Chapter 7 Acids and Bases

Big Idea: A Bronsted-Lowry acid is a proton donor and a Bronsted-Lowry base is a proton acceptor. After an acid/base loses/gains its proton it becomes a conjugate base/acid. Acids and bases can either completely dissociate (strong) or incompletely dissociate (weak). An equilibrium problem must be set up to solve for the pH of a weak acid or base.

- Acids and Bases
- Conjugate Acids/Bases
- Strength of Acids/Bases
- pH/pOH Scales
- pH/pOH of Strong Acids/Bases
- pH/pOH of Weak Acids/Bases
- Acid/Base Properties of Salts
- Acid Rain

Acids and Bases

Acid

- Sour taste (lemon citric acid)
- Dissolve many metals
  (Acid(aq) + metal(s) → salt(aq) + H_2(g))
- Turn litmus paper red

Base

- Bitter taste (unsweetened baker's chocolate)
- Slippery feel (cleaning products)
- Turn litmus paper blue

Acids and Bases

Arrhenius (1884)

- **Acid:** A compound that forms hydrogen ions (H^+) in water.

Examples:
- $HCl(aq)$ acid
- $CH_4(aq)$ not an acid because it does not release (H^+) ions in solution

- **Base:** A compound that forms hydroxide ions (OH^-) in water.

Examples:
- $NaOH(aq)$ base
- NH_3 base because $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

Bronsted-Lowry (1923)

- **Acid:** A proton donor.
- **Base:** A proton acceptor.

Poem –W24

"Equilibrium for funsies"

Today we'll learn a bit about chemistry
That's right, all the tricks that are part of the registry

And while we'll focus on chapter six
We have all the solutions, yes, it's a mix.

Chemical equilibrium, it's a difficult concept
But fear not, for we have a bright prospect

The equilibrium constant, our beloved K
To figure it out there's always a way

At 8 am on a chilly day,
Professor Feldwinn will always say:

You followed all steps, plugged it into the expression
Now there are three ways to solve this hard question,

First, you can try the "guess and check"
Though that will probably break your neck

Then try the quadratic formula with a smile on your face,
But beware, you'll use up notebook space

Finally you can try the method of the assumption
This is the best in terms of time consumption

And this is how you calculate equilibrium concentration and pressure
Hopefully after this, you'll feel a bit fresher.

- ~ Valeria

Acids and Bases

- **Deprotonation:** The loss of a proton from a Bronsted-Lowry acid.

Note: First deprontination is the loss of the first H, the second deprotination is the loss of a second H, and the third deprotination is the loss of a third H.

- **Amphoteric:** A substance that can act as an acid or base.

Example:

- H_2O

Conjugate Acids/Bases

- **Conjugate Acid Base Pair:** Two substances that are related to each other by the transfer of <u>one</u> proton

$$Acid \xrightarrow{donates\ a\ proton} Conjugate\ Base$$

$$Base \xrightarrow{accepts\ a\ proton} Conjugate\ Acid$$

Conjugate Acids/Bases

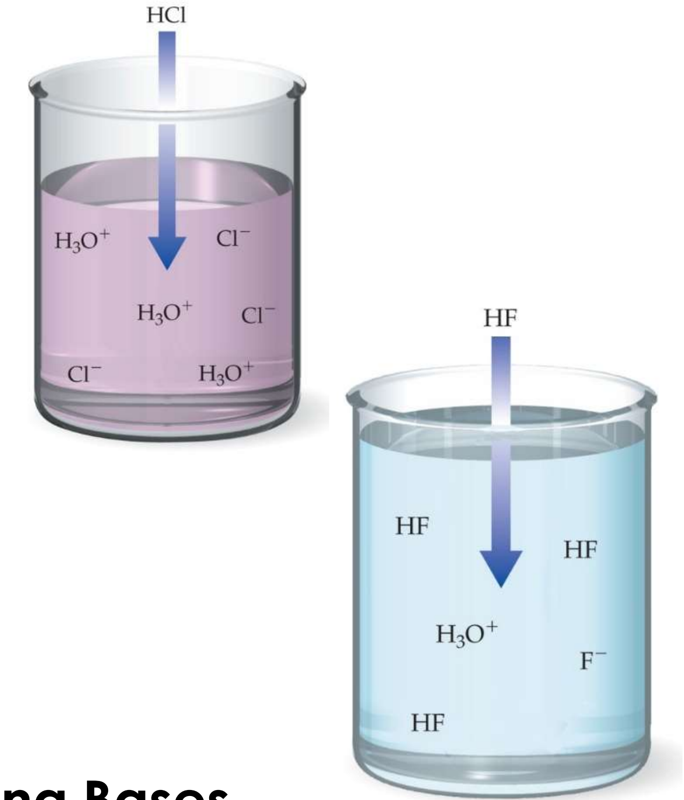
Student Question

Which of the following represent conjugate acid-base pairs? For those pairs that are not conjugates, write the correct conjugate acid or base for each species in the pair.

a) H_2SO_4 and SO_4^{2-}
b) $H_2PO_4^-$ and HPO_4^{2-}
c) $HClO_4$ and Cl^-
d) NH_4^+ and NH_2^-

Strength of Acids/Bases

- **Strong Acid or Base:** An acid/base that completely ionizes in solution.
- **Weak Acid or Base:** An acid/base that does not completely ionize in solution.



