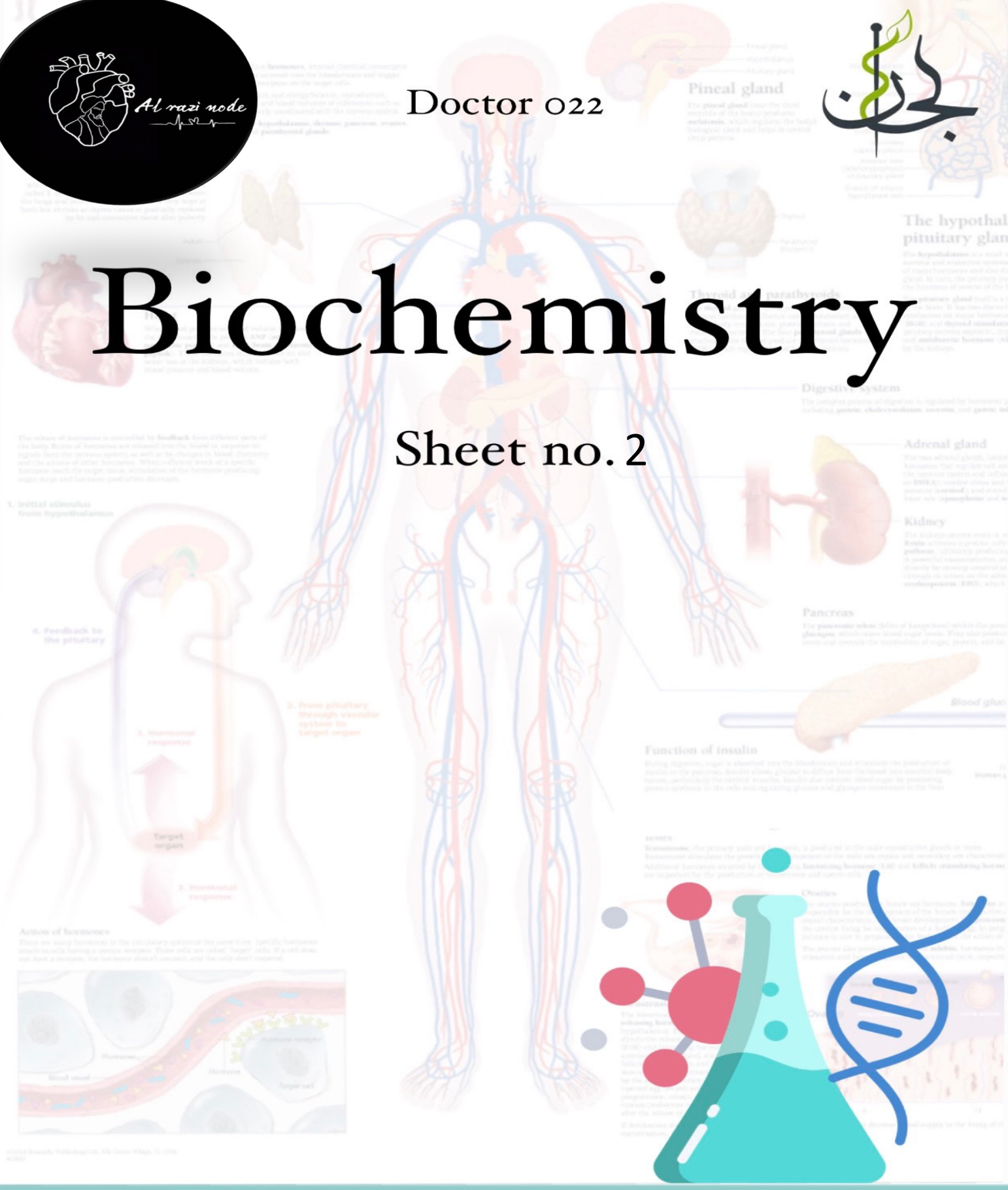


Doctor 022



# Biochemistry

## Sheet no. 2



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Quick note: Dr. Mamoun's explanation in black, slides notes in navy blue & extra information in light blue.

