Strong and Weak Acids and Bases

Chapter 8.2

Strong Acids and Weak Acids

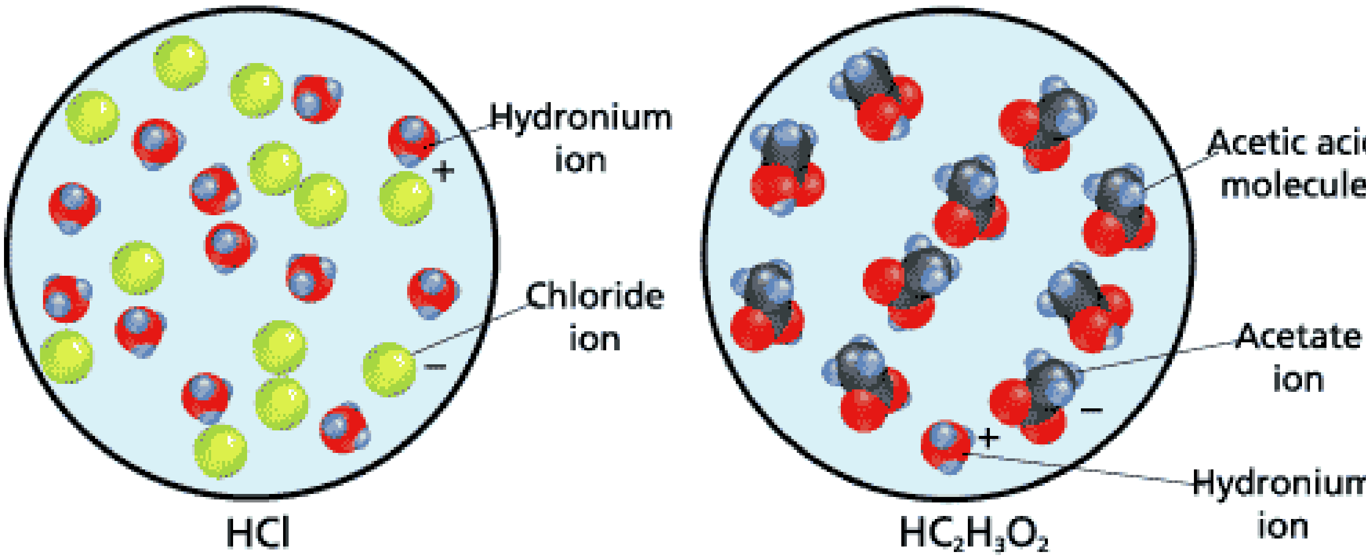
- A **strong acid** is an acid that ionizes almost completely in water

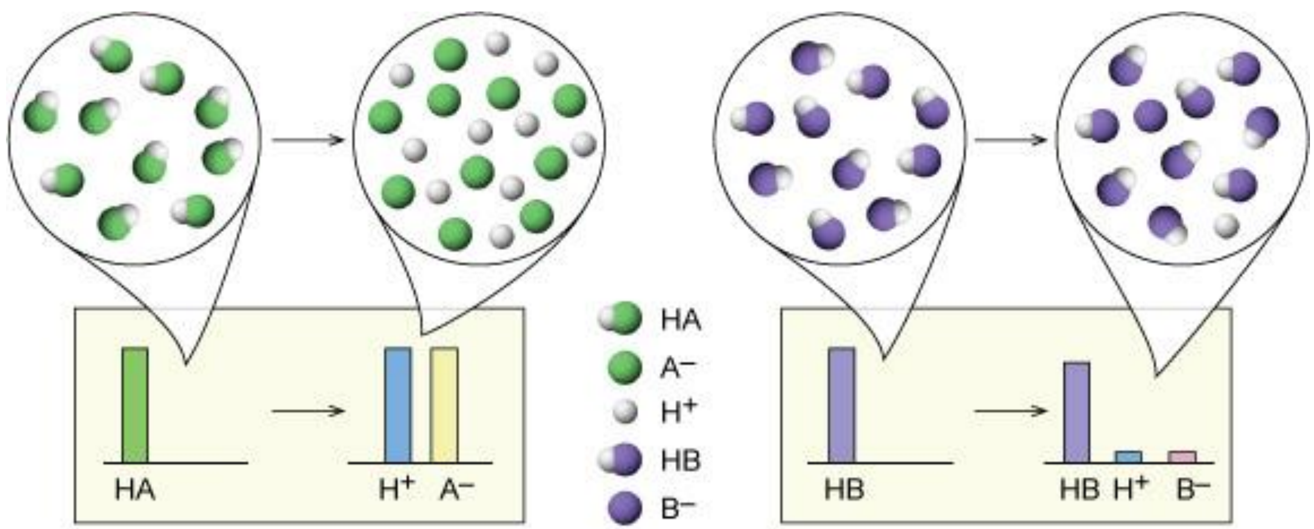
$$\underbrace{HCl_{(aq)}}_{\text{0.0004\% at equilibrium}} + H_2O_{(l)} \rightarrow \underbrace{H_3O^+{}_{(aq)} + Cl^-{}_{(aq)}}_{\text{99.996\% at equilibrium}}$$

