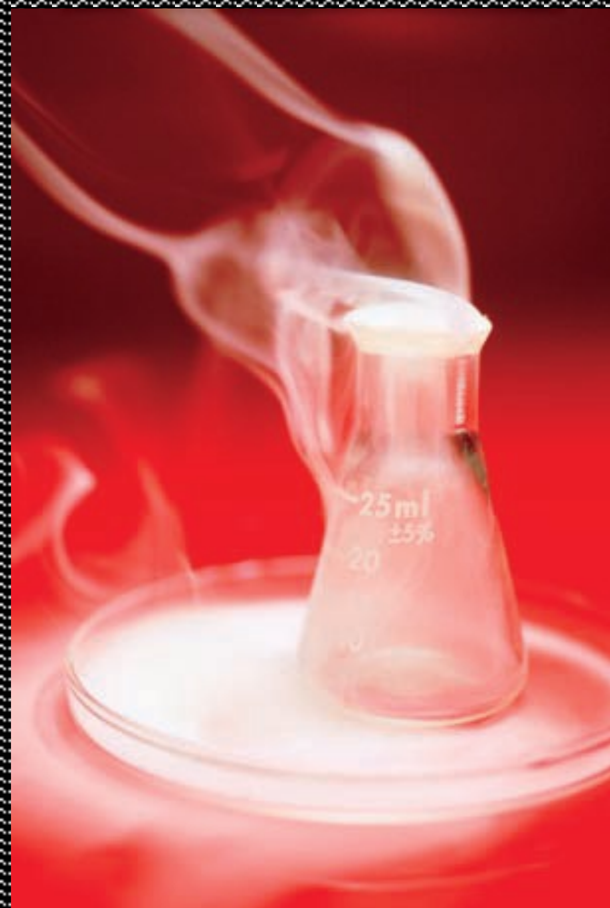
Chapter 8

Acids and Bases

Lecture 12



8.5 Acid Ionization Constant

- The equilibrium constants indicates the strength of the acid, for a weak acid (HA):

$$HA + H_2O \rightleftharpoons A^- + H_3O^+$$

- The equilibrium expression for this ionization is:

$$K_{eq} = \frac{[A^-][H_3O^+]}{[HA][H_2O]}$$

- Since the concentration of water is constant we can combine the two constants together:

$$K_a = K_{eq}\,[H_2O] = \frac{[A^-][H_3O^+]}{[HA]}$$

K_a tells us how the strong acid is

$$HA + H_2O \rightleftharpoons H_3O^+ + A^-$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

$=$

- Acid strength can be expressed as pK_a because the equilibrium constant is a number with negative exponent.

$$pK_a = -\log K_a$$

- There is inverse relationship between K_a and pK_a, The weaker the acid the smaller it K_a value, but the larger its pK_a.
- Example 8.2
- The K_a for benzoic acid is 6.5×10^{-5}. what is the pK_a of this acid?

$$pK_a = -\log K_a$$

$$pK_a = -\log 6.5 \times 10^{-5}$$

$$pK_a = 4.19$$

$K_a = 6.5 \times 10^{-5}$

$pK_a = -\log(6.5 \times 10^{-5}) = 4.19$

K_a

pK_a

- Example 8.3
- Which is the stronger acid:
- (a) Benzoic acid with a k_a of 6.5×10^{-5}, or hydrocynanic acid with a k_a of 4.9×10^{-10}?
- (b) Boric acid with a pK_a of 9.14 or carbonic acid with a pK_a of 6.37?
- Solution:
- (a) Benzoic acid is stronger; it has the greater K_a value.
- (b) Carbonic acid is stronger; it has the smaller pK_a value.

