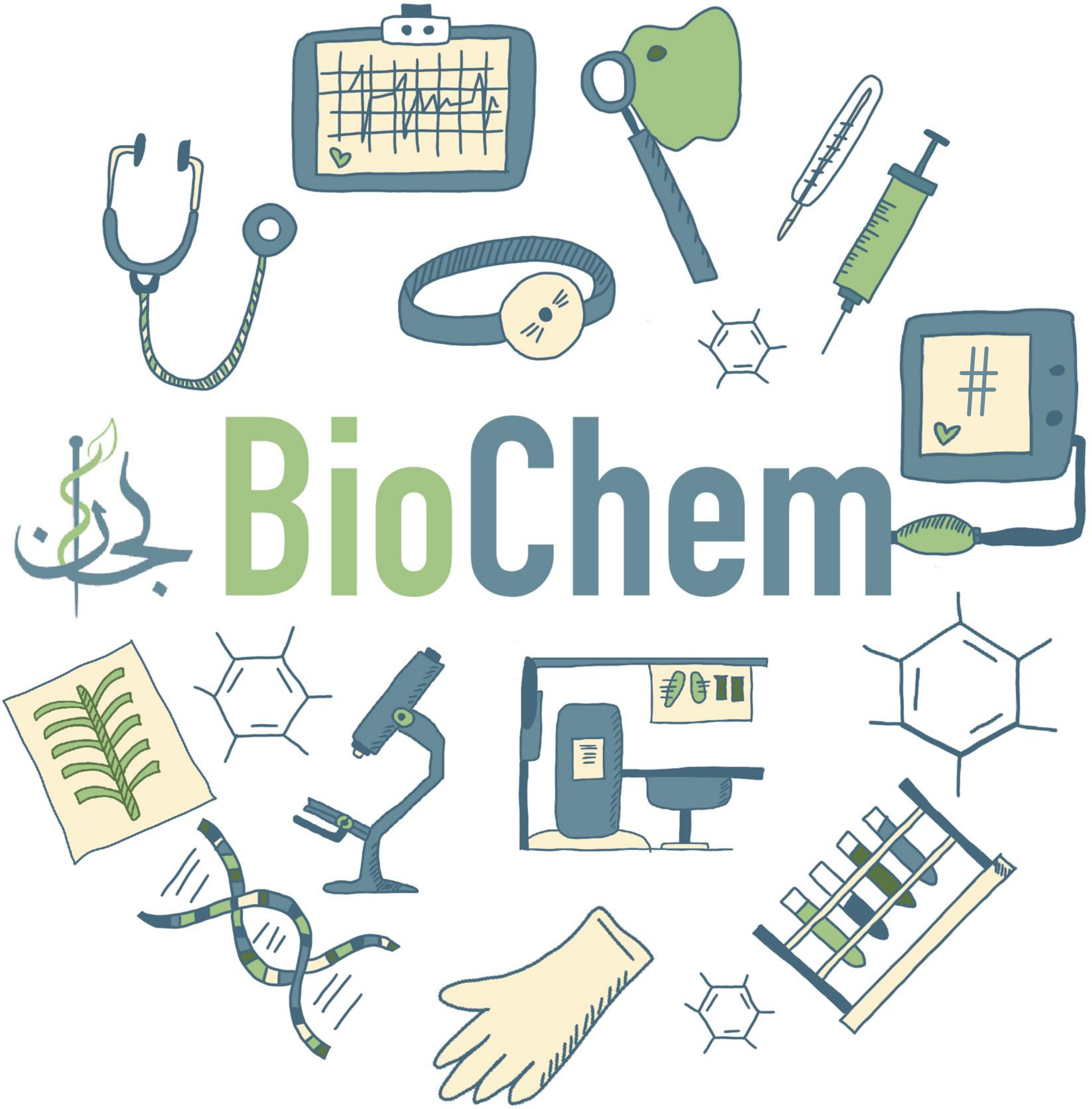

BioChem

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Acids and Bases

In this sheet we will talk about the three definitions of acids and bases, acids and bases strength, equilibrium constant (K_a), pH and some calculations to find the molarity, mass, equivalence, normality and volume in some solutions.

