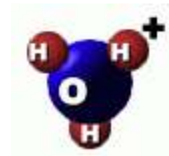
Ch. 17 Notes: ACIDS & BASES

NOTE: Vocabulary terms are in **<u>boldface and underlined</u>**. Supporting details are in *italics.*



I. Properties and Examples of Acids and Bases

A. **<u>Acids</u>** *produce hydrogen ions (H^+) when dissolved in water*
… more accurately, they produce **<u>hydronium ions = H_3O^+</u>**

1) properties: tart, sour, form electrolytic solutions of ions
2) examples: citric acid, vinegar, hydrochloric acid, sulfuric acid
3) *usually have H in front of the formula* or COOH at the end: HCl, CH_3COOH
4) turns litmus paper red
5) pH less than 7

B. **<u>Bases</u>** *produce hydroxide ions (OH^-) when dissolved in water*

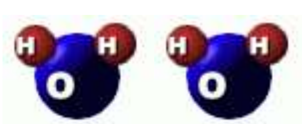
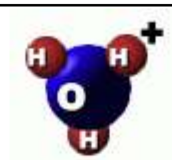
1) properties: bitter, slippery, form electrolytic solutions of ions
2) examples: lye/soap, ammonia, sodium hydroxide, other metal hydroxides
3) *usually have OH at the end of the formula*: KOH, NaOH, $Ca(OH)_2$
   - ammonia (NH_3) is a base, even though for formula doesn't look like one—it forms NH_4OH in water
4) turns litmus paper blue
5) pH greater than 7

C. *self-ionization of water:*

H_2O → H^+ + OH^-

WATER → HYDROGEN ION + HYDROXIDE ION

<u>2</u> H_2O → H_3O^+ + OH^-

2 WATER molecules → HYDRONIUM ION + HYDROXIDE ION

Source: www.worsleyschool.net/science/files/pH/page.html

II. Models of Acid-Base Behavior

A. Arrhenius model (Svante Arrhenius, 1859-1927)

1) *Arrhenius acids*
   a) *produce hydrogen ions (H^+) when dissolved in water*
   b) acidic hydrogen—hydrogen atoms that will be given up by acids as hydrogen ions

$$\boxed{\textbf{HA (aq)} \rightarrow \textbf{H}^+\textbf{ (aq)} + \textbf{A}^-\textbf{ (aq)}}$$

2) *Arrhenius bases—bases that produce hydroxide ions when dissolved in water*

$$\mathbf{BOH\ (aq) \rightarrow B^{+}\ (aq) + OH^{-}\ (aq)}$$

B. Brönsted-Lowry model (details – Chem 1H)
(Johannes Brönsted, 1879-1947) and (Thomas Lowry, 1843-1909)

1) *acid— hydrogen ion donor*
2) *base— hydrogen-ion acceptor*
3) *conjugate base— what the acid becomes after it donating hydrogen ion*
4) *conjugate acid – what the base becomes after accepting hydrogen ion*
5) *water can function as an acid or a base*
6) examples

EXAMPLE 1)

HF (aq)	+ H_2O (l) →	H_3O^+ (aq)	+ F^- (aq)
acid	base	conjugate acid	conjugate base

EXAMPLE 2)

NH_3 (aq)	+ H_2O (l) →	NH_4^+ (aq)	+ OH^- (aq)
base	acid	conjugate acid	conjugate base

C. "-protic" model

1) **<u>monoprotic acids</u>** donate 1 H^+ to the solution (HCl, HNO_3)

HCl (aq) → H^+ (aq) + Cl^- (aq)
HNO_3 (aq) → H^+ (aq) + $(NO_3)^-$ (aq)
$HC_2H_3O_2$ (aq) → H^+ (aq) + $(C_2H_3O_2)^-$ (aq)

2) **<u>diprotic acids</u>** donate 2 H^+ to the solution (H_2S, H_2SO_4)

H_2S(aq) → $\underline{2}$ H^+ (aq) + S^{2-} (aq)
H_2SO_4 (aq) → $\underline{2}$ H^+ (aq) + $(SO_4)^{2-}$ (aq)

3) **<u>triprotic acids</u>** donate 3 H^+ to the solution (H_3BO_3, H_3PO_4)

H_3BO_3 (aq) → $\underline{3}$ H^+ (aq) + $(BO_3)^{3-}$ (aq)
H_3PO_4 (aq) → $\underline{3}$ H^+ (aq) + $(PO_4)^{3-}$ (aq)