Strong Acids		**Strong Bases**	
HCl	HNO_3	LiOH	$Sr(OH)_2$
HBr	$HClO_4$	NaOH	$Ca(OH)_2$
HI	$HClO_3$	KOH	$Ba(OH)_2$
$HBrO_3$	$HBrO_4$	RbOH	$Mg(OH)_2$
H_2SO_4	HIO_4	CsOH	

Strength of Acids/Bases

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

Note: A strong acid is defined as an acid that has a K_a larger than 1. Not all strong acids have the same K_a. For example the K_a of H_3O^+ is 55, whereas the K_a of HCl is 1×10^6. Therefore, H_3O^+ is one of the weakest strong acids.

Strength of Acids/Bases

Name	Formula	K_b
Ammonia	NH_3	1.8×10^{-5}
Methylamine	CH_3NH_2	4.38×10^{-4}
Ethylamine	$C_2H_5NH_2$	5.6×10^{-4}
Aniline	$C_6H_5NH_2$	3.8×10^{-10}
Pyridine	C_5H_5N	1.7×10^{-9}

Note: The stronger the base, the larger the K_b.

Strength of Acids/Bases

Student Question

The K_a values for HPO_4^{2-} and HSO_3^- are 4.8×10^{-13} and 6.3×10^{-8} respectively. Therefore, it follows that HPO_4^{2-} is a _____ acid than HSO_3^- and PO_4^{3-} is a _____ base than SO_3^{2-}.

a) weaker, weaker
b) weaker, stronger
c) stronger, weaker
d) stronger, stronger

Strength of Acids/Bases

Is there a relationship between K_a and K_b?

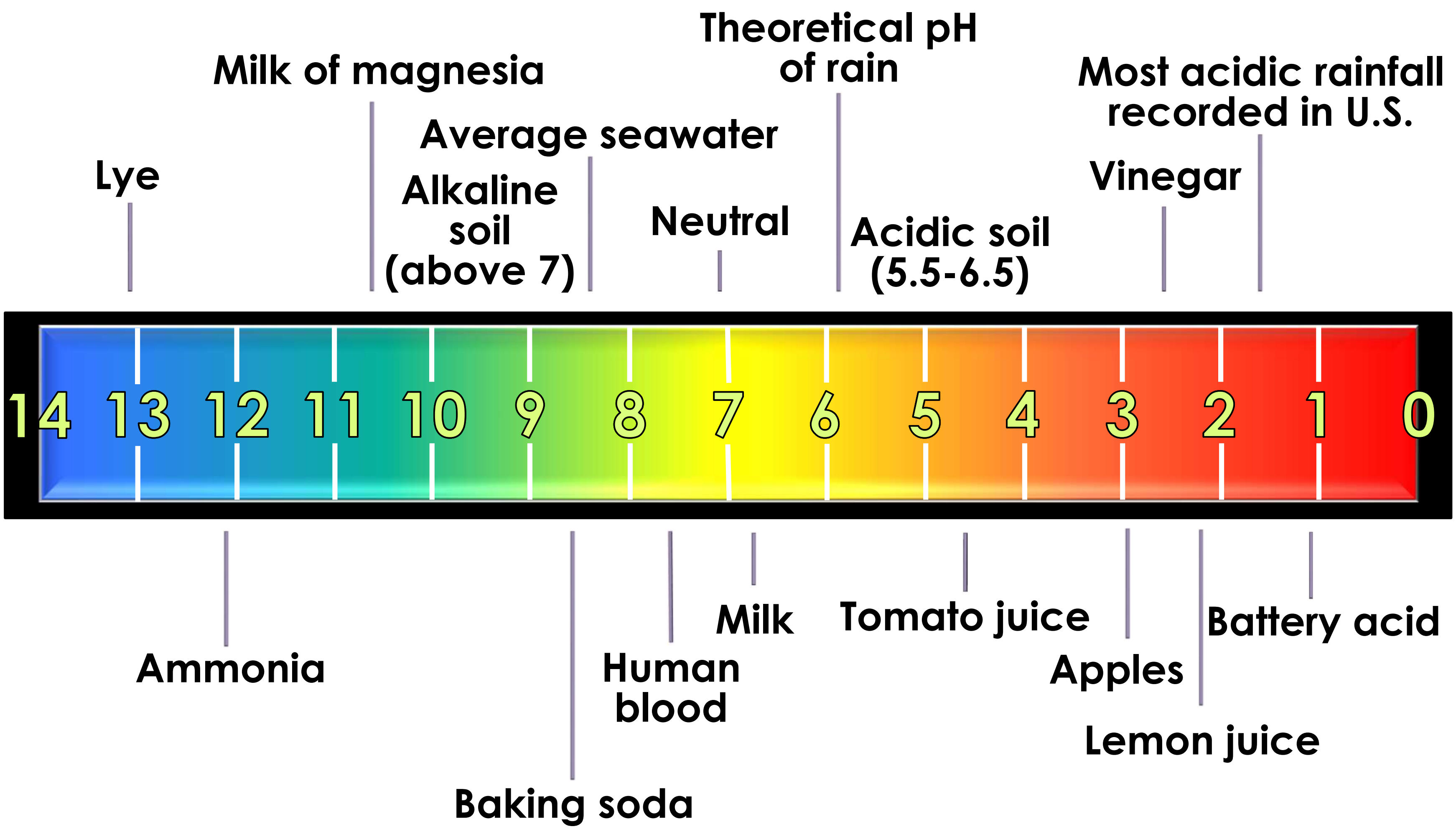
- General Weak Acid Equilibrium Equation
  - $HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$
  - $K_a = \frac{[H^+][A^-]}{[HA]}$
- General Weak Base Equilibrium Equation
  - $B(aq) + H_2O(l) \rightleftharpoons BH^+(aq) + OH^-(aq)$
  - $K_b = \frac{[BH^+][OH^-]}{[B]}$
- Water Equilibrium Equation
  - $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
  - $K_W = [H^+][OH^-] = 1.0 \times 10^{-14}$

