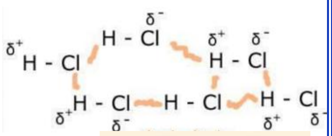
Dr.Ahmad Al-Qawasmi

Biochemistry

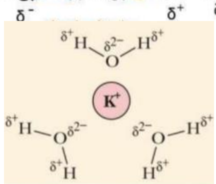
Acids and Bases 1

❖ Water

- Water is a **polar** molecule due to the <u>difference electronegativity</u> between H & O and it is <u>angular</u>
- Water molecules form a network by H-bonding, making it highly **cohesive** aiding in the movement of water along the plants against gravity



- It works as an excellent **solvent** because it is a small molecule and it can form Electrostatic and Hydrogen bonds with other polar molecules
  - ➢ Electrostatic can be dipole – dipole or dipole – charge interactions



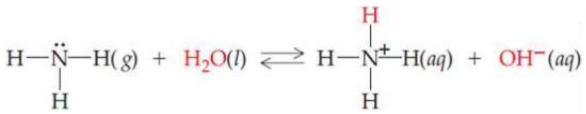
- Water molecule is reactive because it is a **nucleophile**
  - ➢ Nucleophile: Electron-rich molecule which is attracted to positively charged and electron-deficient molecules (Electrophiles)
- Water can be **ionized** forming a positive hydronium (proton) and a negative hydroxide ion
  - ➢ The equilibrium of pure water ionization is toward forming water

$$H_2O + H_2O \rightleftarrows H_3O^{\oplus} + OH^{\ominus}$$

❖ Acids & Bases

- Bronsted- Lowry definition for acids and bases:
  - ➢ **Acid:** a substance that donate (produce) H^+ (Proton donor) when dissolved in water forming H_3O^+
  - ➢ They are classified into:
    - ✓ **Monoprotic acids:** can donate only <u>1 proton</u>, such as **HCl**, **HNO_3** and **CH_3COOH**
    - ✓ **Diprotic acids:** can donate <u>2 protons</u>, such as **H_2SO_4**
    - ✓ **Triprotic acids:** can donate <u>3 protons</u>, such as **H_3PO_3**

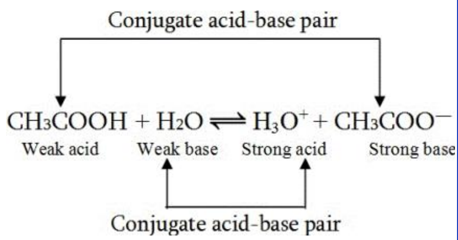
  - ➢ **Base:** a substance that accept H^+ (Proton acceptor) when dissolved in water forming OH^-
    - ✓ Examples: NaOH, NH_3, KOH



- **Water is an amphoteric substance** (can act as an acid in one reaction and as a base in another)
  - ➢ With bases (such as ammonia NH_3) water acts as an acid

    $NH_3 + H2O \leftrightarrows NH_4^+ + OH^-$
  - ➢ With acids (such as Hydrochloric acid HCl) water acts as a base

    $HCl + H_2O \leftrightarrows H_3O^+ + Cl^-$



❖ The strength of Acids & Bases

- **Strength** of acids and bases: ability to release and accept protons, it differs between different molecules
  - ➢ The stronger the acid = the weaker the conjugate base and vice versa
- Strong acids and bases ionize **completely**, so the reaction is a **one-way reaction**
  - ➢ Strong Acids **dissociate completely** 100%
  - ➢ Strong bases have **strong affinity** for proton

$HCl \rightarrow H^+ + Cl^-$
$NaOH \rightarrow Na^+ + OH^-$

- Weak acids and bases ionize **Partially**, and the reaction is a **reverse reaction**
  - ➢ In multi-protic acids each proton is donated at different strength

$HC_2H_3O_2 \leftrightarrows H^+ + C_2H_3O_2$
$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$

- **Strong acids:** HCl, HBr, HI, HNO_3, $HClO_4$, H_2SO_4
- **Strong bases:** LiOH, NaOH, KOH, $Ca(OH)_2$, $Ba(OH)_2$, $Sr(OH)_2$

❖ K_a (acid dissociation constant) & pK_a

- We can find out this constant using the equilibrium constant (K_{eq}) for the reaction ($HA \leftrightarrows H^+ + A^-$)
  - **Equilibrium** is the state when the rate of the forward reaction = the rate of the backward reaction
- HA: acid / A^-: conjugate base
- **$[H^+] = [H3O^+] = [A^-]$**

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

- The value of Ka indicates:
  - If K_a is larger than 1 → the product side is favored → more dissociation → more acidic
  - If K_a is smaller than 1 → the reactants side is favored → less dissociation → less acidic
- $pK_a = -\log K_a$
  - Ka is inversely related to pKa
  - Larger K_a → smaller pK_a → more dissociation → stronger acid
- **Example:** Find the K_a and pK_a of a 0.04 M weak acid HA whose $[H^+]$ is 10^{-4}
  - $K_a = 2.5 \times 10^{-7}$, $pK_a = 6.6$