4) **<u>polyprotic acids</u>** donate more than 1 H^+ to the solution (di- or tri-protic)

D. Lewis model (Gilbert Lewis, 1875-1946) - (Chem 1H)

1) *Lewis acid— electron-pair acceptor*
2) *Lewis base— electron pair donor*

E. Anhydrides – (Chem 1H)

1) **<u>acidic anhydrides</u>**—*nonmetal oxides which react with water to form acids*

CO_2 + H_2O → H_2CO_3
SO_3 + H_2O → H_2SO_4

2) **<u>basic anhydrides</u>**—*metal oxides which react with water to form bases*

Na_2O + H_2O → $\underline{2}$ $NaOH$
ZnO + H_2O → $Zn(OH)_2$

III. Strengths of Acids and Bases

A. acid strength (see diagrams below and on the next page)

1) **strong acids**

a) *completely dissociate into ions*

b) *common examples: HCl, HNO_3, H_2SO_4*

2) **weak acids** *partially dissociate (not all come apart) into ions*

B. base strength

1) **strong bases**—*completely dissociate (come apart) into ions*

2) **weak bases** *partially dissociate (not all come apart) into ions*

C. strength vs. concentration

1) weak and strong refer to dissociation only

2) concentrated vs. dilute

a) amount of particles in the solution

b) **molarity**—(M); *a measure of solution concentration in mol/L*

3) application

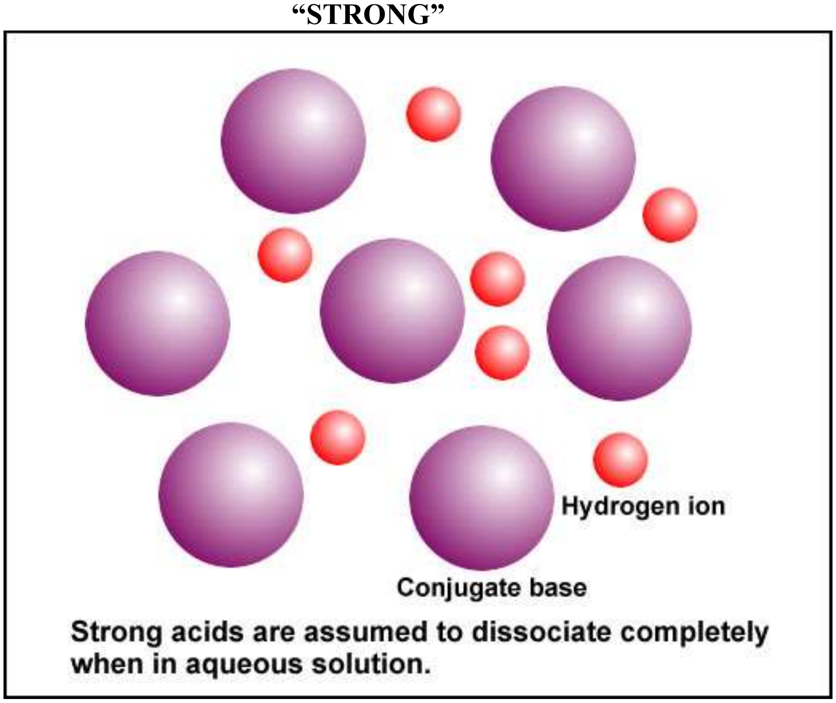
EXAMPLE 3)

SAMPLE 1: a 0.10 M solution of H_2SO_4 SAMPLE 2: a 1.00 M solution of HF

Which is more concentrated? (SAMPLE 2, because the molarity is higher)