Note: K_W is known as the ion product constant.

pH/pOH Scale

- How do you tell if a solution acidic, basic, or neutral?
  - $[H^+] = [OH^-]$ neutral
  - $[H^+] > [OH^-]$ acidic
  - $[H^+] < [OH^-]$ basic
- Are the $[H^+]$ and $[OH^-]$ related?
  - $K_W = [H^+][OH^-] = 1.0 \times 10^{-14}$
    - For neutral solutions $[H^+] = [OH^-] = 1.0 \times 10^{-7}$
    - $[H^+] > 1.0\times10^{-7}$ and $[OH^-] < 1.0\times10^{-7}$ acidic
    - $[H^+] < 1.0\times10^{-7}$ and $[OH^-] > 1.0\times10^{-7}$ basic
- How do you calculate pH?
  - $pH=-\log[H^+]$
    - pH = 7 neutral
    - pH < 7 acidic
    - pH > 7 basic

pH/pOH Scale


Theoretical pH of rain
Milk of magnesia
Most acidic rainfall recorded in U.S.
Average seawater
Lye
Alkaline soil (above 7)
Vinegar
Neutral
Acidic soil (5.5-6.5)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Milk
Tomato juice
Battery acid
Ammonia
Human blood
Apples
Lemon juice
Baking soda

pH/pOH of Strong Acids/Bases

Student Question

Calculate the pH of 0.25 M barium hydroxide.

a) 0.60
b) 13.10
c) 13.40
d) 13.70
e) None of the above

pH/pOH of Weak Acids/Bases

Student Question

What is the pH of a 0.18 M base solution whose conjugate acid has a $K_a = 2.8 \times 10^{-8}$?

a) 3.59
b) 9.85
c) 10.40
d) 13.25
e) None of the above

Acid/Base Properties of Salts

Student Question

Is $NH_4C_2H_3O_2$:

Helpful Information: K_b $NH_3 = 1.8\times10^{-5}$ *and* K_a $HC_2H_3O_2 = 1.8\times10^{-5}$

a) Acid
b) Base
c) Neutral
d) More information needed

Acid Rain

- pH water ~7,
- pH of unpolluted rain ~5.7
- pH of rain in industrial areas has been recorded at ~2.4

Acid Rain

- What are the natural causes of acids in rain?

Source	Causes
CO_2	Decomposition/Respiration/Fires
NO	Electrical Discharge
SO_2	Volcanic Gases

- What are the man made causes of acids in rain?

Source	Causes
CO_2	Fossil Fuel Combustion/Fires
NO	High Temperature Air Combustion
SO_2	Fossil Fuel Combustion

Acid Rain

CO_2 (produced from the combustion of C or C_xH_y)

- Coal $C(s) + O_2(g) \rightarrow CO_2(g)$
- Gas $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
- $CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$

NO (formed from N at high temperatures)

- $N_2(g) + O_2(g) \xrightarrow{\text{heat}} 2NO(g)$
- $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
- $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$

Note: The majority of the NO emissions come from automobiles.