Acid	Name	K_a	pK_a
H_3PO_4	Phosphoric acid	7.5×10^{-3}	2.12
$HCOOH$	Formic acid	1.8×10^{-4}	3.75
$CH_3CH(OH)COOH$	Lactic acid	8.4×10^{-4}	3.08
CH_3COOH	Acetic acid	1.8×10^{-5}	4.75
H_2CO_3	Carbonic acid	4.3×10^{-7}	6.37
$H_2PO_4^-$	Dihydrogen phosphate ion	6.2×10^{-8}	7.21
H_3BO_3	Boric acid	7.3×10^{-10}	9.14
NH_4^+	Ammonium ion	5.6×10^{-10}	9.25
HCN	Hydrocyanic acid	4.9×10^{-10}	9.31
C_6H_5OH	Phenol	1.3×10^{-10}	9.89
HCO_3^-	Bicarbonate ion	5.6×10^{-11}	10.25
HPO_4^{2-}	Hydrogen phosphate ion	2.2×10^{-13}	12.66

8.6: Some Properties of Acids and Bases

- **A. Reactions with metals**
- The active metal reacts with acids to produce H_2 gas (redox reaction)

Mg is oxidized

$$Mg(s) + HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

Magnesium | Hydrochloric acid | Magnesium chloride | Hydrogen

H^+ is reduced

Mg+HCl.swf

$\overset{0}{Mg} + 2\overset{+1}{H}\overset{-1}{Cl} \rightarrow \overset{+2}{Mg}\overset{-1}{Cl_2} + \overset{0}{H_2}\uparrow$

Salt

Hydrogen

oxida

Reduction

Reducing

oxidizing

Mg

Cl

Cl

$MgCl_2$

B. Neutralization

$$\text{Acid} + \text{Base} \longrightarrow \text{Salt} + \text{Water}$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

Corrosive acid | Corrosive alkali | Neutral salt

C. Reaction With Metal Oxide

Na_2O CaO

- Strong acids react with metal oxides to give salt and water.

$$2HCl(aq) + CaO(s) \longrightarrow 2H_2O(l) + CaCl_2(aq)$$

$HCl + NaOH \longrightarrow NaCl + H_2O$

D. Reaction With Metal Hydroxide

- Acids react with metal hydroxide to give salt and water.

$$HCl + KOH \rightarrow KCl + HOH$$

- Both acid and metal hydroxide are ionized in aqueous solutions.
- *The net ionic equation is*

$$H_3O^+ + Cl^- + K^+ + OH^- \longrightarrow 2H_2O + Cl^- + K^+$$

$$H_3O^+ + OH^- \longrightarrow 2H_2O$$

$$HCl + KOH \longrightarrow KCl + H_2O_{(l)}$$

$$H^+ + Cl^- + K^+ + OH^- \longrightarrow K^+ + Cl^- + H_2O$$

$$H^+ + OH^- \longrightarrow H_2O$$

E. Reaction with Carbonate and Bicarbonate

- Strong acids react with carbonate and bicarbonate producing CO_2 gas. The reaction takes place on two steps.

$$2HCl(aq) + Na_2CO_3(aq) \longrightarrow 2NaCl + CO_2(g) + 3H_2O(l)$$

Baking powder contains the weak acid

CO_3^{-2} HCO_3^{-}

$2HCl + Na_2CO_3 \longrightarrow H_2O + CO_2 + 2NaCl$

$H_2CO_3 \longrightarrow H_2O + CO_2$

8.7 Self Ionization of Water

- Water ionizes according to the equation

$$H_2O + H_2O \rightleftharpoons OH^- + H_3O^+$$

Acid | Base | Conjugate base of H_2O | Conjugate Acid of H_2O

- The equilibrium expression is

$$K_{eq} = \frac{[H_3O^+][OH^-]}{[H_2O]^2}$$

- The concentration of water is constant since the degree of self ionization is slight

