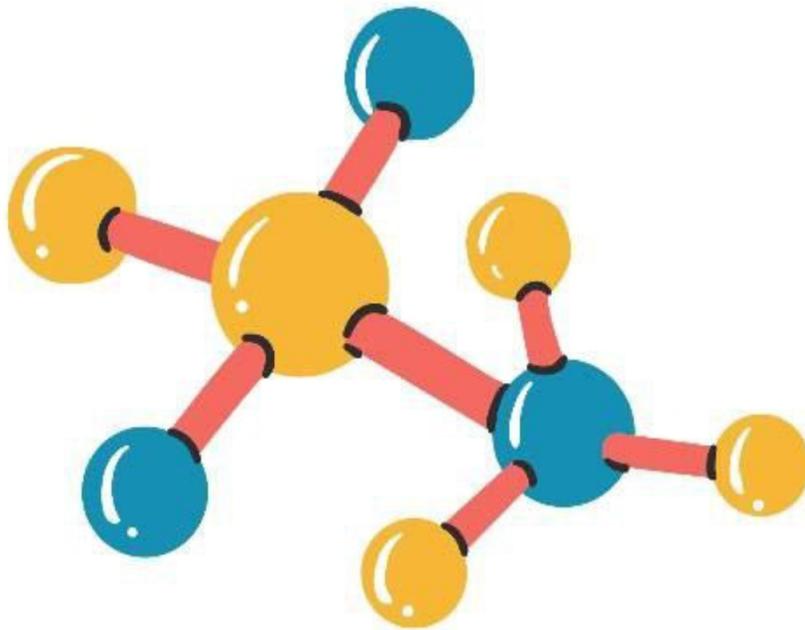


Sheet no. **2**



# Biochemistry



Summer 2022

**Writer:** Ahmad Derbashi

**Corrector:** Salih Al-Qaderi

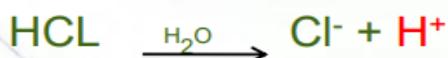
**Doctor :** Dr. Nafez & Dr. Diala

# Acids and Bases

- Acids and bases have different definitions depending on scientists who studied them, as follows:

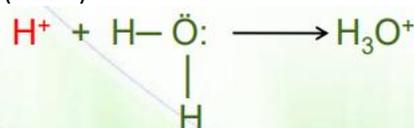
- A-Arrhenius definition of acids and bases:**

1-Acids in H<sub>2</sub>O are H<sup>+</sup>(Proton) donors

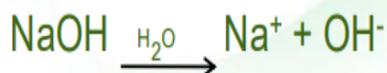


Note that H<sub>3</sub>O<sup>+</sup> is produced because; in Arrhenius definition, reactions has to happen in an aqueous solution (H<sup>+</sup> goes from the acid to the water)

Since H<sup>+</sup> is highly unstable so it couples with water to produce hydronium ion (H<sub>3</sub>O<sup>+</sup>)



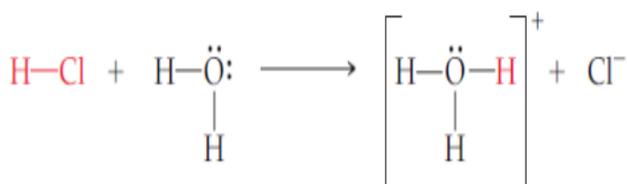
2-Bases in H<sub>2</sub>O are OH<sup>-</sup>(hydroxide) donors



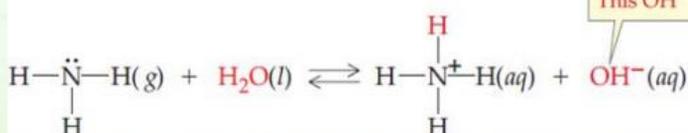
- B-Bronsted-Lowry definition of acids and bases:**

-It focuses on protons,so:

1-Acids are substances able to give a hydrogen ion (proton) to another molecule  $\longrightarrow$  **Proton Donor**



2-Bases are substances that accept protons from other acids  $\longrightarrow$  **Proton Acceptor**

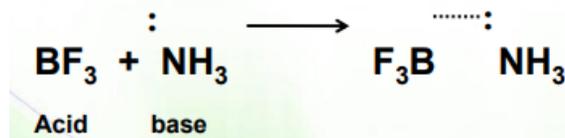


This OH<sup>-</sup> ion comes from H<sub>2</sub>O.