Hydrogen bonds are very important, when hydrogen links to a high electronegativity atom (O, N, S), it attracts electrons; so it has a partial negative charge and it is partial because the atom did not gain the electrons completely and the other atom of the bond will have a partial positive charge for the same reason.

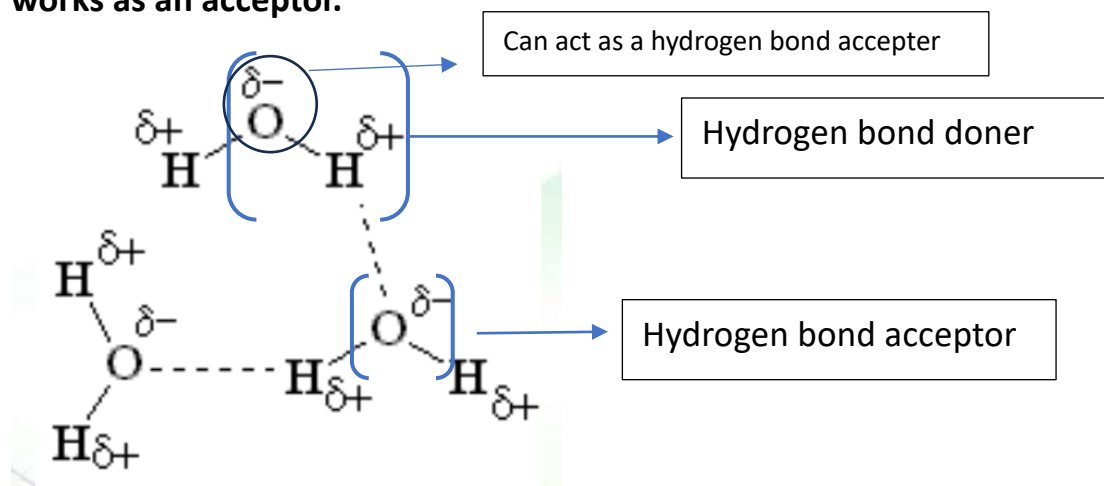
This is according to doctor Mamon:(this is an example of hydrogen bond donors and acceptors)

**The "first" group** (OH, NH, SH) is the hydrogen bond donor not the hydrogen atom -alone-.

**Second group** (as an example of it) such as carbon with a nitrogen (nitrogen can form three covalent bonds) one with the carbon and two of them with the hydrogens, nitrogen itself will have a partial negative charge, this nitrogen atom will be the hydrogen bond acceptor and will form the interaction with hydrogen in the first group.

Pay attention: the first group which is (OH, NH, SH) works as a hydrogen bond donor but the electronegative atom itself works as an acceptor for another bond such as the second group

\*\*\*\* in water (H<sub>2</sub>O): OH is a hydrogen bond doner, the oxygen atom also works as an acceptor.



**Other question:** CO<sub>2</sub> can form a hydrogen bond with H<sub>2</sub>O, but since gases are not soluble, hydrogen and oxygen need carriers to enter our bodies (oxygen carrier is haemoglobin and carbon dioxide forms bicarbonate ion).

CO<sub>2</sub> has polar bonds but it is a nonpolar molecule that can interact with water by forming hydrogen bonds between oxygens in CO<sub>2</sub> and hydrogen atoms in H<sub>2</sub>O (dissolves partially not fully).