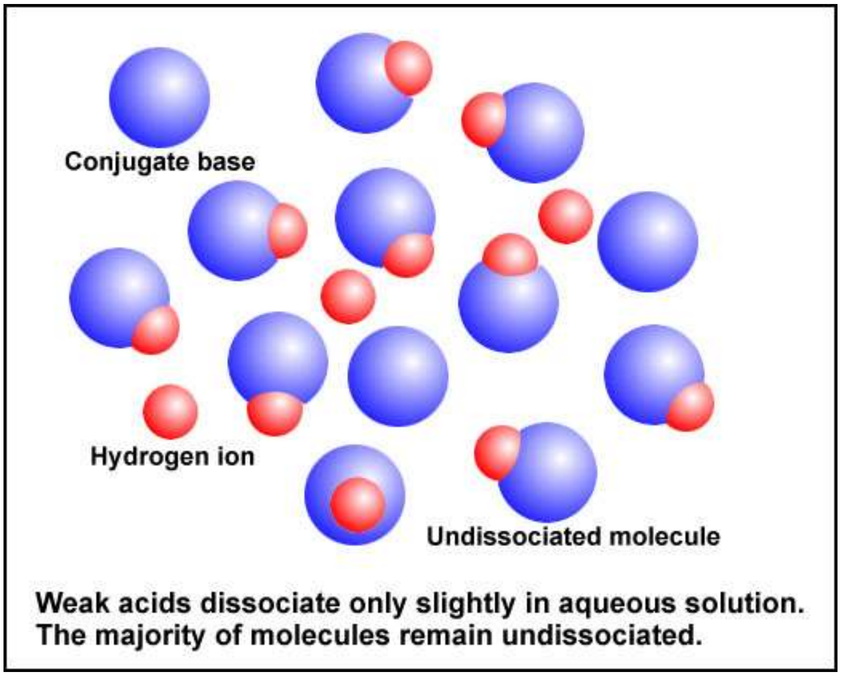
Which is the stronger acid? (SAMPLE 1 because H_2SO_4 is listed as a strong acid and HF isn't)

"STRONG"



Source: www.chem.ubc.ca/.../pH/section1/content.html

"WEAK"



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IV. pH (the power of Hydrogen)

A. neutrality of water

1) *Water is mostly neutral* $[H^+] = [OH^-]$

$[H^+] = 10^{-7}\ M$ *and* $[OH^-] = 10^{-7}\ M$

2) Ion product constant for water = K_w

$$\mathbf{K_w = [H^+]\,[OH^-] = 10^{-14}\ M}$$

3) Acidic solutions: $[H^+] > [OH^-]$

4) Basic (alkaline) solutions: $[OH^-] > [H^+]$

B. **<u>pH</u>** = the negative logarithm of the hydrogen ion concentration

$$\mathbf{pH = -\log\,[H^+]}$$

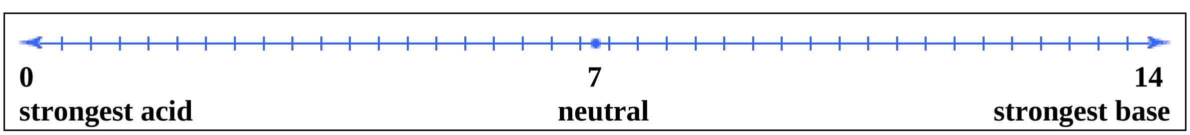
C. *pH is a measure of the acidity or basic quality (alkalinity) of a substance*

D. pH values

1) *acid pH < 7*

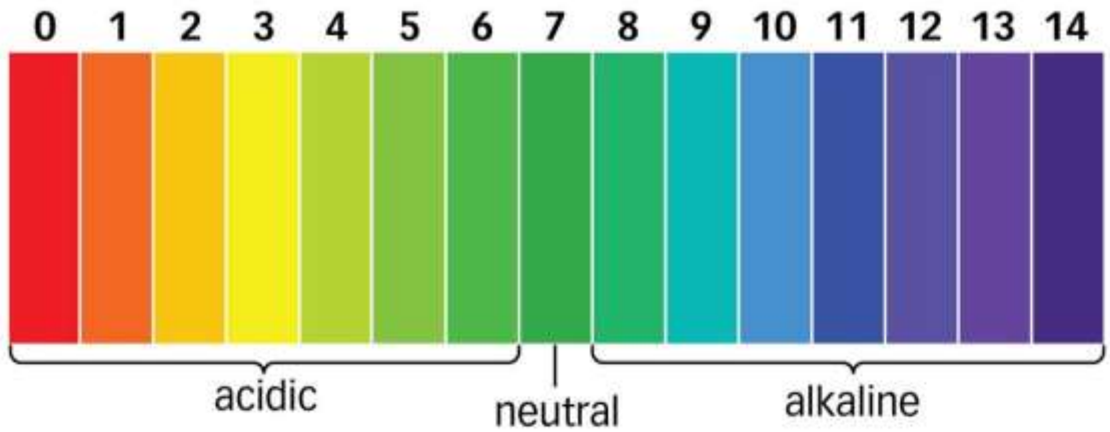
2) *base pH > 7*

3) **<u>neutral</u>** *pH = 7*



E. other important equations

$$\mathbf{pOH = -\log\,[OH^-]}$$
$$\mathbf{pH + pOH = 14.00}$$



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F. examples – pH problems without a calculator