- **C- Lewis definition of acids and bases:**

-It focuses on electrons , so:

\*Acids are **electrons acceptors** while Bases are **electrons donors** , example :



here the NH<sub>3</sub> has a pair of unshared electrons ( donor ) so it is a Lewis Base ( or basically ; a base )

NOTE:It is not necessary for an acid to apply on all three definitions to be an acid,one is enough

يعني اي حمض او قاعدة بتتطبق عليه وحدة من التعريفات الثلاث بعتبره حمض او قاعدة خلص , مش ضروري تتطبق عليهم التعريفات الثلاث

Q: Do we consider H<sub>2</sub>O as acid or base?

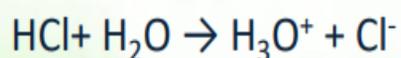
Ans:Water is **amphoteric substance:substances that can act as an acid in one reaction and as a base in another one;** depending on the solution or the other reactants

So for example ;

-With ammonia (NH<sub>3</sub>) water acts as an acid because it donates proton to NH<sub>3</sub> , as follows



-With hydrochloric acid (HCl) , water acts as a base because it accepts proton from HCl , as follows



Note: monoprotic means having one proton like HCl

polyprotic means having more than one proton like diprotic(H<sub>2</sub>SO<sub>4</sub>) or triprotic(H<sub>3</sub>PO<sub>4</sub>)

# Acids and Bases Strength

- What do we mean by their ' Strength ' , what is the scale for both to be weak or strong?
  - One way to think of it,their strength is their ability to release protons (for acids) or their ability to accept protons (for bases) حسب برونستد
  - Acids differ in their ability to release protons , and **STRONG ACIDS dissociate(almost) 100%.** (حسب برونستد)
  - Bases differ in their ability to accept protons , and **STRONG BASES have strong affinity for protons.** (حسب برونستد)

**Strong vs. weak acids**

- Strong acids and bases are one-way reactions
 
$$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$$

$$\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-$$
- one way = irreversible
- Weak acids and bases do not ionize completely
 
$$\text{HC}_2\text{H}_3\text{O}_2 \leftrightarrow \text{H}^+ + \text{C}_2\text{H}_3\text{O}_2^-$$

$$\text{NH}_3 + \text{H}_2\text{O} \leftrightarrow \text{NH}_4^+ + \text{OH}^-$$
- Reversible = partial dissociation

Dr.Nafith said in the lec;

-Acids and bases differ in strength due to:

- 1-their chemical structure
- 2-their need to accept of receive H+ (This in turn

depends on the amount of H+ it already has).For example,the stronger the acid,the higher its concentration of H+ and the more readily and quickly it donates H+(stronger).

We see that strong acids/bases reactions are one way because they are strong , they dissociate (almost) completely. While weak acids/bases reactions are reversible.

For multi-protic acids like (H<sub>2</sub>SO<sub>4</sub>,H<sub>3</sub>PO<sub>4</sub>) (Lined in blue and red) each proton is donated at different strength.

لاحظ انهم يفقدوا البروتونات على مراحل,وكل مرحلة بضعفوا اكثر

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

Base strength increases

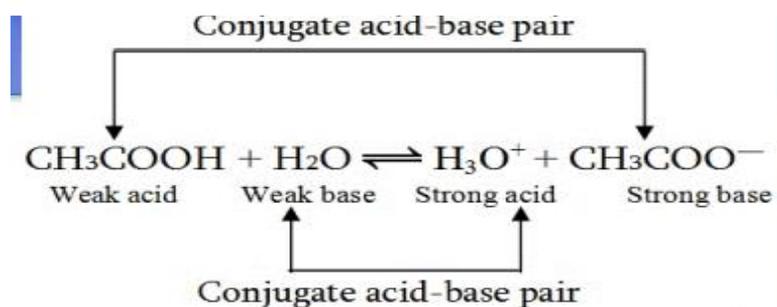
100 percent protonated in H<sub>2</sub>O

Dr. nafez told us to memorize the strong acids and bases(any thing else is automatic ally weak

القوي بعطي ضعيف : القوي بعطي قوي  
والضعيف بعطي قوي

-The stronger the acid,the weaker the conjugate base

-The stronger the base,the weaker the conjugate acid



طيب , عرفنا كيف نميز الحمض الضعيف من القوي والقاعدة القوية من الضعيفة ,  
كيف نميز بين القوية مين اقوى مثلا,وبكم أقوى؟ او الحموض الضعيفة مين اضعف او  
القواعد الضعيفة مين اضعف وهكذا؟الفصل هون هي الارقام , عشان هيك عنا قوانين  
لحساب قوة الحمض او القاعدة بالارقام ← Ka and Kb

## Equilibrium constant and acid dissociation constant Ka

- Acid/base solutions are at constant equilibrium
- concentration of reactants and products may not be equal at equilibrium, means they reached stability with respect to the amount of equal energy not concentration.
- -How do we get Ka formula?