Even if you see it's a long sheet, it's going to be an easy one to study since we have taken all these topics in high school and in general chemistry course in our first semester**.**

We have 3 definitions for acids and bases depending on the scientist who was studying them:

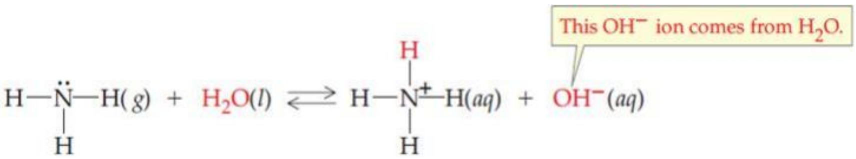
1-Arrhenius definition

-Acid: a substance that produces H^+ when dissolved in water (proton donor).

Here the acid is (HCL) because it gave H^+ to the base (H_2O).
And H_2O became H_3O^+ **(hydronium ion).**

Note: Cl^- is the conjugate base of the acid HCl.
H_3O^+ is the conjugate acid of the base H_2O.

-Base: a substance that produces OH^- when dissolved in water.



Here the NH_3 molecule accepts a proton from water molecule causing the release of OH^- from water molecules in the solution, so here NH_3 is the base and H_2O is the acid.

2-Bronsted-Lowry definition

In this one the main focus is the proton itself and acids again are donors of proton while bases are accepters of these protons.

-Acids donate H^+ (proton donor).

-Bases accept H^+ as it has non bonding pairs of electrons (proton accepter).

$$\underset{\text{Base}}{B:} + \underset{\text{Acid}}{H-A} \rightleftharpoons \underset{\text{Acid}}{BH^+} + \underset{\text{Base}}{A^-}$$

Here the Acid (HA) has a proton and it donates this proton and releases a conjugate base (A^-). And the base here is (B) which has non bonding pair of electrons so it accepts the proton and releases a conjugate acid (BH^+).

3-lewis definition

-acids accept electrons.

-bases donate electrons (non bonding pairs).

$$\underset{\text{Acid}}{BF_3} + \underset{\text{base}}{:NH_3} \longrightarrow F_3B\cdots\cdots:NH_3$$

NH_3 has an unshared pair of electrons that can be shared with the boron atom in the BF_3 molecule.

Here this sort of attractions makes the NH_3 as an electron donor (although it doesn't donate them completely but it shares them partially with the boron in this attraction.

So here NH_3 is electron donor (base) and BF_3 is electron acceptor (acid).

Types of acids

Acids are classified depending on the number of protons they have to:

1- Monoprotic acid: acid with one proton (HCL, HNO_3, CH_3COOH).

2-Diprotic acid: acid with two protons (H_2SO_4).

3-Triprotic acid: acid with three protons (H_3PO_4).

*Diprotic and triprotic are considered polyprotic acids.

Water molecule

it's not considered neither an acid nor a base.
It acts as an acid or a base depending on the solution or the substance that is found with it.

For example in this equation water is mixed with ammonia which is a base, so here water donates a proton and becomes OH^- (here water is an acid).

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

While in this reaction when water is mixed with hydrochloric acid, water accepts a proton and becomes H_3O^+ thus is considered a base.

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

*This type of material that can react as an acid in certain reactions and as a base in others is called amphoteric substance, so water has the characteristic of amphoterism.

*You must differentiate between amphoteric and amphipathic substances.
amphipathic means a molecule that has 2 sides, one of them is polar and the other is non polar.
While amphoteric is a substance that can react as an acid or a base depending on the substance that is mixed with.

