Acids and Bases

Chapter 14

Acid Base Equations

General Form of Dissociation

- Acid
- $HA \rightarrow H^+ + A^-$ or
- $H_2O + A \rightarrow H^+ + AOH^-$
- Base
- $BOH \rightarrow B^+ + OH^-$ or
- $H_2O + B \rightarrow BH^+ + OH^-$
- Strong acids/bases will have a $\rightarrow$, weak acids/bases will have a $\rightleftharpoons$

Some weak acids and bases

Acids	Bases
Carbonic acid	Carbonate
Acetic acid	Acetate
Ammonium	Ammonia
	triethylamine
$(CH_3CH_2)_3NH^+$	$(CH_3CH_2)_3N$

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	$HClO_4$
		Chloric Acid	$HClO_3$

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	$Sr(OH)_2$
All group 1 metals		Barium Hydroxide	$Ba(OH)_2$

Strong acids and bases

- Strong acids and bases are not at equilibrium, there is no reverse reaction.
- Strong acids and bases will **never** be formed in a net ionic equation.
- Adding strong acid or base normally means you will have H^+ or OH^- as a reactant, the rest is a spectator ion.
- All other acids/bases can be formed by reacting the conjugate ion with a strong acid/base.

Weak + Strong reaction

- Reacting an acid with a base will produce water.
- $HCl + NaOH \rightarrow H_2O + NaCl$
- Reacting a **weak** acid with a **strong** base will produce water and conjugate base.
- Sodium hydroxide and carbonic acid
- $H_2CO_3 + OH^- \rightarrow H_2O + HCO_3^-$
- Reacting a weak base with a strong acid will produce conjugate acid.
- Nitric acid and ammonia
- $NH_3 + H^+ \rightarrow NH_4^+$

Examples

- Calcium hydroxide reacts with chlorous acid
- Acetic acid reacts with potassium hydroxide
- Hydrochloric acid reacts with calcium nitrite
- Nitric acid reacts with sodium chlorite
- Hydroiodic acid reacts with sodium hydroxide

Acids and Bases

- Water is the product of all neutralization reactions between an acid and a base
- $H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$
- **The Arrhenius Definitions**.
- An *acid* contains H and forms H^+ (proton)
- When that H^+ is donated to H_2O it forms H_3O^+ (hydronium).
- A *base* contains OH and forms OH^- (hydroxide).

Brønsted-Lowery

- The **Brønsted-Lowery definitions**, the proton transfer:
- An *acid* is a proton (H^+) donor.
- A *base* is a proton (H^+) acceptor.
- which is an acid/base?
- $HF + H_2O \rightleftharpoons H_3O^+ + F^-$
- $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

Follow the proton

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

  H^+ H^+
- $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

  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 <u>*conjugate acids or bases*</u>
- $H_2O + HF \rightleftharpoons H_3O^+ + F^-$
- base acid conjugate acid conjugate base
- $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
- base acid CA CB

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
- $AgOH + H_2O \rightleftharpoons Ag^+ + H_2O + OH^-$
- B A CA CB

Ammonia Smell

- $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
- Ammonia is a gas with a distinct odor
- Ammonium and hydroxide are both odorless.
- What will happen if you add an acid or a base to this equilibrium?
- If base is added to the solution the equilibrium will shift to the left so you will smell ammonia, if hydroxide is removed (acid is added), it will shift to the right to so you won't smell anything.

Pet "Stain" Problem

- Urine has ammonia in it.
- Most cleansers are basic.
- After cleaning, we still leave small amounts behind.
- If it is small amount of ammonia and a basic cleanser the equilibrium will be shifted to the ammonia side so some thing 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

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.**

Acid Equilibrium constant

- For some acid "A"
- $HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$
- $K_a = \dfrac{[H_3O^+]\,[A^-]}{[HA]}$
- It is also written
- $HA \rightleftharpoons H^+ + A^-$
- $K_a = \dfrac{[H^+]\,[A^-]}{[HA]}$

Problems

- Acid Dissociation (Ionization) Reactions.
- Write the simple dissociation (ionization) reaction for each of the following acids. Then write the K_a expression
- Hydrochloric acid
- Acetic acid
- The ammonium ion
- The annilium ion ($C_6H_5NH_3^+$)
- The hydrated aluminum(III) ion $[Al(H_2O)_6]^{3+}$

Acid Strength

- Strong acids dissociate completely in water.
- At equilibrium, Q = K_a >> 1 because [HA] is approx. 0.
- Weak acids are mostly *undissociated*.
- At equilibrium, Q = K_a << 1 because $[H_3O^+]$ and $[A^-]$ are very small.
- The smaller the K_a value, the weaker the acid.

