrogen to be a Bronsted Acid But not all hydrogens can be donated to water

## SELF - IONIZATION OF WATER

In pure water at 25°C:



$$[\text{H}_3\text{O}^+] = 1.0 \times 10^{-7} \text{ M} \quad \text{and} \quad [\text{OH}^-] = 1.0 \times 10^{-7} \text{ M}$$

This condition is NEUTRAL

$$[\text{H}_3\text{O}^+] \times [\text{OH}^-] = 1.0 \times 10^{-14} = K_w$$

$K_w$  is the Ion Product Constant for water

$$\text{ACIDIC: } [\text{H}_3\text{O}^+] > 1 \times 10^{-7} \text{ M} \quad \& \quad [\text{OH}^-] < 1 \times 10^{-7} \text{ M}$$

$$\text{NEUTRAL: } [\text{H}_3\text{O}^+] = 1 \times 10^{-7} \text{ M} \quad \& \quad [\text{OH}^-] = 1 \times 10^{-7} \text{ M}$$

$$\text{BASIC: } [\text{H}_3\text{O}^+] < 1 \times 10^{-7} \text{ M} \quad \& \quad [\text{OH}^-] > 1 \times 10^{-7} \text{ M}$$

1. For a hydronium ion concentration of  $2.0 \times 10^{-4} \text{ M}$ , is the solution acidic, basic or neutral?
2. For a hydronium ion concentration of  $3.0 \times 10^{-8} \text{ M}$  is the solution acidic, basic or neutral?

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$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

p stands for power

The pH of water at 25°C is 7.00, this is NEUTRAL

A pH less than 7.00 is ACIDIC

A pH = 7.00 is NEUTRAL

A pH greater than 7.00 is BASIC

What is the pH of a 0.0025 M soln of HCl?

$$\text{pH} = -\log 0.0025 = -(-2.60) = 2.60$$

1. If the pH = 5.0 is the soln acidic, basic or neutral?
2. What is the pH of 0.0038 M HCl?

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

$$\text{pH} + \text{pOH} = \text{pK}_w = 14$$

$$\text{pH} = 14 - \text{pOH}$$

If NaOH = 0.0023 M calculate the pH

$$\text{pOH} = -\log 0.0023 = 2.64$$

$$\text{pH} = 14 - 2.64 = 11.36$$

1. What is the pH of a 0.0075 M NaOH?

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = \text{antilog } -\text{pH} = \text{inv log } -\text{pH}$$

$$\text{If pH} = 5 \text{ then } [\text{H}_3\text{O}^+] = 10^{-5} \text{ M} = \text{inv log } -5$$

$$\text{If pH} = 2.3 \text{ then } [\text{H}_3\text{O}^+] = 10^{-2.3} \text{ M} = \text{inv log } -2.3 = 0.00501 \text{ M}$$

