Conjugate acids and bases

Different definitions of acids and bases

- Arrhenius definition
- acids generate H_3O^+ in water
- bases generate OH^- in water
- Brønsted Lowry definition
- Acids are proton donors
- Bases are proton acceptors
- which is an acid/base?
- $HF + H_2O \rightleftharpoons H_3O^+ + F^-$
- $CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$
- By Arrhenius, HF is an acid, is a CH_3NH_2 base.

Follow the proton

- $HF + H_2O \rightleftharpoons H_3O^+ + F^-$

H^+ H^+

- $CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$

H^+ H^+

- What about the reverse reaction?

Conjugate acids and bases

- When you run the reverse reaction you find the products are also acids and bases. The acids and bases that are formed are called ***conjugate acids or bases***
- H_2O + **HF** $\rightleftharpoons$ H_3O^+ + **F^-**
  - base acid conjugate acid conjugate base
- CH_3NH_2 + **H_2O** $\rightleftharpoons$ $CH_3NH_3^+$ + **OH^-**
  - base acid CA CB

Label Acid, Base, Conjugate Acid, Conjugate Base

- $HClO_3 + H_2O \rightleftharpoons ClO_3^- + H_3O^+$
-
- $ClO^- + H_2O \rightleftharpoons HClO + OH^-$
- $HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$
- $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
-

Label Acid, Base, Conjugate Acid, Conjugate Base

- $HClO_3 + H_2O \rightleftharpoons ClO_3^- + H_3O^+$
- A B CB CA
- $ClO^- + H_2O \rightleftharpoons HClO + OH^-$
- B A CA CB
- $HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$
- A B CB CA
- $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
- B A CA CB

Conjugate acids and bases ...

- Conjugate acids and bases determine if an acid or base is strong or weak.
- If the conjugate acid/base readily reacts to run the reverse reaction it is a weak acid/base.
- If it does <u>not</u> react in the reverse reaction the acid or base is strong.

More with conjugate acids/bases

- $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$
- Sulfuric acid is a **strong** acid so its conjugate <u>base</u>, HSO_4^-, will <u>not</u> run the reverse reaction.
- HSO_4^- is actually an acid in water.
- $HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$
- SO_4^{2-} will run the reverse reaction, so it is a ***weak*** acid

Strong acids and bases

- The strong acids and bases have no reverse reaction.
- They are not an equilibrium reaction.
- $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
- No amount of stress will force this reaction the other way.
- (no way to make it less acidic, without a different reaction)

Strong acids

Acid	formula	Acid	Formula
Hydrochloric acid	HCl	Sulfuric Acid	H_2SO_4
Hydrobromic acid	HBr	Nitric Acid	HNO_3
Hydriodic acid	HI	Perchloric Acid	$HClO_4$

You need to know the ones in red

Strong bases

- All of group 1 and group 2 elements make strong bases.
- However, most of them are not very soluble.
- For example, $Mg(OH)_2$ is a saturated solution at 1.6×10^{-4} M

Commonly used Strong Bases

these make a lightning bolt on the periodic table!

Name	Formula	Name	Formula
Sodium Hydroxide	NaOH	Calcium Hydroxide	$Ca(OH)_2$
Potassium Hydroxide	KOH	Strontium Hydroxide	$Sr(OH)_2$
		Barium Hydroxide	$Ba(OH)_2$

You need to know the ones in red

Weak acids and bases

- can be forced the other way
- So ammonia…
- $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
- Ammonia is a gas with a distinct odor
- Ammonium and hydroxide are both odorless.
- If base is added to the solution you will smell ammonia, if hydroxide is removed you won't smell anything.

Pet "Stain" Problem

Urine has ammonia in it.

Most cleansers are basic.

After cleaning, we still leaves small amounts behind.

If it is small amount of ammonia and a basic cleanser the equilibrium will be shifted to the ammonia side so something with a great sense of smell (dog) could pick it up.

A slightly acidic cleanser shifts the equilibrium to the ammonium side to solve this problem

Other weak acids and bases

- Weak Acids
  - Acetic Acid (vinegar)
  - Citric Acid
  - Ascorbic Acid (vitamin C)
  - Boric Acid
  - Carbonic Acid
- Weak Bases
  - Sodium Bicarbonate
  - Ammonia
  - Sodium Hypochlorite (bleach)

Indicators

- Indicators are a substance that change color in the presence of (whatever they check for)
- They work because of Le Châtelier's principle. All you need an equilibrium reaction with different colored products and reactants.
- The pen used to check for counterfeit money is a starch indicator

How an acid base indicator works

- A generic indicator will follow this reaction, **HID** is the reactant indicator, and ID^- is its product are in an equilibrium
- **HID** + $H_2O \rightleftharpoons H_3O^+ + ID^-$
- The color differences are important, **HID** is one color and ID^- is a different color! This makes it so we can see a shift in the equilibrium!
- In an acidic solution, (The stress will be increasing H_3O^+) it shifts left so you see reactant indicator color