Acid/base strength

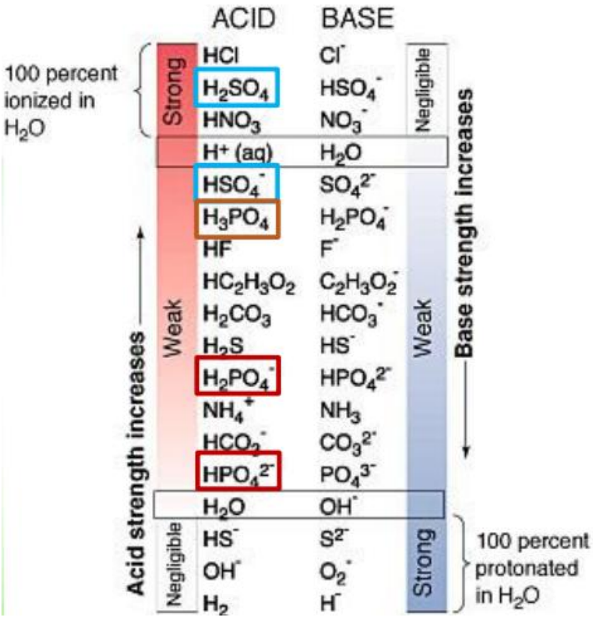
strong acids will dissociate completely, what does that mean?
That means it's going to release protons with almost 100% of the molecules in the solution if that strong acid becomes deprotonated.

In chemistry lab you will be warned a lot when dealing with acids like HCl because it's a very strong acid if it touches an area on your body it's going to burn it.

-Different acids have different ability to release their protons (there are weak and strong acids).
-Even stronger acids are classified according to their strength relative to each other.
-Strong acids release high amount of H^+, while weak acids release low amounts of H^+.

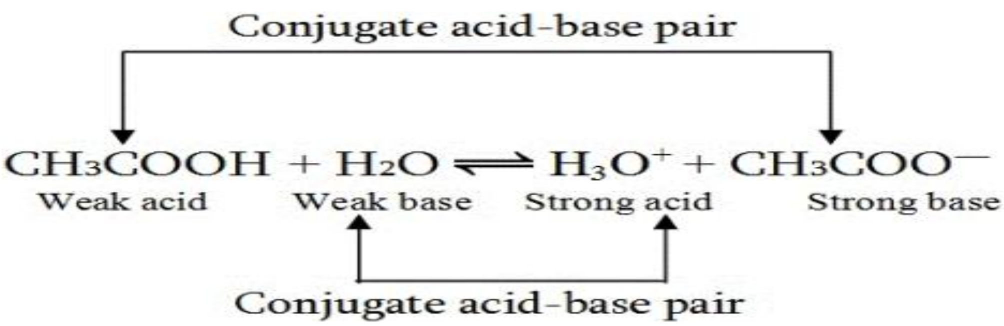
For multiprotic (polyprotic) acids like (H_2SO_4, H_3PO_4) each proton is donated at different strength.
The deprotonation or dissociation of polyprotic acids is going to be gradual,
for example: H_2SO_4 is not going to lose the 2 protons in one step but in 2 steps.
First it will become HSO_4^- then this HSO_4^- will become SO_4^{-2}.
same thing for H_3PO_4 but it will happen in 3 steps.
*always the first step is the fastest and easiest and it has the highest K_a (highest percentage of dissociation and highest percentage of deprotonation).

The second step is a little bit weaker and if there is a third step it will be the weakest.



Notice in this picture that H_2SO_4 is stronger than HSO_3^-

When we dissociate an acid we get a conjugate base in the products.
When we dissociate a base we get a conjugate acid in the products.



*The stronger the acid, the weaker the conjugate base and vice versa.
*The stronger the base, the weaker the conjugate acid and vice versa.

*Strong acids and bases are one way reactions, example: $HCl \longrightarrow H^+ + Cl^-$
*Weak acids and bases are one way reactions, example: $HC_2H_3O_2 \longleftrightarrow H^+ + C_2H_3O_2^-$

*Weak acids don't dissociate completely.

Equilibrium constant

how can we compare the strength of different acids?
We need to do this in calculations.
So let's first calculate the equilibrium constant (K_a) for the acid dissociation reaction

HA <--> $H^+ + A^-$

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

$$K(\text{equilibrium}) = \frac{\text{concentration of products}}{\text{concentrarion of reactants}}$$

*If there is H_2O in the equation then we can also calculate it and it will be in the reactant side, but H_2O concentration is constant in all aqueous solutions and it's (55.5 M) (just for your knowledge) and there is a way to calculate it but it's not required.
*Because its constant and present in all solutions we are going to take it out and leave the equation as it's mentioned above (we are not required to calculate H_2O in the K_a equation).