Consider this equation:  $\text{HA} + \text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{A}^-$  ( $\text{H}^+ = \text{H}_3\text{O}^+$ )

We write equilibrium constant (Keq) for such reactions:

$$\text{Keq} = \frac{[\text{products}]}{[\text{reactants}]}$$

$$\text{For the equation above ; Keq} = \frac{[\text{H}_3\text{O}^+].[\text{A}^-]}{[\text{HA}].[\text{H}_2\text{O}]}$$

and for simplicity, and since  $[\text{H}_2\text{O}]$  is stable ,

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

- In a closer look at the formula , we notice ;

Meaning that we have more protons concentrations in products (at the conjugated base) , thus more dissociation of acid and the products side is favored

← اذا البسط كان اكبر من المقام  
(Ka value is greater than 1)

Meaning that we have more acid concentrations in reactants , less dissociation and reactants side is favored

← اذا كان المقام اكبر من البسط  
(Ka value is less than 1)

**-So we conclude that Ka value indicates the direction of reaction**

- A term to know: pKa  
we use it for simplicity , as we see in the table below Ka values have mines powers , so we use pKa term to get rid of these powers.

Notice that the relation between Ka and pKa is inverse  
علاقة عكسية

### What is pKa?

$$pK_a = -\log K_a$$

Acid	$K_a(M)$	$pK_a$
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

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

**TABLE | 9.4  $K_A$  AND  $pK_A$  VALUES FOR SELECTED ACIDS**

Name	Formula	$K_a$	$pK_a$
Hydrochloric acid	HCl	$1.0 \times 10^7$	-7.00
Phosphoric acid	$H_3PO_4$	$7.5 \times 10^{-3}$	2.12
Hydrofluoric acid	HF	$6.6 \times 10^{-4}$	3.18
Lactic acid	$CH_3CH(OH)CO_2H$	$1.4 \times 10^{-4}$	3.85
Acetic acid	$CH_3CO_2H$	$1.8 \times 10^{-5}$	4.74
Carbonic acid	$H_2CO_3$	$4.4 \times 10^{-7}$	6.36
Dihydrogenphosphate ion	$H_2PO_4^-$	$6.2 \times 10^{-8}$	7.21
Ammonium ion	$NH_4^+$	$5.6 \times 10^{-10}$	9.25
Hydrocyanic acid	HCN	$4.9 \times 10^{-10}$	9.31
Hydrogencarbonate ion	$HCO_3^-$	$5.6 \times 10^{-11}$	10.25
Methylammonium ion	$CH_3NH_3^+$	$2.4 \times 10^{-11}$	10.62
Hydrogenphosphate ion	$HPO_4^{2-}$	$4.2 \times 10^{-13}$	12.38

## The equilibrium constant, $K_a$



Acid

Conjugate  
base

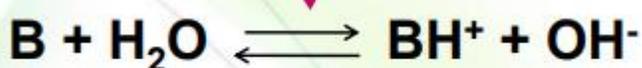
$$K_a = \frac{[H^+][A^-]}{[HA]}$$

Larger  $K_a$  means:  
More dissociation  
Smaller  $pK_a$   
Stronger acid

## Base dissociation constant $K_b$

- When  $K_b$  is greater than 1 it's a strong base and when its less than 1 it's a weak base

((When greater than 1 it means that concentration of  $BH^+$  is higher , thus the base  $B$  had more affinity to accept protons --- so it's a strong base as we said before))



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

Notice that if we reverse the reaction , we can calculate the  $K_a$  for the conjugated acid  $BH^+$



$$K_a = \frac{[B][H^+]}{[BH^+]}$$

## Examples of $K_b$

**TABLE 7.3** Values of  $K_b$  for Some Common Weak Bases

Name	Formula	Conjugate Acid	$K_b$
Ammonia	$NH_3$	$NH_4^+$	$1.8 \times 10^{-5}$
Methylamine	$CH_3NH_2$	$CH_3NH_3^+$	$4.38 \times 10^{-4}$
Ethylamine	$C_2H_5NH_2$	$C_2H_5NH_3^+$	$5.6 \times 10^{-4}$
Aniline	$C_6H_5NH_2$	$C_6H_5NH_3^+$	$3.8 \times 10^{-10}$
Pyridine	$C_5H_5N$	$C_5H_5NH^+$	$1.7 \times 10^{-9}$

## Measurement of concentration

- Solutions can be expressed in terms of its molarity, molality, normality, equivalence. (Normality is not required).

