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 H_3O^+

$$HCl + H_2O = Cl^- + H_3O^+$$

1. Some acids produce the hydronium ion by giving a H^+ ion to water

$$HCl + H_2O \text{ ----> } H_3O^+ + Cl^-$$

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

$$SO_2 + H_2O = H_2SO_3$$

$$H_2SO_3 + H_2O = H_3O^+ + HSO_3^-$$

An ARRHENIUS BASE is a substance which when put in water produces OH^-

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

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

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

$$Na_2O + H_2O = NaOH$$

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

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

Sometimes a soln of ammonia is called ammonium hydroxide

NH_4OH does not exist, but is sometime used to represent

a solution of ammonia $NH_3(aq)$ or $NH_3 + H_2O$

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A "STRONG ACID" reacts completely (ionizes) with water to produce H_3O^+ ions

Strong Acids:

HCl HNO_3 H_2SO_4 HBr HI $HClO_4$

HBr is a strong acid

thus the reaction: $HBr + H_2O \longrightarrow H_3O^+ + Br^-$

occurs completely (100%)

A "WEAK ACID" reacts partially with water

$HC_2H_3O_2$ is a weak acid

Thus the reaction: $HC_2H_3O_2 + H_2O \longrightarrow H_3O^+ + C_2H_3O_2^-$

occurs partially (about 5%)

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

Strong Bases

NaOH KOH LiOH $Ba(OH)_2$ $Sr(OH)_2$ $Ca(OH)_2$

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

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

Ammonia is a weak base

thus the reaction: $NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$

occurs partially

or it dissolves partially in water to give hydroxide ion

$Mg(OH)_2$ is a weak base

thus the rxn:

$$Mg(OH)_2 \xrightarrow{H_2O} Mg^{+2} + 2OH^-$$

occurs partially

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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

HCl	+	H_2O	=	H_3O^+	+	Cl^-
BRONSTED ACID		BRONSTED BASE		CONJUGATE ACID		CONJ BASE

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_2O and HSO_4^- 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

$HCl + NaOH \longrightarrow NaCl + H_2O$

$HC_2H_3O_2 + KOH \longrightarrow KC_2H_3O_2 + H_2O$

MONOPROTIC - give up one hydrogen ion - HCl

DIPROTIC - give up two hydrogen ions - H_2SO_4

TRIPROTIC - give up three hydrogen ions - $H3PO_4$

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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$CaCO_3$ - limestone ,marble
Seashells and chalk are almost entirely $CaCO_3$
antacids and mild abrasive in toothpaste and household cleansers

$$CaCO_3 \xrightarrow[900°C]{\text{heat}} CaO + CO_2$$
lime

$CaO + H_2O \longrightarrow Ca(OH)_2$ called slaking
slaked lime

This is the first rxn when water is added to cement

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BUFFERS

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

$HC_2H_3O_2$ and $C_2H_3O_2^-$ (as a soluble salt such as $KC_2H_3O_2$)

Buffers resist change in acidity (pH)

$$HC_2H_3O_2 + NaOH = NaC_2H_3O_2 + H_2O$$

$$KC_2H_3O_2 + HCl = HC_2H_3O_2 + KCl$$

$$C_2H_3O_2^- + HCl = HC_2H_3O_2 + Cl$$

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Give the conj base of:

HF

HI

HCN

H_3O^+

$HC_2H_3O_2$

Give the conj acid of:

OH^-

I^-

H_2O

$C_2H_3O_2^-$

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

   $H{:}Cl + H_2O = H{:}OH_2^+ + Cl{:}^-$

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:

$$H_2O + H_2O = H_3O^+ + OH^-$$

$[H_3O^+] = 1.0 \times 10^{-7}$ M and $[OH^-] = 1.0 \times 10^{-7}$ M

This condition is NEUTRAL

$$[H_3O^+] \times [OH^-] = 1.0 \times 10^{-14} = Kw$$

Kw is the Ion Product Constant for water

ACIDIC: $[H_3O^+] > 1 \times 10^{-7}$ M & $[OH^-] < 1 \times 10^{-7}$ M

NEUTRAL: $[H_3O^+] = 1 \times 10^{-7}$ M & $[OH^-] = 1 \times 10^{-7}$ M

BASIC: $[H_3O^+] < 1 \times 10^{-7}$ M & $[OH^-] > 1 \times 10^{-7}$ M

1. For a hydronium ion concentration of 2.0×10^{-4} M, is the solution acidic, basic or neutral?

2. For a hydronium ion concentration of 3.0×10^{-8} M is the solution acidic, basic or neutral?

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

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?

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?

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

$$pH + pOH = pKw = 14$$

$$pH = 14 - pOH$$

If NaOH = 0.0023 M calculate the pH

pOH = -log 0.0023 = 2.64

pH = 14 - 2.64 = 11.36

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

$[H_3O^+] = 10^{-pH}$ = antilog -pH = inv log -pH

If pH = 5 then $[H_3O^+] = 10^{-5}$ M = inv log -5

If pH = 2.3 then $[H_3O^+] = 10^{-2.3}$ M = inv log -2.3 = 0.00501 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: HI > HCl thus As Bases Cl^- > I^-