K_a is the acid dissociation constant and if K_a is high that means we have high concentration of hydronium ion (H_3O^+), high concentration of H^+ thus a strong acid.

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

How can K_a value affect the direction of reaction ?
The value of the Ka indicates direction of reaction.
1-When Ka is greater than 1 the product side is favored (products more than reactants).
2-When Ka is less than 1 the reactants are favored (reactants more than products) (reverse direction is favored).

What is pK_a ?

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

Acid	K_a(M)	pK_a
HCOOH (Formic acid)	1.77×10^{-4}	3.8
CH_3COOH (Acetic acid)	1.76×10^{-5}	4.8
$CH_3CHOHCOOH$ (Lactic acid)	1.37×10^{-4}	3.9
H_3PO_4 (Phosphoric acid)	7.52×10^{-3}	2.2
$H_2PO_4^{\ominus}$ (Dihydrogen phosphate ion)	6.23×10^{-8}	7.2
$HPO_4^{2\ominus}$ (Monohydrogen phosphate ion)	2.20×10^{-13}	12.7
H_2CO_3 (Carbonic acid)	4.30×10^{-7}	6.4
$HCO_3^{\ominus}$ (Bicarbonate ion)	5.61×10^{-11}	10.2
$NH_4^{\oplus}$ (Ammonium ion)	5.62×10^{-10}	9.2
$CH_3NH_3^{\oplus}$ (Methylammonium ion)	2.70×10^{-11}	10.7

The **K_a values** if you look at this table for example and specifically when we talk about weak acids, it's going to be numbers that have powers with negative charges and these numbers are kind of hard to deal with so it's better to convert these values to numbers without powers.

So how can we do this?

By taking the logarithm of K_a and then multiply it by -1 to get rid of the negative charge.

$$pK_a = -\log K_a$$

For example the first value for formic acid (HCOOH)

$K_a=1.77*10^{-4}$

pK_a =-log(K_a) =4 – log(1.77)=3.8

The reason for using pK_a? It facilitates dealing with the numbers, **especially when dealing with weak acids.**

The K_a values for strong acids is much higher than in weak acids and that's against what we have learned in high school as we thought that strong acids don't have a K_a value (this is not true actually)because they do have a K_a value but it's very high as you see in the table and that will be reflected on the pK_a.

*Notice that pK_a is the smallest for the strongest acid.

*pK_a and K_a are inversely related (the higher the K_a the lower the pk_a and vice versa).

TABLE | 9.4 K_A AND pK_A VALUES FOR SELECTED ACIDS

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

Summary:

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

Larger K_a means:
more dissociation, smaller pK_a ,stronger acid

Base dissociation constant

السلايد رقم 13 عليها شرح دقيقتين، ضروري ترجعوا للفيديو وتحضروا هالدقيقتين الوقت : 14:15-16:10

https://www.youtube.com/watch?v=OENAzrw-tmw

Base dissociation constant (K_b)

Reverse the reaction:

$BH^+ \rightleftharpoons B + H^+$ $\quad$ $B + H_2O \rightleftharpoons BH^+ + OH^-$

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

TABLE 7.3 Values of K_b for Some Common Weak Bases

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

Just like we said before

$$\mathrm{K(equilibrium)} = \frac{\text{concentration of products}}{\text{concentrarion of reactants}}$$

So $\mathbf{K_a}$ can be calculated when we find H^+ in the products.
While $\mathbf{K_b}$ can be calculated when we find OH^- in the products.

Expression

Solutions can be expressed (described) in terms of concentration or molarity.

For the previous equations, for K_a and K_b we need molarity.

What is molarity ?
The number of moles (n) over the volume of the solution (M=n/V).
Unit of molarity is mol/liter.

How can we know the number of moles (n)?
By dividing the mass (m) over the molecular weight (MW).
n=m/MW

Since n=m/MW (mol=grams/MW) you can calculate the grams of a substance you need to dissolve in a known volume of water to obtain a certain concentration (M) using the following formula
grams= M* Volume* MW

***the mass must be in grams.**

A molar solution is one in which 1 liter of solution contains the number of grams equal to its molecular weight (one liter of solution contains exactly 1 mole of the substance).

