Lecture 6

pH Calculations for the Hydrolysis of Salts

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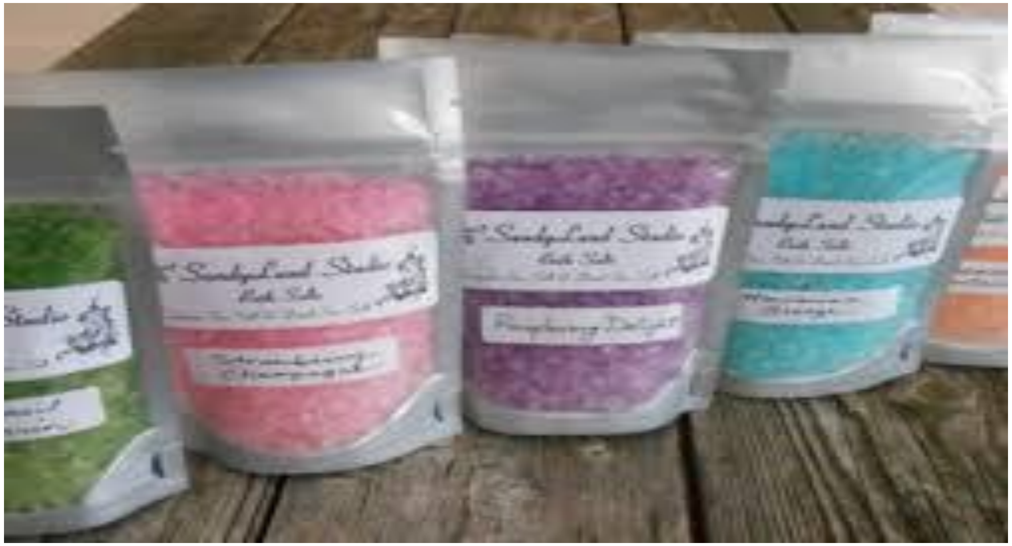

Definitions

Arrehenius

only in water

- Acids – produce H^+
- Bases - produce OH^-

Bronsted-Lowry

any solvent

- Acids – donate H^+
- Bases – accept H^+

Lewis

used in organic chemistry, wider range of substances

- Acids – accept e^- pair
- Bases – donate e^- pair

The Bronsted-Lowry Concept

Conjugate pairs

HCl Cl^-

CH_3COOH CH_3COO^-

NH_4^+ NH_3

HNO_3 NO_3^-

How does a conjugate pair differ?

H^+ transfer

- Conjugate acid- compound formed when an base gains a hydrogen ion.

- Conjugate base – compound formed when an acid loses a hydrogen ion.

Acids and bases come in pairs

- General equation is:

$$HA_{(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + A^-_{(aq)}$$

- Acid + Base ↔ Conjugate acid + Conjugate base
- $NH_3 + H_2O \leftrightarrow NH_4^{1+} + OH^{1-}$

  base acid c.a. c.b.
- $HCl + H_2O \leftrightarrow H_3O^{1+} + Cl^{1-}$

  acid base c.a. c.b.
- Amphoteric – a substance that can act as both an acid and base- as water shows

Conjugate Acid-Base Pairs

- The conjugate base of a strong acid, is an example of a ***weak conjugate base.***
- The conjugate base of a weak acid, is an example of a ***strong conjugate base.***
- Conversely, a strong base has a ***weak conjugate acid*** and a weak base has a ***strong conjugate acid.***

Relationship Between pK_a of an Acid and pK_b of its Conjugate Base

$CH_3CO_2H_{(aq)}$ + $H_2O_{(l)}$ ←→ $H_3O^+_{(aq)}$ + $CH_3CO_2^-{}_{(aq)}$

acetic acid *acetate*

$$K_a = \frac{[CH_3CO_2^-][H_3O^+]}{[CH_3CO_2H]} = 1.8\times10^{-5}$$

But let us also consider the hydrolysis reaction of acetate,

where acetate acts as a base:

$CH_3CO_2^-{}_{(aq)}$ + $H_2O_{(l)}$ ←→ $OH^-_{(aq)}$ + $CH_3CO_2H_{(aq)}$

acetate *acetic acid*

$$K_b = \frac{[CH_3CO_2H][OH^-]}{[CH_3CO_2^-]} = 5.6\times10^{-10}$$

$$K_aK_b = \frac{[CH_3CO_2^-][H_3O^+]}{[CH_3CO_2H]} \times \frac{[CH_3CO_2H][OH^-]}{[CH_3CO_2^-]}$$

$$K_aK_b = [H_3O^+] \times [OH^-]$$

$$K_aK_b = K_w$$

$$pK_a + pK_b = pK_w \qquad \text{OR} \qquad pK_a + pK_b = 14 \text{ at } 25\ ^\circ C$$

This is a general result, the K_a of an acid and the K_b of it's conjugate base are related. From this we can write three equivalent statements…

The higher the K_a of an acid, the lower the K_b of its conjugate base.

The lower the pK_a of an acid, the higher the pK_b of its conjugate base.

The stronger an acid is, the weaker is it's conjugate base!

Salts

- Ionic compounds that dissolve ~ 100 % in water

What is a SALT?

- Composed of the negative ion of an acid and the positive ion of a base.
- One of the products of a Neutralization Reaction
- Examples: KCl, $NaCl$, $MgSO_4$, Na_3PO_4