As Acids: H_3PO_4 > $H_2PO_4^-$ > HPO_4^{-2}

As Bases: PO_4^{-3} > HPO_4^{-2} > $H_2PO_4^-$

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

BRONSTED ACID	CONJ BASE
HI (Strongest Acid)	I^- (Weakest Base)
H_2SO_4	HSO_4^-
HCl	Cl^-
HNO_3	NO_3^-
"STRONG" ACIDS Above	
---- H_3O^+ ----------	H_2O ----------
"WEAK" ACIDS Below Line	"WEAK" BASES Below Line
HSO_4^-	SO_4^{-2}
H_3PO_4	$H_2PO_4^-$
$*HC_2H_3O_2$	$C_2H_3O_2^-$
H_2CO_3	HCO_3^-
H_2S	HS^-
$H_2PO_4^-$	HPO_4^{-2}
NH_4^+	NH_3
$*C_6H_5OH$	$C_6H_5O^-$
HCO_3^-	CO_3^{-2}
HPO_4^{-2}	PO_4^{-3}
---- H_2O ----------	OH^- -------"STRONG" BASES Below Line
$*C_2H_5OH$	$C_2H_5O^-$
NH_3 (Weakest Acid)	NH_2^- (Strongest Base)

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37. ACIDS AND BASES

1. Write the products of the following reactions and balance the equation

   a. $NaOH + HCl =$

   b. $KOH + HNO_3 =$

   c. $Mg(OH)_2 + HCl =$

   d. $HC_2H_3O_2 + KOH =$

   e. $NaOH + H_2SO_4 =$

2. Write an equation showing what happens when the following substances are put in water

   a. HBr

   b. HI

   c. NH_3

   d. $HC_2H_3O_2$

   e. HF

   f. NaOH

3. Indicate if the following will react with water completely, or partially

   a. HBr

   b. HI

   c. NH_3

   d. $HC_2H_3O_2$

   e. HF

4. Indicate if the solutions from 2 above are acidic or basic

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38. ACID, BASES and SALTS

1. Which of the following substances are ionic?

   $HC_2H_3O_2$, NaOH, HCl, NH_3, SO_2, HBr, NaCl, H_2O, CH_3OH, HF, CaO, CO_2

2. Which of the following substances are Arrhenius acids?

   $HC_2H_3O_2$, NaOH, HCl, NH_3, SO_2, HBr, CaO, CO_2

3. Which of the following substances are strong acids?

   $HC_2H_3O_2$, NaOH, HCl, NH_3, SO_2, HBr, NaCl, H_2O, CO_2

4. Which of the following substances are acid anhydrides?

   $HC_2H_3O_2$, NaOH, HCl, NH_3, SO_2, HBr, NaCl, CH_3OH, HF, CaO, CO_2

5. Which of the following substances are basic anhydrides?

   $HC_2H_3O_2$, NaOH, HCl, NH_3, SO_2, HBr, NaCl, CH_3OH, HF, CaO, CO_2

6. Which of the following substances are Arrhenius bases?

   $HC_2H_3O_2$, NaOH, HCl, NH_3, SO_2, HBr, CH_3OH, HF, CaO, CO_2

7. Indicate if the following will react with water completely, or partially

   a. HBr

   b. HI

   c. NH_3

   d. $HC_2H_3O_2$

   e. HF

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8. Give the conjugate base of

   a. HBr

   b. H_2O

   c. H_3O^+

   d. $HC_2H_3O_2$

   e. NH_4^+

9. Give the conjugate acid of

   a. Cl^-

   b. OH^-

   c. NH_3

10. Write the reaction of the following with water

   a. HBr

   b. HI

   c. NH_3

   d. $HC_2H_3O_2$

   e. HF

   f. NH_4^+ from NH_4Cl

11. Indicate if the solutions from 10 above are acidic or basic

12. Complete the following reactions and write a balanced molecular equation.

   a. $NaOH + HCl =$

   b. $KOH + HNO_3 =$

   c. $NaCN + HCl =$

   d. $Mg(OH)_2 + HCl =$

   e. $HC_2H_3O_2 + KOH =$

   f. $NaOH + H_2SO_4 =$

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39. ACIDITY OF SOLUTIONS

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

   a. $[H_3O^+] = 1.0E-8$ M

   b. $[H_3O^+] = 1.0E-6$ M

   c. $[H_3O^+] = 1.0E-7$ M

   d. $[H_3O^+] = 6.8E-7$ M

   e. $[H_3O^+] = 7.5E-6$ M

   f. $[OH^-] = 1.0E-8$ M

   g. $[OH^-] = 1.00$ M

   h. $[OH^-] = 1.0E-6$ M

   i. $[OH^-] = 1.0E-7$ M

   j. $[OH^-] = 6.5E-6$ M

   k. $[OH^-] = 7.3E-7$ M

   l. $[H_3O^+] = 1.0E-14$ M

   m. $[H_3O^+] = 7.7E-7$ M

   n. $[OH^-] = 2.0E-1$ M

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

   a. pH = 1.0

   b. pH = 6.9

   c. pH = 7.1

   d. pH = 7.00

   e. pH = 14

CHAPTER 15

40. pH CALCULATIONS

1. For 0.0010 M HCl calculate
   a. $[H_3O^+]$
   b. $[OH^-]$
   c. pH
2. For 0.00237 M HBr calculate
   a. $[H_3O^+]$
   b. $[OH^-]$
   c. pH
3. For 0.00473 M KOH calculate
   a. $[OH^-]$
   b. $[H_3O^+]$
   c. pH
4. Calculate the pH of
   a. 1.00E-4 M HCl
   b. 7.0E-5 M HBr
   c. 5.0E-8 M H_3O^+
   d. 3.0E-11 M H_3O^+
   e. 8.5E-6 M KOH