Acid and bases can also be expressed in terms of their normality (N) or equivalence (Eq) we will explain them more in this sheet.

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

Solution: We will use the equation from above (grams= M* Volume* MW)
grams =58.4 * 5 * 0.1 = 29.29 gram.

Another way to solve it which I think is better
we need the mass, we will use the main equation
n=m/MW → m=n*MW
we need n (number of moles to solve this equation)
M=n/V → from this equation we find that n=MV = 5*0.1 = 0.5 moles
now we have (n) and (MW) we can find the mass (m=0.5*58.4=29.29 gram).

Equivalents (acids, bases and ions)

When it comes to acids, bases and ions, it is useful to think of them as equivalents (because it is more accurate to compare between two solutions).

Equivalent of acids relate to how **many protons(H^+)** can be donated(moles of protons). Equivalent of bases relate to how **many protons(H^+)** can be accepted, or (OH-) can a bases donate .

For example: one equivalent of a **strong acid** gives one mole of protons ; because strong acid is going to **dissociate completely**, and here we are talking specifically about monoprotic acid .

Similarly, one equivalent of a **strong base** gives one mole of (OH^-) ;because the **complete dissociation.**

Ions have a special situation, one g-Eq ***(gram equivalent)*** of any ion is define as the **molar mass** of the ion divided by the **ionic charge**.

$$\text{g-Eg for any ion} = \frac{Molar\ mass}{ionic\ charge}$$

Example1

A) 1mol HCl = 1mol [H^+] = 1 equivalent

B) 1mol H_2SO_4= 2mol [H^+] = 2 equivalent

C) 1 equivalent of Na^+ = 23.1g

D) 1 equivalent of cl^- = 35.5g

E) 1 equivalent of Mg^{+2} $= \frac{24.3g}{2} =$12.15g (molar mass of Mg divided by the ionic charge)

Remember (very important)

One equivalent of any acid **neutralizes** one equivalent of any base.

Exercise1: Calculate **milligrams** of Ca^{+2} in blood if total concentration of Ca^{+2} is 5mEq/L. (molar mass of Ca^{+2}=40.1g)

1 Eq of ca^{+2} = $\frac{40.1\ g}{2}$ = 20.1g (molar mas of Ca^{+2} divided by the ionic charge)

Convert mEq $\longrightarrow$ Eq

$$\frac{5\ mEq}{L} \times \frac{1\ Eq}{1000\ mEq} \times \frac{20.1\ g}{1\ Eq} = 0.1\ g/L = 100\ mg/L$$

Normal solution

Normality (N) considers both the **Molarity** of the solution and the **equivalent content** of the acid or base.

$$N = n \times M \text{ (where n is an integer)}$$

Note

n: Is the number of protons donated by the acid or number of protons accepted by base or the number of OH a base can donate.

Example2

A) 3M H_2SO_4 solution is the same as a 6N H_2SO_4 solution.

B) 1M $Ca(OH)_2$ solution is the same as a 2N $Ca(OH)_2$ solution.

Note → The normality of a solution is **NEVER** less than the molarity

Exercise2 : What is the **normality of H_2SO_4** Solution made by dissolving 6.5 g into 200 mL ?(MW=98)

Note that : volume in liters

First ….we get Molarity thin multiply it by n(here n =2)

$$M = \frac{moles}{Volume} = \frac{grams}{MW \times Volume} = \frac{6.5}{98 \times 0.2} = 0.33 \text{ molar}$$

N = M ×n = 0.33 ×2 = 0.66 N

****from Dr. mamoun lecture (very useful)**

One of the application of using normality is the process of **neutralization**

Neutralization is the process in which we reach a PH=7 for a solution after mixing up a certain amount of acid and base.

For example: if we have HCl solution that we want to neutralize, we add NaOH to a solution to reach a PH=7

Remember: one mole of HCl releases one mole (one equivalent) of protons (H^+) and one mole of NaOH release one mole of hydroxyl (OH^-) so it is 1:1 ratio regarding to equivalent.