2. If pH = 8.50 what is the hydronium ion concentration?

## ACID STRENGTH

Acids are listed in order of decreasing strength in the following table

The stronger a Bronsted acid - the weaker its conj base

As Acids:  $\text{HI} > \text{HCl}$  thus As Bases  $\text{Cl}^- > \text{I}^-$

As Acids:  $\text{H}_3\text{PO}_4 > \text{H}_2\text{PO}_4^- > \text{HPO}_4^{2-}$

As Bases:  $\text{PO}_4^{3-} > \text{HPO}_4^{2-} > \text{H}_2\text{PO}_4^-$

thus the conj bases are listed in order of increasing strength as bases

BRONSTED ACID	CONJ BASE
HI (Strongest Acid)	I <sup>-</sup> (Weakest Base)
H <sub>2</sub> SO <sub>4</sub>	HSO <sub>4</sub> <sup>-</sup>
HCl	Cl <sup>-</sup>
HNO <sub>3</sub>	NO <sub>3</sub> <sup>-</sup>
"STRONG" ACIDS Above	
----- H <sub>3</sub> O <sup>+</sup> -----	H <sub>2</sub> O -----
"WEAK" ACIDS Below Line	
HSO <sub>4</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>
H <sub>3</sub> PO <sub>4</sub>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>
*HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>
H <sub>2</sub> CO <sub>3</sub>	HCO <sub>3</sub> <sup>-</sup>
H <sub>2</sub> S	HS <sup>-</sup>
H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	HPO <sub>4</sub> <sup>-2</sup>
NH <sub>4</sub> <sup>+</sup>	NH <sub>3</sub>
*C <sub>6</sub> H <sub>5</sub> OH	C <sub>6</sub> H <sub>5</sub> O <sup>-</sup>
HCO <sub>3</sub> <sup>-</sup>	CO <sub>3</sub> <sup>-2</sup>
HPO <sub>4</sub> <sup>-2</sup>	PO <sub>4</sub> <sup>-3</sup>
----- H <sub>2</sub> O -----	OH <sup>-</sup> -----
"STRONG" BASES Below Line	
*C <sub>2</sub> H <sub>5</sub> OH	C <sub>2</sub> H <sub>5</sub> O <sup>-</sup>
NH <sub>3</sub> (Weakest Acid)	NH <sub>2</sub> <sup>-</sup> (Strongest Base)

- 
1. Write the products of the following reactions and balance the equation
- $\text{NaOH} + \text{HCl} =$
  - $\text{KOH} + \text{HNO}_3 =$
  - $\text{Mg}(\text{OH})_2 + \text{HCl} =$
  - $\text{HC}_2\text{H}_3\text{O}_2 + \text{KOH} =$
  - $\text{NaOH} + \text{H}_2\text{SO}_4 =$
2. Write an equation showing what happens when the following substances are put in water
- HBr
  - HI
  - $\text{NH}_3$
  - $\text{HC}_2\text{H}_3\text{O}_2$
  - HF
  - NaOH
3. Indicate if the following will react with water completely, or partially
- HBr
  - HI
  - $\text{NH}_3$
  - $\text{HC}_2\text{H}_3\text{O}_2$
  - HF
4. Indicate if the solutions from 2 above are acidic or basic

- 
- Which of the following substances are ionic?  
 $\text{HC}_2\text{H}_3\text{O}_2$ ,  $\text{NaOH}$ ,  $\text{HCl}$ ,  $\text{NH}_3$ ,  $\text{SO}_2$ ,  $\text{HBr}$ ,  $\text{NaCl}$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{HF}$ ,  
 $\text{CaO}$ ,  $\text{CO}_2$
  - Which of the following substances are Arrhenius acids?  
 $\text{HC}_2\text{H}_3\text{O}_2$ ,  $\text{NaOH}$ ,  $\text{HCl}$ ,  $\text{NH}_3$ ,  $\text{SO}_2$ ,  $\text{HBr}$ ,  $\text{CaO}$ ,  $\text{CO}_2$
  - Which of the following substances are strong acids?  
 $\text{HC}_2\text{H}_3\text{O}_2$ ,  $\text{NaOH}$ ,  $\text{HCl}$ ,  $\text{NH}_3$ ,  $\text{SO}_2$ ,  $\text{HBr}$ ,  $\text{NaCl}$ ,  $\text{H}_2\text{O}$ ,  $\text{CO}_2$
  - Which of the following substances are acid anhydrides?  
 $\text{HC}_2\text{H}_3\text{O}_2$ ,  $\text{NaOH}$ ,  $\text{HCl}$ ,  $\text{NH}_3$ ,  $\text{SO}_2$ ,  $\text{HBr}$ ,  $\text{NaCl}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{HF}$ ,  $\text{CaO}$ ,  
 $\text{CO}_2$
  - Which of the following substances are basic anhydrides?  
 $\text{HC}_2\text{H}_3\text{O}_2$ ,  $\text{NaOH}$ ,  $\text{HCl}$ ,  $\text{NH}_3$ ,  $\text{SO}_2$ ,  $\text{HBr}$ ,  $\text{NaCl}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{HF}$ ,  $\text{CaO}$ ,  
 $\text{CO}_2$
  - Which of the following substances are Arrhenius bases?  
 $\text{HC}_2\text{H}_3\text{O}_2$ ,  $\text{NaOH}$ ,  $\text{HCl}$ ,  $\text{NH}_3$ ,  $\text{SO}_2$ ,  $\text{HBr}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{HF}$ ,  $\text{CaO}$ ,  $\text{CO}_2$
  - Indicate if the following will react with water completely, or partially
    - $\text{HBr}$
    - $\text{HI}$
    - $\text{NH}_3$
    - $\text{HC}_2\text{H}_3\text{O}_2$
    - $\text{HF}$