### **-Molarity:**

\*We know that 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 one in which 1 liter of solution contains the number of grams equal to its molecular weight.  $M = \text{moles} / \text{volume}$

Exercise:

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

Ans:

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

we need number of moles so  $\text{moles} = M * V(L)$

$\text{moles} = 0.5 \text{mol}$

$-\text{Mass}(\text{grams}) = 0.5 * 58.4 = 29.2$

NOTE: its solved in another way in slides , but Dr.Diala said its better to use this way

## Equivlanets (Acids/Bases/and Ions)

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

\*1 equivalent of a strong acid contains 1 mol of H<sup>+</sup> ions, and 1 g-Eq of an acid is the mass in grams that contains 1 mol of H<sup>+</sup> ions.

\*Similarly, 1 equivalent of a strong base contains 1 mol of OH ions, and 1 g-Eq of a base is the mass in grams that contains 1 mol of OH ions.

### Examples:

- 1- 1 mol HCl = 1 mol [H<sup>+</sup> ] = 1 equivalent
  - 2- 1 mol H<sub>2</sub> SO<sub>4</sub> = 2 mol [H<sup>+</sup> ] = 2 equivalents
- \*\*\*\*Remember: One equivalent of any acid neutralizes one equivalent of any base

\*For ions, a 1 g-Eq of any ion is defined as the molar mass of the ion divided by the ionic charge without the sign (negative or positive), only number.

- \*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

Equivalence is a property of acids and bases

- For ACIDS and BASES

-For acids, one equivalent is the amount of the acid (in moles) that supplies one mole  $H^+$  ions

-For bases, one equivalent is the amount of the base (in moles) that supplies one mole  $OH^-$  ions

for example, One equivalent of  $HCl = 1 \text{ mol}$

and One equivalent of  $NaOH = 1 \text{ mol}$

why? Because the amount needed for  $HCl$  to produce  $1 \text{ mol } H^+$  is  $1 \text{ mol}$ , thus One Eq =  $1 \text{ mol}$  ( and so for  $NaOH$ )

That's why we said One eq of any base can neutralize one eq of any acid, because both will produce same quantity of  $H^+$  and  $OH^-$ !!!!

Q: What is one Eq of  $H_2SO_4$ ?

Ans: we call that one Eq of an acid is the amount of it needed to produce  $1 \text{ mol } H^+$

Now  $1 \text{ mol } H_2SO_4$  produces  $2 \text{ mol } H^+$ , can we say one Eq =  $1 \text{ mol } H_2SO_4$ ? NO, we say One Eq =  $0.5 \text{ mol } H_2SO_4$  because it is the amount needed of it to produce  $1 \text{ mol } H^+$

Exercise; what is one eq of  $Al(OH)_3$ ?

- For Ions:

Equivalent of ion is amount of ion(in grams) needed to supply or react with 1 mole of electrons, that's why we divide the mass of 1 mol of ion by its charge

يعني مثلا عنا صوديوم +1 , بدنا الكمية منه اللي بتتعاادل مع 1 مول الكترونات , كم بتطلع ؟ بالزبط 1 مول .. وبنحولها لغرامات ..

شرح اكثر : ذرة صوديوم وحدة بتعاادل الكترون واحد , فالكمية اللازمة عشان تعادل 1 مول الكترونات هي 1 مول , بس بنحولها لغرامات

طب مثلا عنا مغنيسيوم +2, شو الكمية منه اللي بتعاادل 1 مول الكترونات ؟ اذا حكيينا انها 1 مول بتطلع ضعف شحنة الالكترونات لانه شحنته موجب 2 , عشان هيك بنقسم على 2 او على الشحنة بشكل عام , هيك طلعتنا الكمية بالمولات , بعدين بنحولها لغرامات

شرح اكثر : ذرة مغنيسيوم وحدة بتعاادل الكترونين , فالكمية اللازمة عشان تعادل 1 مول الكترونات هي نص مول مغنيسيوم +2 .. وبنحولها لغرامات

Calculate milligrams of  $Ca^{+2}$  in blood if total concentration of  $Ca^{+2}$  is 5 mEq/L.