Another example : if we have **two moles** of H_2SO_4 and we want to neutralize it by NaOH , how many moles of NaOH do we need ?

We have two moles of H_2SO_4 = 4 moles of H^+ = 4 equivalent .

But one mole of NaOH = one mole of OH^- =1equivalent

So we need 4 equivalent of OH^- to neutralize 4 equivalent of H

Then we need 4 moles of NaOH.

Normality and equivalents

to connect normality with equivalent and specifically when we talk about titration or neutralization of an acid by a base or base by an acid .

$$\textbf{Normality (N)} = \frac{Equivalent\ of\ acid\ or\ base}{liters\ of\ solution}$$

we said that **the same** number equivalent of an acid is **neutralized** by the same number equivalent of a base , and to have the same number of equivalent for aced and a base we multiply **normality** with the **liters of the solution**(volume).

Problem 1

Titration (neutralization) of a 12.0 mL solution of HCl requires 22.4 mL of 0.12M NaOH. What is the molarity of the HCl solution?

* This is a neutralization process **(they need equal equivalent to neutralize each other)**

Equivalent of HCl solution = Equivalent of NaOH solution

Normality(HCl) × volume (HCl) = Normality (NaOH) × volume(NaOH)

M × n × Volume (HCl) = M × n × volume (NaOH)

M *12 = 0.12 * 22.4

Molarity of HCl solution =0.224 M

Problem 2

What **volume** of 0.085 M HNO_3 is required to titrate **(neutralize)** 15.0 mL of 0.12 M $Ba(OH)_2$ solution ?

Normality × Volume(HNO_3) = Normality × Volume $Ba(OH)_2$

M× n × volume(HNO_3) = M × n × volume $Ba(OH)_2$

0.085 × Volume(HNO_3) = 0.12 × 2 × 15.0

Volume of HNO3 = 42.32 mL

can use this hint also :If number of H^+ and OH^- is **different**, convert M to N ,find the answer in N ,then convert N to M.

If number of H^+ and OH^- is **the same** just take the Molarity (because n will be canceled)

Problem 3 (Try it on your own)

Titration of a 10.0 mL solution of KOH requires 15.0 mL of 0.0250 M H_2SO_4 solution. What is the **molarity** of the KOH solution?

M × n × Volume(KOH)= M × n × Volume(H_2SO_4)

M× 1 × 10 = 15 × 2 × 0.0250

Molarity of KOH = 0.075 molar

Ionization of water

Water dissociates into **hydronium(H_3O^+)** and **hydroxyl (OH^-)** ions(not an acid nor a base)

For simplicity, we refer to the hydronium as a **hydrogen ion (H^+)** and write the reaction equilibrium as:

$$\boxed{H_2O \rightleftharpoons H^+ + OH^-}$$

This reaction, since it's not a strong acid or base , in equilibrium. The equilibrium constant K_{eq} of the dissociation of water is :

$$\boxed{K_{eq} = \frac{[H^+][OH^-]}{[H_2O]}}$$

We know that the concentration of the water = **55.5 M**

In water solution ⟶ $[H^+] = [OH^-] =$ **1×10^{-7} M**

SO, the equilibrium constant (K_{eq}) for water ionization under standard condition is

1.8×10^{-16} M.

for the sake of clarification, we know that 1 liter of water is 1 kg in mass.

So, 1 liter of water contains 1000 grams of water

The molecular weight (MW) for water is 18 g/mole

So, $\frac{1000}{18}$ = 55.5 mole and to calculate the concentration $\frac{55.5}{1\,(volume)}$ =55.5 M

Ion product of water K_W

The amount of $[OH^-] \times [H^+]$ **is constant in any solution** and equal **10^{-14} M (at 25°C)** and if we rearrange the previous equation :

$K_{eq} \times [H2O] = [OH^-][H^+] = 10^{-14}\ M^2 = K_W$

⟶Another way to find K_W by multiplying **K_a** and **k_b**

(because water can behaves as an acid or a base (amphoteric)).

$$K_a \cdot K_b = \left(\frac{[H_3O^+]\cancel{[A^-]}}{\cancel{[HA]}}\right)\left(\frac{\cancel{[HA]}[OH^-]}{\cancel{[A^-]}}\right)$$