- A **weak acid** is an acid that only partially ionizes in water

$$\underbrace{HC_2H_3O_{2(aq)}}_{\text{98.7\% at equlibrium}} + H_2O_{(l)} \rightleftharpoons \underbrace{H_3O^+{}_{(aq)} + C_2H_3O_2^-{}_{(aq)}}_{\text{1.3\% at equilibrium}}$$

Strong Acids and Weak Acids





(a) Strong acid

(b) Weak acid

Acid Strength and K_a

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq).$$

$$K_a = \frac{[H^+(aq)][A^-(aq)]}{[HA(aq)]}$$

Property	Strong acid	Weak acid
Value of acid ionization constant, K_a	K_a is large	K_a is small
Position of the ionization equilibrium	far to the right	far to the left
Equilibrium concentration of $H^+(aq)$ compared with original concentration of HA	$[H^+(aq)]_{equilibrium} \approx [HA(aq)]_{initial}$	$[H^+(aq)]_{equilibrium} << [HA(aq)]_{initial}$

Types of Acids

- Oxyacids
- Organic Acids
- Binary Acids

Acid formula	Name	Value of K_a
$HClO_4$(aq)	perchloric acid	very large
HNO_3(aq)	nitric acid	very large
HCl(aq)	hydrochloric acid	very large
HSO_4^-(aq)	hydrogen sulfate ion	1.2×10^{-2}
$HClO_2$(aq)	chlorous acid	1.2×10^{-2}
HF(aq)	hydrofluoric acid	6.6×10^{-4}
HNO_2(aq)	nitrous acid	4.6×10^{-4}
$HC_2H_3O_2$(aq)	ethanoic acid	1.8×10^{-5}
HClO(aq)	hypochlorous acid	3.5×10^{-8}
HCN(aq)	hydrocyanic acid	6.2×10^{-10}
NH_4^+(aq)	ammonium ion	5.8×10^{-10}
HCO_3^-(aq)	hydrogen carbonate ion	4.7×10^{-11}

increasing acid strength (↑)

Strong Bases and Weak Bases

- A **strong base** is a base that dissociates completely in water
  - Hydroxides of group 1 and group 2 elements tend to be strong bases

$$KOH(s) \rightarrow K^+(aq) + OH^-(aq)$$

- A **weak base** is a base that only partially dissociates in water
  - Many organic bases are weak bases

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

Base Ionization Constant (K_b)

- The base **ionization constant (K_b)** is the equilibrium constant for the ionization of a base (it is also called the base dissociation constant)

$$\underset{\text{base}}{B(aq)} + \underset{\text{acid}}{H_2O(l)} \rightleftharpoons \underset{\substack{\text{conjugate}\\ \text{acid}}}{BH^+(aq)} + \underset{\substack{\text{conjugate}\\ \text{base}}}{OH^-(aq)}$$

$$K_b = \frac{[BH^+(aq)][OH^-(aq)]}{[B(aq)]}$$

Practice

- Write the K_b equation for ammonia

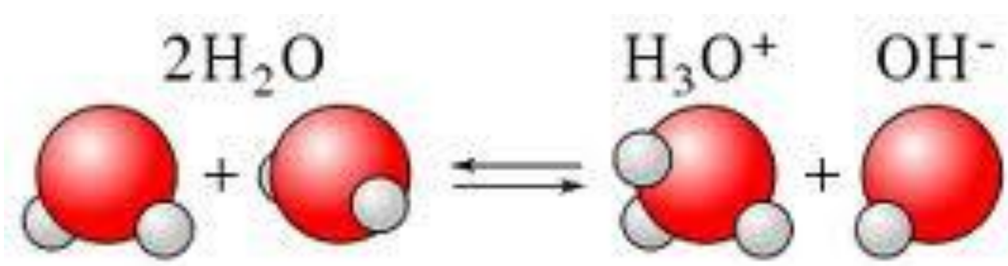
Base Ionization Constant (K_b)