❖ Measurements of concentration

- We use concentration (**Molarity**) to express solutions
  - Molarity (M) = Number of moles / Volume (L)
  - Number of moles = Mass (gram) / MW (gram/mole)
- **Example:** How many grams do you need to make 5M NaCl solution in 100 ml (MW 58.4)?
  - 29.29g
- We use Equivalent (Eq) to express acids, bases & ions

Equivalent in acids and bases

- It is the number of **moles** (of H^+ or OH^-)
  - 1 mol of HCl = 1 mol of $[H^+]$ = 1 Eq
  - 1 mol of NaOH = 1 mol of $[OH^-]$ = 1 Eq
- If we have a multi-protic acid → it should be multiplied by the number of moles of the proton
  - 1 mol of H_2SO_4 = 2 mol of $[H^+]$ = 2 Eq

Equivalent in ions

- The mass of an equivalent of ion (g-Eq) is number of **grams** divided by its charge
  - 1 equivalent of Na^+ → 23.1 g
  - 1 equivalent of Cl^- → 35.5 g
  - 1 equivalent of Mg^{+2} → 24.3/2 = 12.15g

- **Example:** Calculate milligrams of Ca^{+2} in blood if total concentration of Ca^{+2} is 5 mEq/L (MW= 40):
  - 100 mg/L
- **Important note:**
  - 1 Eq of any acid **neutralizes (titrates)** 1 Eq of any base
  - Neutralization requires an **equal** number of **equivalences** of the acid and base
  - Titration: the slow addition of one solution of a known concentration to a known volume of another solution of unknown concentration until the reaction reaches neutralization
  - Eq of acids and bases = N × moles = N × Volume × Molarity

- **<u>Example:</u>** Titration of a 12.0 mL solution of HCl requires 22.4 mL of 0.12 M of NaOH, what is the molarity of HCl ??
  - 0.224 M

- **<u>Example:</u>** What volume of 0.085 M HNO_3 is required to titrate 15.0 mL of 0.12 M $Ba(OH)_2$ solution?
  - 42.35 mL

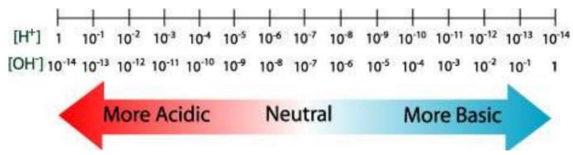
❖ Ionization of water

- Water dissociates to a slight extent to form hydronium ($H3O^+$) & hydroxyl (OH^-) ions
  - $H_2O \leftrightarrow H^+ + OH^-$
  - We can refer to hydronium ion (H_3O^+) as a Hydrogen ion (H^+)

- $Keq = [H_3O^+] \times [OH^-] / [H_2O]$
  - [H2O] = 55.6 moles
  - $Keq = 1.8 \times 10^{-16}$ M

- **$K_w = [H_3O^+] \times [OH^-]$**
  - K_w is the equilibrium constant of water
  - **$K_w = 1 X 10^{-14}$**

- The product of multiplying $[H_3O^+]$ with $[OH^-]$ must equal 10^{-14} in **any solution**
  - Because <u>Pure</u> water is neutral → $[H^+] = [OH^-] = (10^{-14/2}) = 10^{-7}$ M
  - If we add an acid, $[H^+]$ increases and $[OH^-]$ decreases
  - $[H^+]$ and $[OH^-]$ are **inversely related**



- **<u>Example:</u>** What is the $[H^+]$ of a 0.05 M $Ba(OH)_2$:
  - $[H^+] = 10^{-13}$

Past papers

1. **Water can form all of these non-covalent interactions, EXCEPT:**
   A. Hydrophobic interactions
   B. Ionic interactions
   C. Hydrogen bonds
   D. Van der Waals
   E. None of the above

2. **Given the pKa of different acids, which one will have the strongest conjugate base when being dissociated in water:**
   A. 3.5
   B. 2.9
   C. 4.76
   D. 7.2
   E. 12.4

3. Water has high specific heat, boiling point, melting point & other physical properties due to:

A. It is an amphipathic molecule
B. High ion product of water
C. It can dissociate to protons and hydroxyl groups
D. It can form Hydrogen bonds with each other
E. It is an amphipathic molecule

4. What do we mean by ion product of water?

A. Product of concentrations of hydrogen ions and hydroxyl ions in water or an aqueous solution of an electrolyte
B. The sum of concentrations of hydrogen ions and hydroxyl ions in water or solution of electrolytes
C. The product of concentrations of hydrogen ion and hydroxyl ions that are derived only from water molecules in aqueous solution of electrolytes
D. The number of ionized molecules of H2O in one mole of a pure water
E. The total number of negatively and positively charged ions in one liter of an aqueous solution of electrolytes

5. The ability of water to form hydrogen bonds is attributed to:

A. The partial positive charge of O
B. The partial negative charges of H
C. Polar covalent bonds between atoms in water molecules
D. None of the above

6. Water is considered:

A. Amphipathic
B. Amphoteric
C. Non-polar
D. Buffer

7. What is the concentration of H2PO4 if we have 0.5 eq in 500ml

A. 0.5 M
B. 0.25 M
C. 1 M