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

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

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

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

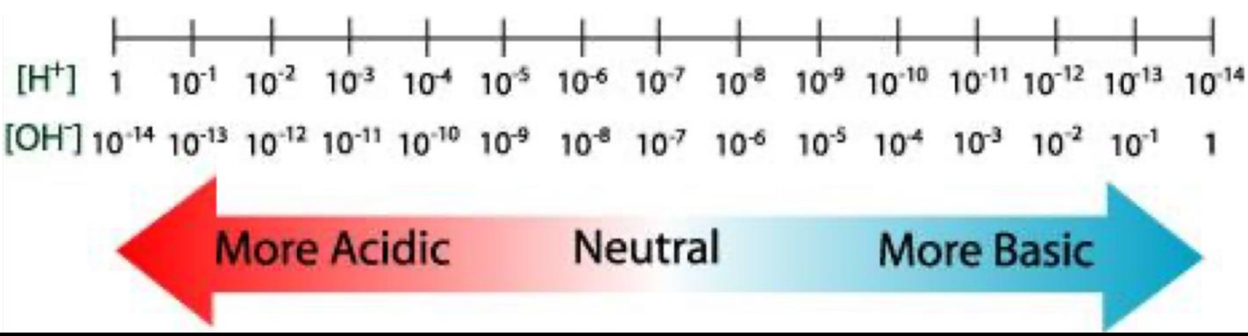
$[H^+]$ and $[OH^-]$

We know that the concentration of **$[H^+]$ and $[OH^-]$ = 10^{-7} M** for pure water (equal concentration).

For other solutions, and since **K_W** is a fixed value ,the concentration of **$[H^+]$ and $[OH^-]$** are inversely changing .

If the concentration of H+ is high, then the concentration of OH- **must** be low, and vice versa.

For example : If $[H^+] = 10^{-2}$ M , then $[OH^-] = 10^{-12}$ M .



When we have high [OH-] → [H+] goes down → solution become more basic

When we have high [H+] → [OH-] goes down → solution become more acidic.

I will not give up until i reach

SHORT QUIZ

Q1) if 100ml of Hocl is titrated with 0.25M Naoh answer what follows

1) calculate the volume of Naoh needed to fully titrate the acid:

A) 150ml. B)125ml. C)200ml. D) 125ml

2) If 225ml of Naoh is added how much is the resulting ph?

A)12.28. B)10.37. C)8.7. D)7

Q2) What volume of0.15M Ba(oH)2 is required to neutralize 45 ml of 0.29M HCl

A)21.75ml. B)43.5ml. C)87ml. D)45ml

Q3) what mass of a certain monoprotic acid will be neutralized by 32.57ml of 0.175 M NaoH? (M.W of the acid = 204.22g/mol)

A)2.32g. B)1.16g. C)4.65g. D)5.5g

Q4) 50ml of Hcl is titrated with 0.2M NaoH answer the following

1)what is the ph after the addition of 30ml of NaoH

A)1.35. B)0.624. C)5.45. D)3.2

2)what is the ph after the addition of 125ml of NaoH

A)3.3. B)7. C)8.6. D)2.4

3)what is the ph after the addition of 200ml of NaoH

A)8.9. B)12.78. C)9.7. D)5.7

Nostalgic????? Me too

Q5)

HA	Ph=3.3
HB	Pka=2.3
HC	[H+]=2*10^-4
HD	[D-]=3*10^-9

Based on the following schedule And assuming that they have equal concentration answer the Following: (M=1mol/L)

1) what is the strongest conjugate base?

A)A- B)B- C)C- D)D-

2)which is the stongest acid ?

A)HA. B)HB. C)HC. D)HD

3) Arrange the acids by strength

A) HA > HB > HC > HD

B) HB > HA > HC > HD

C) HB > HC > HA > HD

D) Hd > HA > HB > HC

Ezz....

ANSWERS

Q1.1	C	Q4.2	B
Q1.2	A	Q4.3	B
Q2	B	Q5.1	D
Q3	B	Q5.2	B
Q4.1	B	Q5.3	B