$$K_w = K_{eq}[H_2O]^2 = [H_3O^+][OH^-]$$

- In pure water the $[H_3O^+] = [OH^-] = 1.0 \times 10^{-7}$

$$K_w = 1.0 \times 10^{-14}$$

$$H_2O + H_2O \longrightarrow H_3O^+ + OH^-$$

$$K_{eq} = [H_3O^+][OH^-]$$

$$K_w = 1 \times 10^{-14}$$

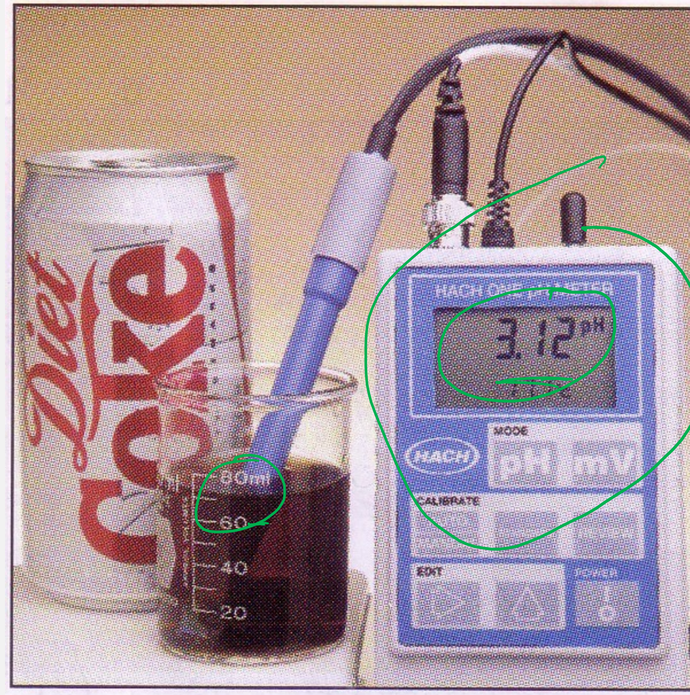
$$K_w = [H_3O^+][OH^-]$$

8.8 pH and pOH

- Because hydronium ion concentrations for most solutions are numbers with negative exponents, these concentrations are more commonly expressed as pH

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

$$pOH = -\log[OH^{-}]$$



The pH of this soft drink is 3.12. Soft drinks are often quite acidic.

$$pH = -\log[H^+]$$

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

$$\boxed{pH + pOH = 14}$$

$$[H^+][OH^-] = 1\times10^{-14}$$

$$K_w = 1.0 \times 10^{-14}$$

$$K_w = [H^+][OH^-] = 1 \times 10^{-14}$$

$$-\log K_w = -\log [H^+] + -\log [OH^-] = -\log (1 \times 10^{-14})$$

since $pK_w = -\log K_w = -\log 1.0 \times 10^{-14}$

$$pH + pOH = 14$$

pOH = 12

pH + pOH = 14

2 + 12 = 14

acidic

A solution is acidic if its pH is less than 7

A solution is basic if its pH is more than 7

A solution is neutral if its pH is equal to 7

- **Example**
- (a) The $[H_3O^+]$ of a certain liquid detergent is 1.4×10^{-9}M. What is its pH
- (b) The pH of black coffee is 5.3. what is its $[H_3O^+]$.

$$pH = -\log[1.4 \times 10^{-9}] = 8.85$$

$$[H_3O^+] = 10^{-pH} = 10^{-5.3} = 5.01 \times 10^{-6}\ M$$

A solution is acidic if its pH is less than 7
A solution is basic if its pH is more than 7
A solution is neutral if its pH is equal to 7

- **Example**
- (a) The $[H_3O^+]$ of a certain liquid detergent is 1.4×10^{-9}M. What is its pH
- (b) The pH of black coffee is 5.3. what is its $[H_3O^+]$.
- Solution

$$pH = -\log[H^+]$$

- (a)

$$pH = -\log[1.4 \times 10^{-9}] = 8.85$$

- (b)

$$[H_3O^+] = \text{antilog}-5.3 = 5 \times 10^{-6}$$

$$10^{-5.3}$$

$pH = 3.11$ $[H_3O^+] = ??$

$pOH = ??$ $[OH^-] = ??$

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END OF THE LECTURE