- K_b values can be looked up on p. 727 of your textbook
- Similarly to acids, weak bases will have a small value for K_b and strong bases will have a large value for K_b

Name of base	Formula	K_b
dimethylamine	$(CH_3)_2NH(aq)$	9.6×10^{-4}
butylamine	$C_4H_9NH_2(aq)$	5.9×10^{-4}
methylamine	$CH_3NH_2(aq)$	4.4×10^{-4}
aniline	$C_6H_5NH_2(aq)$	4.1×10^{-10}
ammonia	$NH_3(aq)$	1.8×10^{-5}
hydrazine	$N_2H_4(aq)$	1.7×10^{-6}
morphine	$C_{17}H_{19}NO_3(aq)$	7.5×10^{-7}
hypochlorite ion	$ClO^-(aq)$	3.45×10^{-7}
pyridine	$C_5H_5N(aq)$	1.7×10^{-9}
ethanoate ion	$C_2H_3O_2^-(aq)$	5.6×10^{-10}
urea	$NH_2CONH_2(aq)$	1.5×10^{-14}

Water is Amphiprotic

- Water can behave as both an acid and a base in the *same reaction*
- The **autoionization of water** is the transfer of a hydrogen ion from one water molecule to another



The Ion-Product Constant for Water (K_w)

$$2\,H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq) \quad K = \frac{[H_3O^+(aq)][OH^-(aq)]}{[H_2O(l)]^2}$$

$$K = [H_3O^+(aq)][OH^-(aq)]$$

$$K_w = [H^+(aq)][OH^-(aq)]$$

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

- In a NEUTRAL solution $[H^+] = [OH^-]$
- In an ACIDIC solution $[H^+] > [OH^-]$
- In a BASIC solution $[H^+] < [OH^-]$

Practice

- If a solution has a hydroxide ion concentration of $3.5x10^{-5}$ mol/L what is the hydronium ion concentration? Is the solution acidic or basic?

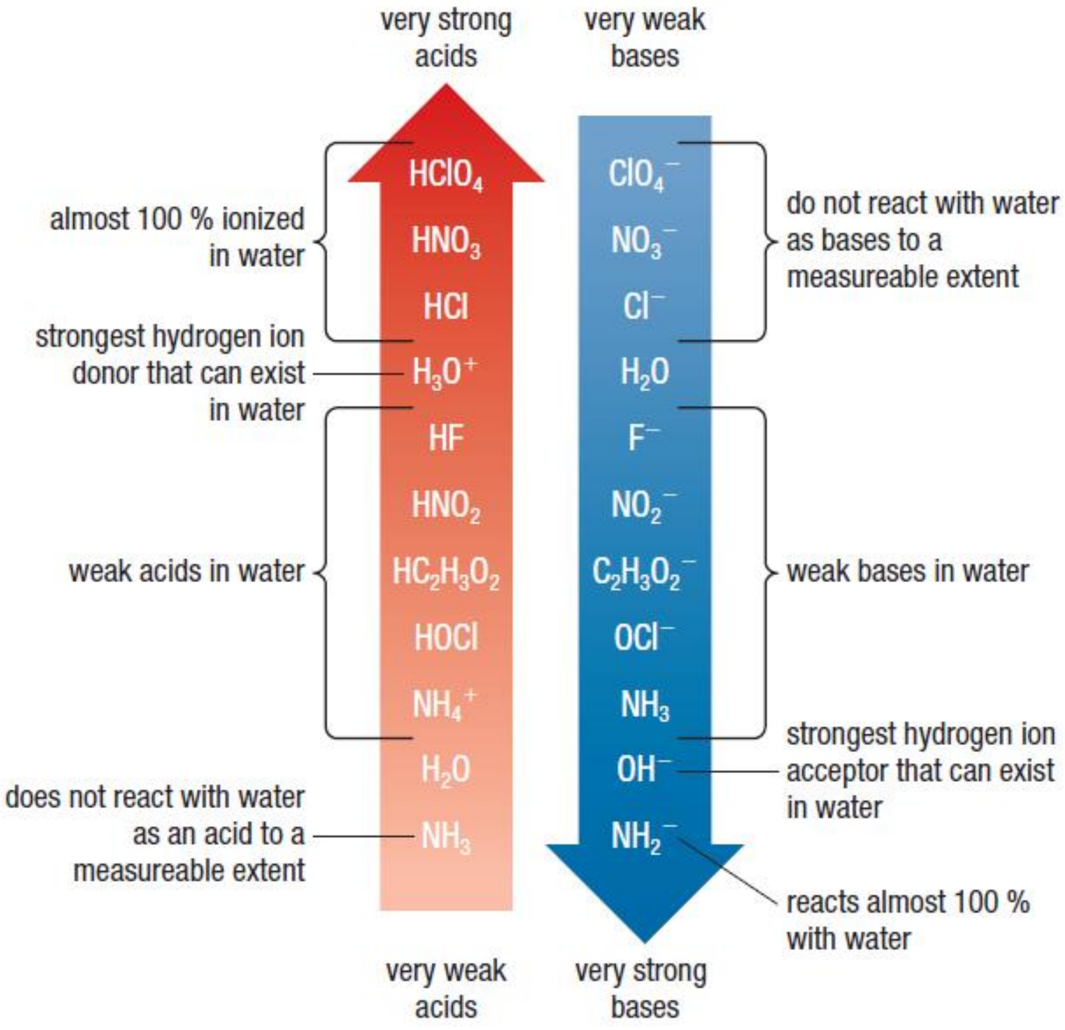
The Relationship Between K_w, K_a and K_b