Acids in general (strong or weak) they can be classified into three types depending on how many protons they can release:

Monoprotic acid: HCl, HNO<sub>3</sub>, CH<sub>3</sub>COOH

Diprotic acid: H<sub>2</sub>SO<sub>4</sub>

Triprotic acid: H<sub>3</sub>PO<sub>3</sub>

**\*\*Bases are usually mono bases (accept 1 proton), water is amphoteric.**

**\*\*acids in general have different strength (the tendency of releasing the proton), the easier releasing means stronger acid.**

**\*\* releasing of first proton is easy, but the second one has some difficulties due to the negative charge (resists releasing), Existence of proton increases stability due to attraction to negative one**

ACID		BASE		
100 percent ionized in H <sub>2</sub> O	Strong	HCl	Cl <sup>-</sup>	
		H <sub>2</sub> SO <sub>4</sub>	HSO <sub>4</sub> <sup>-</sup>	
		HNO <sub>3</sub>	NO <sub>3</sub> <sup>-</sup>	
	Acid strength increases	Weak	H <sup>+</sup> (aq)	H <sub>2</sub> O
			HSO <sub>4</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
			H <sub>3</sub> PO <sub>4</sub>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>
			HF	F <sup>-</sup>
			HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>
			H <sub>2</sub> CO <sub>3</sub>	HCO <sub>3</sub> <sup>-</sup>
			H <sub>2</sub> S	HS <sup>-</sup>
H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>			HPO <sub>4</sub> <sup>2-</sup>	
NH <sub>4</sub> <sup>+</sup>			NH <sub>3</sub>	
HCO <sub>3</sub> <sup>-</sup>			CO <sub>3</sub> <sup>2-</sup>	
Negligible	Strong	HPO <sub>4</sub> <sup>2-</sup>	PO <sub>4</sub> <sup>3-</sup>	
		H <sub>2</sub> O	OH <sup>-</sup>	
		HS <sup>-</sup>	S <sup>2-</sup>	
		OH <sup>-</sup>	O <sub>2</sub> <sup>-</sup>	
		H <sub>2</sub>	H <sup>-</sup>	
		100 percent protonated in H <sub>2</sub> O		

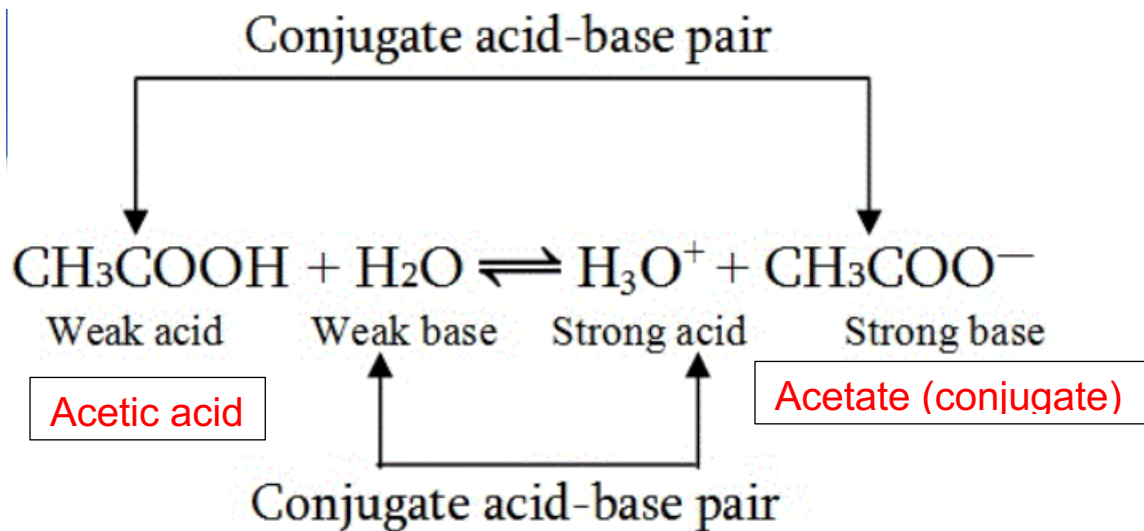
Strong acids dissociate 100%.