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8. Give the conjugate base of
- HBr
  - H<sub>2</sub>O
  - H<sub>3</sub>O<sup>+</sup>
  - HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>
  - NH<sub>4</sub><sup>+</sup>
9. Give the conjugate acid of
- Cl<sup>-</sup>
  - OH<sup>-</sup>
  - NH<sub>3</sub>
10. Write the reaction of the following with water
- HBr
  - HI
  - NH<sub>3</sub>
  - HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>
  - HF
  - NH<sub>4</sub><sup>+</sup> from NH<sub>4</sub>Cl
11. Indicate if the solutions from 10 above are acidic or basic
12. Complete the following reactions and write a balanced molecular equation.
- NaOH + HCl =
  - KOH + HNO<sub>3</sub> =
  - NaCN + HCl =
  - Mg(OH)<sub>2</sub> + HCl =
  - HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> + KOH =
  - NaOH + H<sub>2</sub>SO<sub>4</sub> =

## 39. ACIDITY OF SOLUTIONS

-----  
1. Indicate if the following are acidic, basic or neutral

- a.  $[\text{H}_3\text{O}^+] = 1.0\text{E}-8 \text{ M}$
- b.  $[\text{H}_3\text{O}^+] = 1.0\text{E}-6 \text{ M}$
- c.  $[\text{H}_3\text{O}^+] = 1.0\text{E}-7 \text{ M}$
- d.  $[\text{H}_3\text{O}^+] = 6.8\text{E}-7 \text{ M}$
- e.  $[\text{H}_3\text{O}^+] = 7.5\text{E}-6 \text{ M}$
- f.  $[\text{OH}^-] = 1.0\text{E}-8 \text{ M}$
- g.  $[\text{OH}^-] = 1.00 \text{ M}$
- h.  $[\text{OH}^-] = 1.0\text{E}-6 \text{ M}$
- i.  $[\text{OH}^-] = 1.0\text{E}-7 \text{ M}$
- j.  $[\text{OH}^-] = 6.5\text{E}-6 \text{ M}$
- k.  $[\text{OH}^-] = 7.3\text{E}-7 \text{ M}$
- l.  $[\text{H}_3\text{O}^+] = 1.0\text{E}-14 \text{ M}$
- m.  $[\text{H}_3\text{O}^+] = 7.7\text{E}-7 \text{ M}$
- n.  $[\text{OH}^-] = 2.0\text{E}-1 \text{ M}$

2. Indicate if the following are acidic, basic or neutral

- a.  $\text{pH} = 1.0$
- b.  $\text{pH} = 6.9$
- c.  $\text{pH} = 7.1$
- d.  $\text{pH} = 7.00$
- e.  $\text{pH} = 14$

- 
1. For 0.0010 M HCl calculate
    - a.  $[\text{H}_3\text{O}^+]$
    - b.  $[\text{OH}^-]$
    - c. pH
  2. For 0.00237 M HBr calculate
    - a.  $[\text{H}_3\text{O}^+]$
    - b.  $[\text{OH}^-]$
    - c. pH
  3. For 0.00473 M KOH calculate
    - a.  $[\text{OH}^-]$
    - b.  $[\text{H}_3\text{O}^+]$
    - c. pH
  4. Calculate the pH of
    - a.  $1.00\text{E-}4$  M HCl
    - b.  $7.0\text{E-}5$  M HBr
    - c.  $5.0\text{E-}8$  M  $\text{H}_3\text{O}^+$
    - d.  $3.0\text{E-}11$  M  $\text{H}_3\text{O}^+$
    - e.  $8.5\text{E-}6$  M KOH