Ans:

we get the Eq value , =  $40.1g/2=20.1g$

Grams of  $Ca^{+2}$  in blood = =  $(5 \text{ mEq/L}) \times (1 \text{ Eq}/1000 \text{ mEq}) \times (20.1 \text{ g}/ 1 \text{ Eq}) = 0.1 \text{ g/L} = 100 \text{ mg/L}$

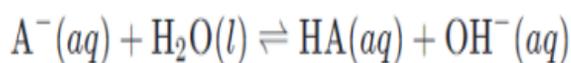
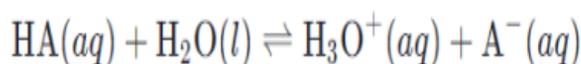
- Ionization of water :

Water dissociates into hydronium( $\text{H}_3\text{O}^+$ ) and hydroxyl ( $\text{OH}^-$ ) ions .

-For simplicity , we refer to the hydronium ion as a hydrogen ion ( $\text{H}^+$ ) and write the reaction equilibrium as:



- Ion product of the water:



$$K_a \cdot K_b = \left( \frac{[\text{H}_3\text{O}^+][\cancel{\text{A}^-}]}{[\text{HA}]} \right) \left( \frac{[\cancel{\text{HA}}][\text{OH}^-]}{[\cancel{\text{A}^-}]} \right)$$

$$= [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$= K_w = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

## The Equilibrium constant of water

H<sub>2</sub>O dissociates to a slight extent to form hydrogen H<sup>+</sup> and Hydroxyl OH<sup>-</sup> ions , as the reaction below



-The equilibrium constant of the dissociation of water is

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

and under standard conditions , the Keq for water ionization is  $1.8 \times 10^{-16} \text{ M}$ .

**K<sub>w</sub>**: since there are 55.6 moles of water in 1 liter , the result is :  $K_{\text{eq}} (55.5 \text{ M}) = [\text{H}^{\oplus}] [\text{OH}^{\ominus}]$

So the product of the hydrogen and hydroxide ion concentrations results in a value of  $1 \times 10^{-14}$ .

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

This constant ,K<sub>w</sub>, is called The ion product of water.

-Notice that the [H<sup>+</sup>] of pure water is only 0.0000001M

Q:Why is there 55.6 moles of water in 1 liter , as we indicated above?

Ans:

The condensity of water is 1kg/1L so 1L has 1000g mass of water,and since molar mass=mass/n of moles

$$\longrightarrow n \text{ moles} = \text{mass} / \text{molar mass}$$

$$\longrightarrow = 1000 / 18 = 55.6 \text{ moles}$$

- **[H<sup>+</sup>] and [OH<sup>-</sup>] :**

-For pure water , there are equal concentrations of H<sup>+</sup> and OH<sup>-</sup> , each with a value of  $1 \times 10^{-7} \text{M}$ .

Since  $K_w$  is a fixed value , the concentrations of H<sup>+</sup> and OH<sup>-</sup> are inversely changing, for example : if the concentration of H<sup>+</sup> is high, the concentrations of OH<sup>-</sup> must be low , and vice versa.

\*If  $[\text{H}^+] = 10^{-2}$  , then  $[\text{OH}^-] = 10^{-12}$

## From -20 Sheet

### Extra Practice Questions:

Q1) What **volume** of 0.15M Ba(OH)<sub>2</sub> is required to neutralize 45 ml of 0.29M HCl.

Q2) It takes 83 mL of a 0.45 M NaOH solution to neutralize 235 mL of an HCl solution. What is the **concentration** of the HCl solution?

Q3) It takes 38 mL of 0.75 M NaOH solution to completely neutralize 155 mL of a sulfuric acid solution (H<sub>2</sub>SO<sub>4</sub>). What is the **concentration** of the H<sub>2</sub>SO<sub>4</sub> solution?

Q4) It takes 12.5 mL of 0.30 M HCl solution to neutralize 285 mL of NaOH solution. What is the **mass** in grams of the NaOH solution? (mw of NaOH = 40g/mol)

Q5) 33 mL of 3M Hydrochloric acid HCl is titrated with sodium hydroxide NaOH to form water and sodium chloride. How many **mmols** of sodium hydroxide are consumed in this rxn?

ANSWERS KEY	
QUESTION	ANSWER
Q1	43.5 ml* you can also convert to Liters
Q2	0.16 M
Q3	0.092 M
Q4	0.15 g
Q5	~100 mmol

# GOOD LUCK