-Bases differ in their ability to accept protons. Strong bases have a strong affinity for protons

- For multi-protic acids (H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>PO<sub>4</sub>), each proton is donated at different strengths, **it is harder to release the second proton in comparison to the first one.**

-(H<sub>2</sub>PO<sub>4</sub><sup>-</sup>) is an acid for HPO<sub>4</sub><sup>2-</sup> and conjugated base for (H<sub>3</sub>PO<sub>4</sub>)

**-the stronger the acid, the weaker the base and vice versa**

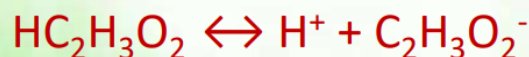


Lactic acid – lactate (conjugated base), formic acid – formate (conjugated base)

- Strong acids and bases are one-way reactions



- Weak acids and bases do not ionize completely



#Pay attention to the arrow's shape

Equilibrium constant:

Any acid (strong or weak) is in equilibrium in three forms, such as: HCL, H<sup>+</sup>,CL<sup>-</sup>  
this equilibrium is present in constant (K) for both strong and weak acids

$$K_a = \frac{[\text{H}_3\text{O}^+] \cdot [\text{A}^-]}{[\text{HA}]}$$

**Note:  $\text{H}_3\text{O}^+ = \text{H}^+$**

$K_a$  = concentration of products / concentration of reactants

The value of the  $K_a$  indicates the direction of the reaction: When  $K_a$  is greater than 1 the product side is favoured (more acidic) = concentration of products is higher than concentration of reactants and that means it is a “strong acid”

When  $K_a$  is less than 1 the reactants are favoured (less acidic) = concentration of products is lower than concentration of reactants and that means “weak acid”

Any disturbance in concentrations leads to distortion in equilibrium

$$pK_a = \{-\log K_a\}$$

Positive answer

$K_a$  less than one so weak acid so high tendency to acidic form (attached to proton)

**TABLE 2.4** Dissociation constants and  $pK_a$  values of weak acids in aqueous solutions at 25°C

Acid	<i>not for memorisation</i>	$K_a$ (M)	$pK_a$
HCOOH (Formic acid)		$1.77 \times 10^{-4}$	3.8
CH <sub>3</sub> COOH (Acetic acid)		$1.76 \times 10^{-5}$	4.8
CH <sub>3</sub> CHOHCOOH (Lactic acid)		$1.37 \times 10^{-4}$	3.9
H <sub>3</sub> PO <sub>4</sub> (Phosphoric acid)		$7.52 \times 10^{-3}$	2.2
H <sub>2</sub> PO <sub>4</sub> <sup>⊖</sup> (Dihydrogen phosphate ion)		$6.23 \times 10^{-8}$	7.2
HPO <sub>4</sub> <sup>⊖</sup> (Monohydrogen phosphate ion)		$2.20 \times 10^{-13}$	12.7
H <sub>2</sub> CO <sub>3</sub> (Carbonic acid)		$4.30 \times 10^{-7}$	6.4
HCO <sub>3</sub> <sup>⊖</sup> (Bicarbonate ion)		$5.61 \times 10^{-11}$	10.2
NH <sub>4</sub> <sup>⊕</sup> (Ammonium ion)		$5.62 \times 10^{-10}$	9.2
CH <sub>3</sub> NH <sub>3</sub> <sup>⊕</sup> (Methylammonium ion)		$2.70 \times 10^{-11}$	10.7

\* The lower the  $pK_a$  is, the more acidic it is.

\* formic acid is a weak acid but stronger than acetic acid, it has a higher tendency to dissociate into products compared to acetic acid.

\* $\text{H}_3\text{PO}_4 > \text{H}_2\text{PO}_4^- > \text{HPO}_4^{2-}$  tendency to lose protons

\*carbonic acid pKa is 6.4 (remember that)

Name	Formula	$K_a$	p $K_a$
Hydrochloric acid	HCl	$1.0 \times 10^7$	-7.00

\* $K_a$  is much much much higher than one

\*For each molecule of HCl I have 10 million molecules of hydrogen or  $\text{Cl}^-$

\* strong acids Involved in equilibrium but the arrow mainly goes toward the products

\* strong acids dissociate almost 100%

Solutions can be expressed in terms of its concentration or molarity.