$$HA(aq) + H_2O(l) \rightleftharpoons A^-(aq) + H_3O^+(aq) \qquad K_a = \frac{[H_3O^+(aq)][A^-(aq)]}{[HA(aq)]}$$

$$A^-(aq) + H_2O(l) \rightleftharpoons HA(aq) + OH^-(aq) \qquad K_b = \frac{[HA][OH^-]}{[A^-]}$$

$K_aK_b = K_w$

- A strong acid or base has a very weak conjugate
- A weak acid or base has a weak conjugate
- A very weak acid or base has a strong conjugate



Practice

- Chlorous acid ($HClO_2$) has a K_a of $1.2x10^{-2}$. What is the base ionization constant for its conjugate base?

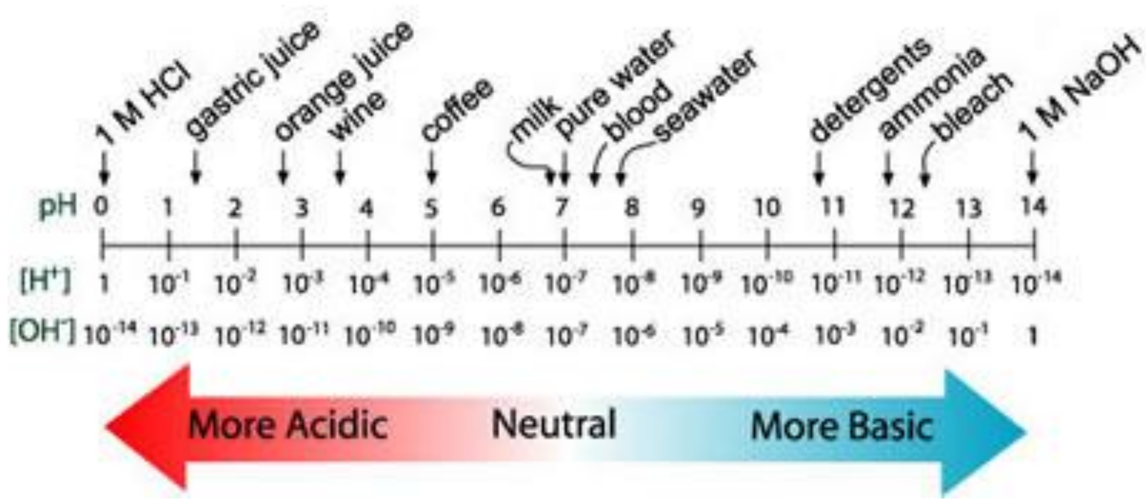
pH and pOH

- **pH** is the negative logarithm of the concentration of hydrogen ions in an aqueous solution