Acid Rain

SO_2 (formed from the combustion of S)

- $S(s) + O_2(g) \rightarrow SO_2(g)$
- $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
- $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

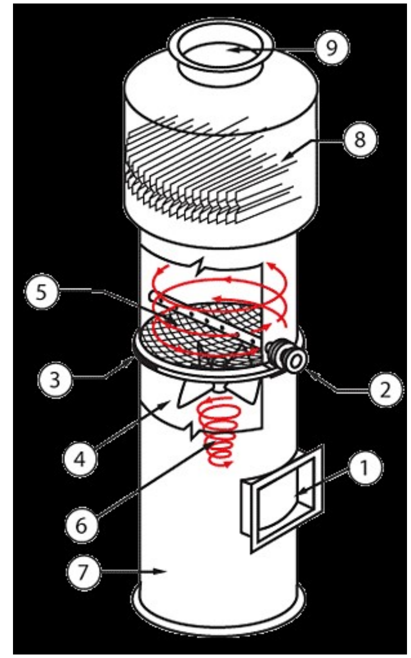
Note: The majority of all SO_2 emissions come from the production of electricity.

Note: Why are we more worried about controlling SO_2 and NO emissions for acid rain?

Acid Rain

NO

- Three Way Catalytic converters (1981)
- $2NO(g) \xrightarrow{Pt\ or\ Rh} N_2(g) + O_2(g)$



SO_2

- Scrubbers (in the 1990)
- (limestone slurries are put into the smoke stacks)
- $CaCO_3(s) + H_2SO_4(aq) \rightarrow CaSO_4(aq) + H_2O(l) + CO_2(g)$

Note: Acid rain level have dropped 65% since 1976.

Take Away From Chapter 7

Big Idea: A Bronsted-Lowery acid is a proton donor and a Bronsted-Lowery base is a proton acceptor. After an acid/base loses/gains its proton it becomes a conjugate base/acid. Acids and bases can either completely dissociate (strong) or incompletely dissociate (weak). An equilibrium problem must be set up to solve for the pH of a weak acid or base.

- **Acids and Bases**
  - Know the different acid/base definitions.
    - Arrhenius
      - Acid: Forms H^+ in water
      - Base: Forms OH^- in water
    - Bronsted-Lowery
      - Acid: Proton donor
      - Base: Proton acceptor

Numbers correspond to end of chapter questions.

Take Away From Chapter 7

- **Conjugate Acids/Bases** (20)
  - Be able to recognize conjugate acid base pairs.
    - Pairs that differ by 1 hydrogen atom (H_3PO_4 and $H_2PO_4^-$).
- **Strength of Acids/Bases**
  - Memorize the strong acids and bases. (24,33)
    - Strong Acids: HCl, HBr, HI, HNO_3, $HBrO_3$, $HBrO_4$, HIO_4 $HClO_4$, $HClO_3$, and H_2SO_4 (1st deprotonation)
    - Strong Bases: LiOH, NaOH, KOH, RbOH, CsOH, $Sr(OH)_2$, $Ca(OH)_2$, $Ba(OH)_2$, and $Mg(OH)_2$
  - Know the relationship between $[H^+]$ and $[OH^-]$ (40,41)
    - $[H^+][OH^-]=1.0\times10^{-14}$
  - Be able to change between K_a and K_b values.
    - $K_a = \frac{K_w}{K_b}$
    - $K_b = \frac{K_w}{K_a}$
  - Know that the stronger the acid/base the weaker the conjugate acid/base. (31)
    - Be able to order acids/bases in increasing strength using K_a and/or K_b values (27,28,29,30,69,70)

Numbers correspond to end of chapter questions.

Take Away From Chapter 7

- **pH/pOH Scale** (74,75)
  - Be able to calculate the pH of a solution.
    - $pH = -log[H^+]$
  - Be able to calculate the pOH of a solution.
    - $pOH = -log[OH^-]$
  - Be able to convert between pH and pOH
    - $14 = pH + pOH$
- **pH/pOH of Strong Acids/Bases**
  - Be able to calculate the pH and pOH of strong acids and strong bases.
- **pH/pOH of Weak Acids/Bases** (79)
  - Be able to identify the major species in solution. (51)
  - Be able to calculate the pH and pOH of weak acids and bases (ICE table). (47,48,49,52,53,55,61,65)
  - Be able to calculate the water solubility of a substance given the pH of a saturated solution. (56)

Numbers correspond to end of chapter questions.

Take Away From Chapter 7

- **Acid/Base Properties of Salts** (101,103,105,109,131)
  - Be able to determine if a salt is an acidic, basic, or neutral
  - Be able to calculate the pH of a salt with only one acid/base cation/anion
- **Acid Rain**

Numbers correspond to end of chapter questions.