How an acid base indicator works in an

- Acidic solution

	HID	$+ H_2O \rightleftharpoons$	H_3O^+	$+ ID^-$
Stress			+S	
Shift	+x	+x	-x	-x
Final	↑	↑	↑	↓

- What this means…
- **HID** + $H_2O \rightleftharpoons H_3O^+ + ID^-$
- Lots of **HID** means I will see its color, and small amounts ID^- of means I won't see it any of its color in the solution

How an acid base indicator works in a

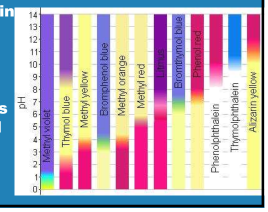
- basic solution
- OH^- will react with H_3O^+ decreasing it
- HID + H_2O ⇌ H_3O^+ + ID^-
- Stress -S
- Shift -x -x +x +x
- Final ↓ ↓ ↓ ↑
- What this means…
- instead we shift right
- HID + H_2O ⇌ H_3O^+ + ID^-
- Lots of ID^- means I will see its color, and small amounts HID of means I won't see it any of its color in the solution

Acid Base indicators

- Acid base indicators change color at certain pH levels
- They don't have to change at 7 (most don't)
- Universal indicator solution (phenolphthalein, bromthymol blue and methyl red dissolved in ethanol and water) changes color at each integral pH value

Other pH indicators

- Litmus and phenolphthalein are indicators
- Red cabbage juice has a pigment that changes colors at different pH values



Buffers

- Buffers are solutions that resist a change in pH when acids or bases are added.
- They use weak acids/bases and Le Châtelier's principle.
- They have a large amount of weak acid and conjugate base compared to H_3O^+
- WA = weak acid
- HWA + H_2O ⇌ H_3O^+ + WA^-

pH

- pH depends on the concentration of hydronium, H_3O^+
- HWA + H_2O ⇌ H_3O^+ + WA^-
- Normal concentrations for a buffer would be around 1 M for HWA, 1 M WA^-, and $1x10^{-4}$ M H_3O^+
- That's is 10,000x more HWA and WA^- than H_3O^+

What it does

- HWA + H_2O ⇌ H_3O^+ + WA^-
- So adding more H_3O^+ forces the equation to SHIFT the left, by speeding up the reverse reaction.
- The additional H_3O^+ will readily react with the excess conjugate base, WA^-
- However, it can't make that much more weak acid, HWA, because it was already 10,000x greater

Buffer

- $HWA_{(aq)}$ + $H_2O_{(l)}$ ⇌ $H_3O^+_{(aq)}$ + $WA^-_{(aq)}$
- 1M $1x10^{-4}$ 1M
- S +S
- S +x +x -x -x
- $K = \frac{[H_3O^+][WA^-]}{[HWA]}$
- $K = 1x10^{-4}$
- If the stress were to double the $[H_3O^+]$…

Buffer

- Then the Q would be 2K or $2x10^{-4}$
- K<Q, the reaction shifts left
- The shift value (x) won't quite be $1x10^{-4}$ (equal to S), but it will be just slightly less ($0.9998x10^{-4}$M)
- So almost all of the added hydronium shifts and pH doesn't change.

What it does in a base

- Everything is the same, but in reverse.
- Adding OH^- is the same as removing H_3O^+ which forces the equation to SHIFT to the right
- The new hydroxide will react with the excess weak acid, speeding up the forward reaction
- Which replaces the H_3O^+ that was removed.

Buffer

- $HWA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + WA^-_{(aq)}$
- 1M $\qquad$ 1×10^{-4} $\qquad$ 1M

S $\qquad$ -S

S $\quad$ -x $\quad$ -x $\quad$ +x $\quad$ +x

- $K = \dfrac{[H_3O^+][WA^-]}{[HWA]}$
- $K = 1\times10^{-4}$
- If the stress was equal to the $[H_3O^+]$... (but now removing)

Buffer

- Then the Q would be 0 or
- K>Q, the reaction shifts right
- The shift value (x) won't quite be 1×10^{-4} (equal to S), but it will be just slightly less (0.9998×10^{-4}M)
- So almost all of the added hydroxide shifts to replace almost all of the hydronium and pH doesn't change.

Buffer capacity

- There is a breaking point where buffers can no longer resist changes in pH, called the buffer capacity.
- However, the acid or base added need to significantly change the ratio of [HWA] / $[WA^-]$ to reach the buffer capacity.

What does this have to do with my life?

- Your blood is a buffered solution
- The pH must remain between 7.35-7.45
- Outside of that range can kill you
- below this range is called acidosis
- above is called alkalosis