K_a values of some weak acids

ka	name	formula
$5.4 * 10^{-2}$	Oxalic acid	$HO_2C_2O_2H$
$1.3 * 10^{-2}$	Sulfurous acid	H_2SO_3
$1.0 * 10^{-2}$	Hydrogen sulfate ion	HSO_4^-
$7.1 * 10^{-3}$	Phosphoric acid	H_3PO_4
$7.2 * 10^{-4}$	Nitrous acid	HNO_2
$6.6 * 10^{-4}$	Hydrofluoric acid	HF
$1.8 * 10^{-4}$	Methanoic acid	HCO_2H
$6.3 * 10^{-5}$	Benzoic acid	C_6H_5COOH
$5.4 * 10^{-5}$	Hydrogen oxalate ion	$HO_2C_2O^{2-}$
$1.8 * 10^{-5}$	Ethanoic acid	CH_3COOH
$4.4 * 10^{-7}$	Carbonic acid	CO_3^{2-}
$1.1 * 10^{-7}$	Hydrosulfuric acid	H_2S
$6.3 * 10^{-8}$	Dihydrogen phosphate ion	$H_2PO_4^-$
$6.2 * 10^{-8}$	Hydrogen sulfite ion	HS^-
$2.9 * 10^{-8}$	Hypochlorous acid	HClO
$6.2 * 10^{-10}$	Hydrocyanic acid	HCN
$5.8 * 10^{-10}$	Ammonium ion	NH_4^+
$5.8 * 10^{-10}$	Boric acid	H_3BO_3
$4.7 * 10^{-11}$	Hydrogen carbonate ion	HCO_3^-
$4.2 * 10^{-13}$	Hydrogen phosphate ion	HPO_4^{2-}
$1.8 * 10^{-13}$	Dihydrogen borate ion	$H_2BO_3^-$
$1.3 * 10^{-13}$	Hydrogen sulfide ion	HS-
$1.6 * 10^{-14}$	Hydrogen borate ion	HBO_3^{2-}

21

Strong acids

- Strong acids are not an equilibrium reaction.
- $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
- K_a cannot be accurately determined in water because the reaction lies so far to the right that [HCl] is too small to measure.
- That is true for all strong acids, so K_a is normally only used for weak acids.

Water

- Water is a stronger base than the conjugate acid of a strong base.
- Water would be weaker than the conjugate acid of a weak base
- Remember water can act as an acid or a base.
- Amphoteric substances, like water, act as either an acid or a base

The Autoionization of Water and the Ion-Product (Dissociation)

- K_w is the constant for Water
- $H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$
- At 25° C
- $K_c = K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$
- if $[H_3O^+] = [OH^-] = 1.0 \times 10^{-7}$M
- if $[H_3O^+] > [OH^-]$ = Acidic.
- if $[H_3O^+] < [OH^-]$ = Basic.
- if $[H_3O^+] = [OH^-]$ = Neutral.

Calculating $[H_3O^+]$ and $[OH^-]$

- Calculate $[H_3O^+]$ or $[OH^-]$ as required for each of the following solutions at 25° C, and state whether the solution is neutral, acidic, or basic.
- 1.0×10^{-5} M OH^-
- 2.3×10^{-7} M OH^-
- 10.0 M H_3O^+

Problem

- At 60° C, the value of K_w is 1.0×10^{-13}.
- Using LeChatelier's principle, predict whether the reaction
- $H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$
- is exothermic or endothermic.
- Calculate $[H_3O^+]$ and $[OH^-]$ in a neutral solution at 60° C.

pH

- $[H_3O^+] = 10^{-pH}$
- Equation sheet

$$K_w = [H^+][OH^-] = 1.0 \times 10^{-14} \text{ at } 25°C$$
$$= K_a \times K_b$$
$$pH = -\log[H^+],\ pOH = -\log[OH^-]$$
$$14 = pH + pOH$$
$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$
$$pK_a = -\log K_a,\ pK_b = -\log K_b$$

Sig Figs and pH

- The number of **decimal places** in the log value, pH value, is equal to the number of **significant figures** in the number that we took the logarithm of, concentration.
- Calculate pH and pOH for each of the following solutions.
- 2.7×10^{-3} M OH^-
- 3.4×10^{-5} M H_3O^+
- 1.54×10^{-10} M OH^-

pH problem

- The pH of a sample of human blood was measured to be 7.41 at 25° C.
- Calculate pOH, $[H_3O^+]$, and $[OH^-]$ for the sample.