Acids, bases and ions can also be expressed in terms of their normality (N) or equivalence (Eq).

Molarity of solutions: three values determine the Molarity: molecular weight, grams, volume.

- Moles of a solution are the amount in grams in relation to its molecular weight (MW or a.m.u.).

$$\text{moles} = \text{grams} / \text{MW}$$

- A molar solution is where the number of grams equal to its molecular weight (moles) in 1 liter of solution.

$$M = \text{moles} / \text{volume (L)}$$

- Since ( $\text{mol} = \text{grams} / \text{MW}$ ), you can calculate the grams of a chemical you need to dissolve in a known volume (L) of water to obtain a certain concentration (M) using the following formula:

$$\text{grams} = M \times \text{volume (L)} \times \text{MW}$$

**micro =  $10^{-6}$  , milli =  $10^{-3}$  , nano =  $10^{-9}$**

**main unit = grams and litre**

**simple Exercise:**

- How many grams do you need to make 5M NaCl solution in 100 ml (MW 58.4)?

$$\text{grams} = 58.4 \times 5 \text{ M} \times 0.1 \text{ liter} = 29.29 \text{ g}$$

**May any of the variables be required**

**Equivalents: we use it to measure the amount of acids, bases and ions, it refers to molarity, moles and molecular weight**

**When it comes to acids, bases and ions, it is useful to think of them as equivalents.**

**An equivalent is the amount of moles of hydrogen ions that an acid can donate, or a base can accept.**

A 1 g-Eq of any ion is defined as the molar mass of the ion divided by the ionic charge.

Equivalent refers to number of moles donated or can be accepted ,by bases, or the amount of charges (either protons or hydroxyl ions)

1 mol of HCL will form 1 mole of protons that will be equal to one equivalent

1 mol of H<sub>2</sub>SO<sub>4</sub> will form 2 moles of protons that will be equal to two equivalents so two charged molecules

If I need 1 eq of H<sub>2</sub>SO<sub>4</sub> so we need ½ mole to have one charge molecule

For ions , one eq = molar weight of the ion

\*One equivalent of Na<sup>+</sup> = 23.1 g

\*One equivalent of Cl<sup>-</sup> = 35.5 g

\*One equivalent of Mg<sup>2+</sup> = (24.3)/2 = 12.15 g (divided by the charge, negative is not important)

Remember: One equivalent of any acid neutralizes one equivalent of any base.

## Molarity and equivalents

Q: If we have 1 mole of H<sub>3</sub>PO<sub>4</sub> will it give us 3 moles of H<sup>+</sup>?

No that is not necessary because it is weak acid and it does not dissociate completely.

When we have 1 mole of a strong acid such as HCl it will give 1 mole of H<sup>+</sup>

So you might ask, but in the case of 1 mole of H<sub>2</sub>SO<sub>4</sub> it will give us 1 H<sup>+</sup> and 1 HSO<sub>4</sub><sup>-</sup>, but 1 HSO<sub>4</sub><sup>-</sup> will not give us 1 mole of H<sup>+</sup> and 1 SO<sub>4</sub><sup>2-</sup>, that is right but we can assume that 1 mole of H<sub>2</sub>SO<sub>4</sub> will give us 2 moles of H<sup>+</sup>.



**Neutralization:** to neutralize Hydrochloric acid (HCl), we need to add a strong base e.g. NaOH in the same concentration as the strong acid. As HCl dissociates completely into protons and NaOH dissociates completely into hydroxyl ions. (n is the same for HCl & NaOH)

To neutralize sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) we need a doubled concentration of NaOH since H<sub>2</sub>SO<sub>4</sub> produces 2 protons while NaOH produces 1 hydroxyl ion.