EXAMPLE 4) If [H+] of a solution = 1.0×10^{-11} M…

a) Find pH. b) Find pOH. c) Find $[OH^-]$. d) Acid, base, or neutral?

a) $[H^+] = 1.0 \times 10^{-11}$ M so $\boxed{pH = 11}$

b) $pH + pOH = 14$ $11 + pOH = 14$ $\boxed{pOH = 3}$

c) $[H^+]\,[OH^-] = 10^{-14}$ M $[10^{-11}]\,[OH^-] = 10^{-14}$ M $\boxed{[OH^-] = 10^{-3}\text{ M}}$

d) base (pH = 11)

EXAMPLE 5) If $[OH^-]$ of a solution = 1.0×10^{-9} M…

a) Find pOH. b) Find pH. c) Find $[H^+]$. d) Acid, base, or neutral?

a) $[OH^-] = 1.0 \times 10^{-9}$ M so $\boxed{pOH = 9}$

b) $pH + pOH = 14$ $pH + 9 = 14$ $\boxed{pH = 5}$

c) $[H^+]\,[OH^-] = 10^{-14}$ M $[H^+]\,[10^{-9}] = 10^{-14}$ M $\boxed{[H^+] = 10^{-5}\text{ M}}$

d) acid (pH = 5)

G. examples – pH problems with a calculator (Chem 1H)

*** About antilog – some calculators have the 10^x key. You are responsible for knowing how to use your calculator and our classroom calculators. ***

EXAMPLE 6) If [H+] of a solution = 4.98×10^{-11} M…

a) Find pH. b) Find pOH. c) Find $[OH^-]$. d) Acid, base, or neutral?

a) $pH = -\log[H^+]$ $-\log[4.98 \times 10^{-11}] =$ $\boxed{pH = 10.3}$

b) $pH + pOH = 14.00$ $10.3 + pOH = 14.00$ $\boxed{pOH = 3.7}$

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

$3.7 = -\log[OH^-]$ antilog $-3.7 = [OH^-] = 0.00019952 =$ $\boxed{2.0 \times 10^{-4}\text{ M} = [OH^-]}$

d) base (pH = 10.3)

EXAMPLE 7) If pOH of a solution = 8.39…

a) Find pH. b) Find $[H^+]$. c) Find $[OH^-]$. d) Acid, base, or neutral?

a) pH + pOH = 14.00 pH + 8.39 = 14.00 $\boxed{pH = 5.61}$

b) pH = -log $[H^+]$

5.61 = -log$[H^+]$ antilog -5.61 = $[H^+]$ $\boxed{2.45 \times 10^{-6}\ M = [H^+]}$

c) pOH = -log$[OH^-]$

8.39 = -log$[OH^-]$ antilog -8.39 = $[OH^-]$ $\boxed{4.07 \times 10^{-9}\ M = [OH^-]}$

d) acid (pH = 5.61)

V. Neutralization reactions

ACID + BASE → WATER + SALT

A. **<u>neutralization</u>**—when acid and base "cancel each other out"

B. *acid-base neutralization net ionic equation*: $\mathbf{H^+ + OH^- \rightarrow H_2O}$

C. common acids

1) **hydrochloric acid = HCl**
2) **acetic acid = $HC_2H_3O_2$ or CH_3COOH**
3) **nitric acid = HNO_3**
4) **sulfuric acid = H_2SO_4**
5) **phosphoric acid = H_3PO_4**
6) **carbonic acid = H_2CO_3**

D. acid naming rules for acids (Chem 1H):

1) *naming binary acids, ending in -IDE:* *hydro-STEM-ic acid*
(HBr = hydrobromic acid)
2) *naming oxyacids with an anion ending in –ATE:* *STEM-ic acid*
($HClO_3$ = chloric acid)
3) *naming oxyacids with an anion ending in –ITE:* *STEM-ous acid*
(H_2SO_3 = sulfurous acid)

NOTE: (STEM is the element name, other than H or O)

E. classic *double displacement reactions* **AB + CD → AD + CB**

1) You will have to write and balance these double displacement reactions.
2) If the formula is not provided, you must "crisscross" to get it.
3) Remember, to get the products, you must "un-crisscross" and "re-crisscross" the reactant ions.
4) If you have trouble balancing, keep water as H(OH) to make it easier.
5) Practice naming the salt that is formed.