$$pH = -\log[H^+] \qquad [H^+] = 10^{-pH}$$

- **pOH** is the negative logarithm of the concentration of hydroxide ions in an aqueous solution

$$pOH = -\log[OH^-] \qquad [OH^-] = 10^{-pOH}$$



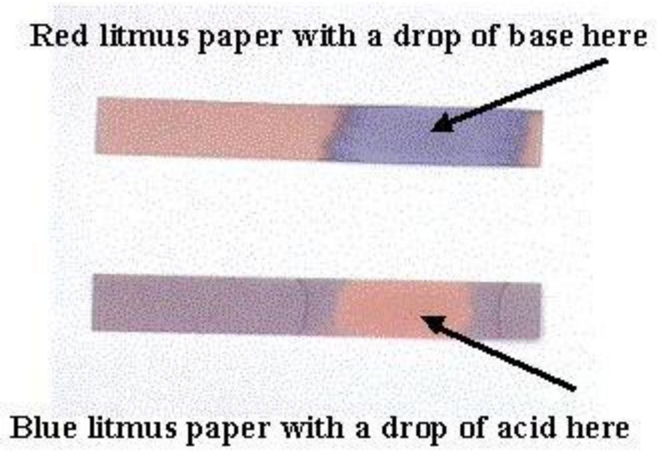
Practice

1. A solution has a pH of 2.6. What is the hydrogen ion concentration in the solution?

2. A solution has a hydroxide ion concentration of 3.2×10^{-4}. What is the pH of the solution?

Measuring pH

- A **pH meter** is an electronic device that measures the acidity of a solution and displays the result as a pH value
- An **acid-base indicator** is a substance that changes colour within a specific pH range