(1 mol of HCl needs 1 mol of NaOH to be neutralized. 1 mol of H<sub>2</sub>SO<sub>4</sub> needs 2 mol of NaOH to be neutralized.)

- Neutralization results in equal concentration for both H<sup>+</sup> & OH<sup>-</sup>.

**Note:** equivalent is more accurate than either molarity or volume to measure the amount, that's why we need to use this equation:

$$\text{Equivalents} = n \times M \times \text{volume (L)}$$

\*n: no. of protons/electrons that are gained/lost (no. of charges that can be

carried)

\*M: molarity

- For an acid to be neutralized by a base, the equivalent of both must be equal. One equivalent of any acid neutralizes one equivalent of a base. Then (n x M x vol) of an acid is neutralized by (n x M x vol) of a base.

This is done in a process known as **Titration**.

**Titration** is 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.

### **Problems:**

10.92: Titration of a 12.0 mL solution of HCl requires 22.4 mL of 0.12 M NaOH. What is the molarity of the HCl solution?

note that each one produces 1 mole of H<sup>+</sup> or OH<sup>-</sup> , so 1M of HCl is equal to 1M of NaOH, so 1M HCl produces 1M of H<sup>+</sup> , which is neutralized by 1M NaOH, which produces 1M OH

Eq of acid = Eq of base

$$n \times M1 \times Vol1 = n \times M2 \times Vol2$$

$$1 \times M2 \times 12 = 1 \times 0.12 \times 22.4$$

$$M2 = (0.12 \times 22.4) / 12$$

$$M2 = 0.224 \text{ M}$$

10.93 what volume of 0.085 M HNO<sub>3</sub> is required to titrate 15.0 mL of 0.12 M Ba(OH)<sub>2</sub> solution?

note that 1 mole of HNO<sub>3</sub> produces 1 mole of H<sup>+</sup> , but 1 mole of Ba(OH)<sub>2</sub> produces 2 moles of OH<sup>-</sup> . In other words, the n is different.

Also, remember that Equivalents = n x M x volume (L), where n is the number of charges or the number of H<sup>+</sup> (or OH<sup>-</sup>) the acid or base can produce or accept.

- Titration means that we add an acid to a base slowly. At one point during titration, the acid and the base neutralize or cancel each other. In other words, “to titrate” means “to neutralize”. At the point of neutralization, the concentration of H<sup>+</sup> is equal to the concentration of OH<sup>-</sup>. The best way to calculate how much acid is needed to neutralize a base (or the opposite) is to calculate the equivalents.

Eq of acid = Eq of base

$$n \times M1 \times Vol1 = n \times M2 \times Vol2$$

$$1 \times 0.085 \times Vol = 2 \times 0.12 \times 15$$

$$Vol = (2 \times 0.12 \times 15) / 1 \times 0.085$$

$$Vol = 42.35 \text{ mL}$$

## Ionization of water

- Water dissociates into hydronium (H<sub>3</sub>O<sup>+</sup>) and hydroxyl (OH<sup>-</sup>) ions.

For simplicity, we refer to H<sub>3</sub>O<sup>+</sup> as H<sup>+</sup> and write the reaction equilibrium as:



The equilibrium constant K<sub>eq</sub> of the dissociation of water is:

$$K_{\text{eq}} = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]}$$

Q: does H<sub>2</sub>O have a concentration? Yes it does (it's constant) about 55.6 M.

Q: How did we know that the molarity of H<sub>2</sub>O in is 55.6 M?

ans: Density of water is 1kg/1L so 1L has 1000g mass of water.