EXAMPLE 8)

hydrochloric acid + strontium hydroxide → _____ + _____

$H^+\ Cl^-$		$Sr^{2+}\ (OH)^-$		$H^+\ (OH)^-$		$Sr^{2+}\ Cl^-$
A B	+	C D	→	A D	+	C B
Acid	+	Base	→	Water	+	Salt
<u>2</u> HCl	+	$Sr(OH)_2$	→	<u>2</u> H_2O	+	$SrCl_2$

salt = strontium chloride

EXAMPLE 9)

phosphoric acid + magnesium hydroxide → _______ + _______

H^+ $(PO_4)^{3-}$		Mg^{2+} $(OH)^-$		H^+ $(OH)^-$		Mg^{2+} $(PO_4)^{3-}$
A B	+	C D	→	A D	+	C B
H_3PO_4	+	$Mg(OH)_2$	→	H_2O	+	$Mg_3(PO_4)_2$
<u>2</u> H_3PO_4	+	<u>3</u> $Mg(OH)_2$	→	<u>6</u> H_2O	+	$Mg_3(PO_4)_2$

salt = magnesium phosphate

VI. Titration

A. **<u>titration</u>**—*adding a specific amount of a solution of known concentration to a solution of unknown concentration, to calculate the molarity (M) of the unknown solution*

B. **<u>(titrant)</u>** –*standard solution*—the solution of known concentration

C. **<u>equivalence point</u>** of the titration: when *(mol H^+) = (mol OH^-)*

D. **<u>end point</u>** = *the point in the titration when the indicator changes color*

E. **<u>indicator</u>**

a) *a dye which is a different color in an acid vs. a base*

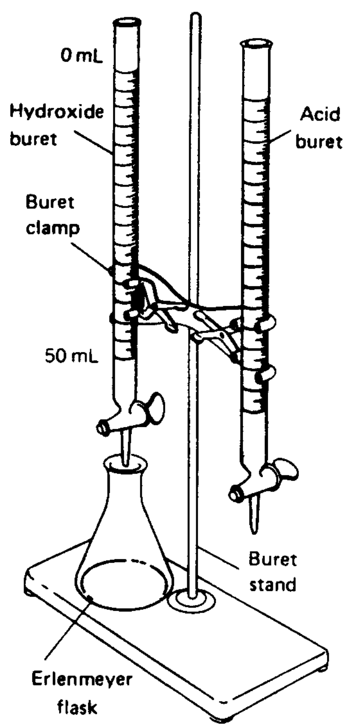
b) bromothymol blue = yellow in acid, blue in base

c) phenolphthalein (PHTH) = clear in acid, "funky fuchsia" in base

d) other indicator dyes: methyl red, crystal violet, Orange IV…

F. $M_AV_A = M_BV_B$ (M = molarity, V = volume)

TITRATION LAB SETUP



VII. Salt hydrolysis (Chem 1H)

A. Not all salt solutions are neutral!
B. *neutral (normal) salts*… H^+ ions are completely replaced in the rxn.
C. **salt hydrolysis**—*when salts produce acidic or basic solutions in water*
D. *salts produce acidic solutions when the cations from the base will donate H^+ to the solution*
E. salts producing basic solutions when *the anions from the acid will accept H^+ ions from the solution*

Acid	Base	Salt	Example
Strong	Strong	Neutral	$NaOH + HCl \rightarrow NaCl + H_2O$
Strong	Weak	Acidic	$HCl + NH_4OH \rightarrow NH_4Cl + H_2O$
Weak	Strong	Basic	$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
Weak	Weak	Neutral	$CH_3COOH + NH_4OH \rightarrow CH_3COONH_4 + H_2O$

Source: ncerthelp

VIII. Buffered solutions

A. **Buffers**
   1) *solutions resistant to pH changes when small amounts of acid or base are added*
   2) *a mixture of a weak acid and its conjugate base OR a weak base and its conjugate acid*
   3) works best with nearly equal concentrations of the acid or base and its conjugate base or acid
B. buffers work according to LeChatlier's principle
C. **buffering capacity**—*the amount of acid or base that a solution can absorb without a significant change in pH*