pH and pOH

- Since $[H^+]$ and $[OH^-]$ are related through K_w

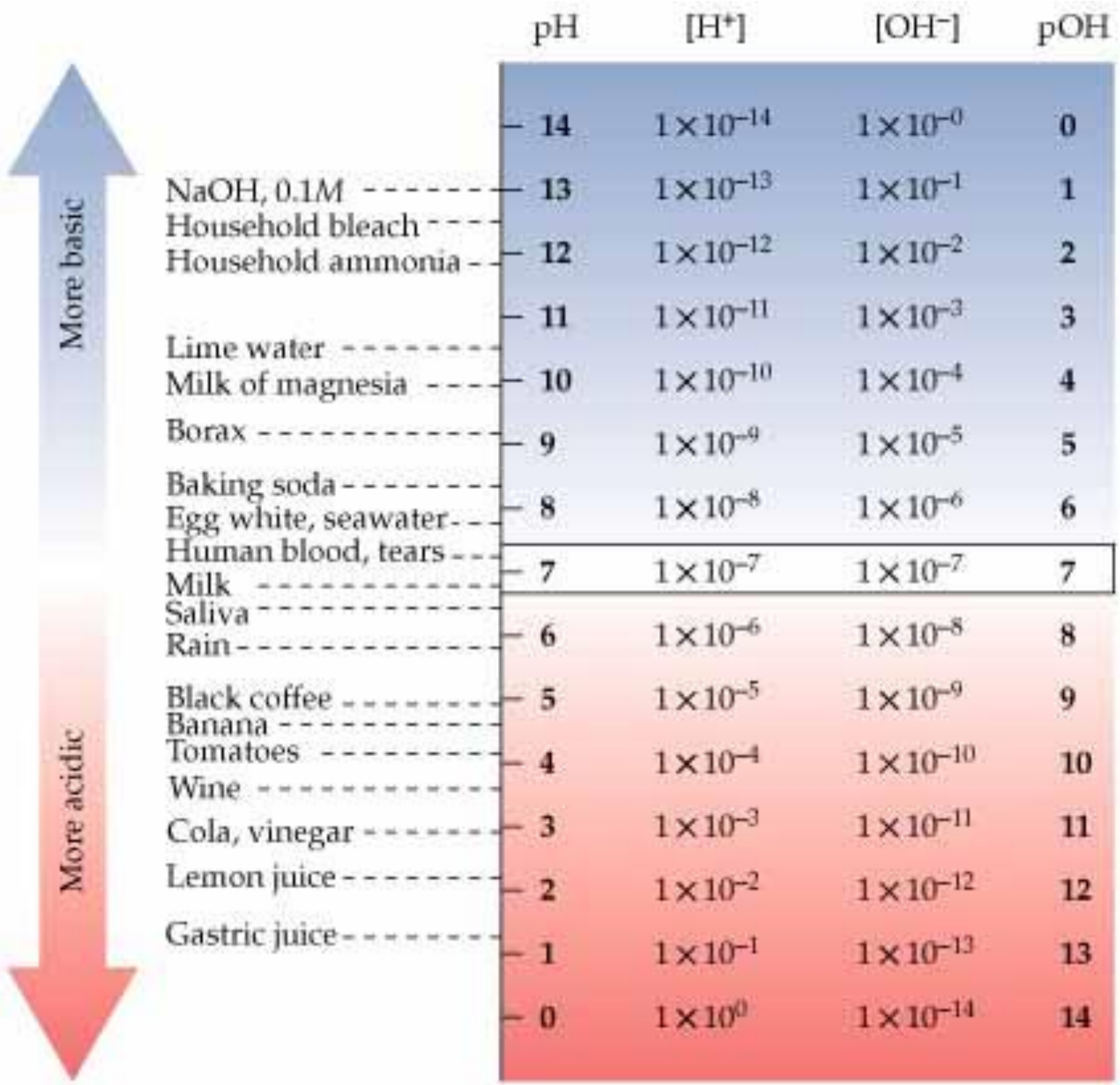
$$[H^+]\,[OH^-] = K_w$$

$$[H^+]\,[OH^-] = 1.0x10^{-14}$$

- pH and pOH are related through pK_w

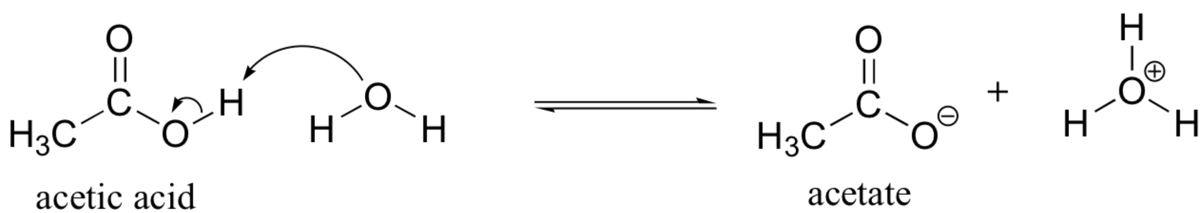
$$pH + pOH = pK_w$$

$$pH + pOH = 14$$


pH
[H⁺]
[OH⁻]
pOH
More basic
More acidic
NaOH, 0.1M
Household bleach
Household ammonia
Lime water
Milk of magnesia
Borax
Baking soda
Egg white, seawater
Human blood, tears
Milk
Saliva
Rain
Black coffee
Banana
Tomatoes
Wine
Cola, vinegar
Lemon juice
Gastric juice
14 1×10^{-14} 1×10^{-0} 0
13 1×10^{-13} 1×10^{-1} 1
12 1×10^{-12} 1×10^{-2} 2
11 1×10^{-11} 1×10^{-3} 3
10 1×10^{-10} 1×10^{-4} 4
9 1×10^{-9} 1×10^{-5} 5
8 1×10^{-8} 1×10^{-6} 6
7 1×10^{-7} 1×10^{-7} 7
6 1×10^{-6} 1×10^{-8} 8
5 1×10^{-5} 1×10^{-9} 9
4 1×10^{-4} 1×10^{-10} 10
3 1×10^{-3} 1×10^{-11} 11
2 1×10^{-2} 1×10^{-12} 12
1 1×10^{-1} 1×10^{-13} 13
0 1×10^{0} 1×10^{-14} 14

Practice

- For the following equilibrium system calculate:



a) K_a
b) K_b
c) $[H^+]$
d) $[OH^-]$
e) pH
f) pOH

HOMEWORK

Required Reading:

p. 495-509

(remember to supplement your notes!)

Questions:

p. 502 #1,2

p. 505 #1-3

p. 508 #1-4

p. 509 #1-10