\*\*no. of moles = mass/molar mass = 1000/18 = 55.6 moles

\*\*molarity = no. of moles/ volume of solution(L) = 55.6/1 = 55.6 M

\*\*\*The equilibrium constant for water ionization under standard conditions is:  $1.8 \times 10^{-16}$  M. (memorize it)

- Every 1 M of 55.6 M in water dissociates into  $1.8 \times 10^{-16}$  of [H<sup>+</sup>][OH<sup>-</sup>].  
 $\sqrt{1.8 \times 10^{-16}}$  of each

\*\*\*\*توضيح للنقطة الي انذكرت:

$$K_{\text{eq}} = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]}$$

لو فرضنا تركيز الماء 1M وعوضنا بالقانون:

$$K_{\text{eq}} \cdot [\text{H}_2\text{O}] = [\text{H}^+][\text{OH}^-]$$

$$***[\text{H}^+] = [\text{OH}^-] = x***$$

$$K_{\text{eq}} \cdot [\text{H}_2\text{O}] = x^2$$

$$\sqrt{K_{\text{eq}} \cdot [\text{H}_2\text{O}]} = x$$

So, if we supposed [H<sub>2</sub>O] = 1M (which is 55.6 M originally and not 1M)

$$\text{Then } \sqrt{K_{\text{eq}}} = x$$

$$X = \sqrt{1.8 \times 10^{-16}}$$

**\*\*Since there are 55.6 moles of water in 1 liter, the product of the hydrogen and hydroxide ion concentrations results in a value of  $1 \times 10^{-14}$  for:**

$$K_{eq} (55.5 \text{ M}) = [\text{H}^{\oplus}] [\text{OH}^{\ominus}]$$

This constant,  $K_w$ , is called the ion product for water:

$$K_w = [\text{H}^{\oplus}] [\text{OH}^{\ominus}] = 1.0 \times 10^{-14} \text{ M}^2 \quad (\text{memorize it})$$

Water will mainly exist in the form of  $\text{H}_2\text{O}$  rather than ions. But has an equal concentration of protons and hydroxyl ions  $[\text{H}^+] = [\text{OH}^-] = 1.0 \times 10^{-7} \text{ M}$ . It is considered a weak acid and a weak base due to the little concentrations of both ions.

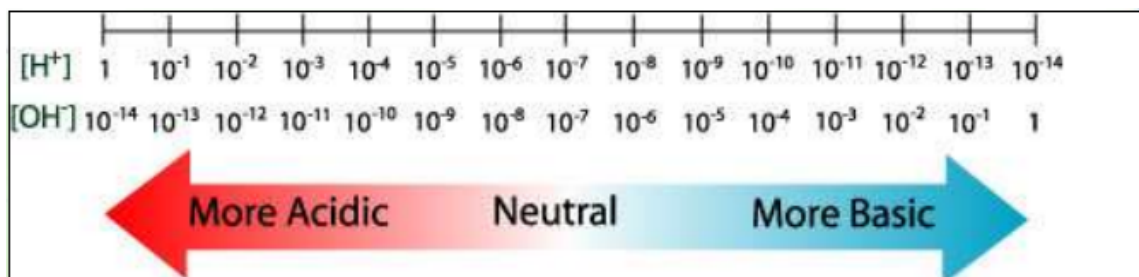
**\*\*Since  $K_w$  is a fixed value, the concentrations of  $[\text{H}^+]$  and  $[\text{OH}^-]$  are inversely changing.**

- If the concentration of  $\text{H}^+$  is high, then the concentration of  $\text{OH}^-$  must be low, and vice versa. For example, if  $[\text{H}^+] = 10^{-2} \text{ M}$ , then  $[\text{OH}^-] = 10^{-12} \text{ M}$ .

Adding an acid or a base to the pure water will disturb the equivalent:

-If we add an acid to the water,  $[\text{H}^+]$  increases and  $[\text{OH}^-]$  decreases so that  $[\text{H}^+][\text{OH}^-] = K_w = 1.0 \times 10^{-14} \text{ M}^2$ .

-If we added a strong base for example and  $[\text{OH}^-]$  became  $10^{-3} \text{ M}$  then  $[\text{H}^+]$  would be  $10^{-11} \text{ M}$ .



قف دون رأيك في الحياة مجاهدًا

إن الحياة عقيدة وجهادٌ