BIOCHEMISTRY

faculty of medicine - JU2017

carbohydrates isomers ketone starch lipid protein amine

Sheet ◉ Slides ○

Done By

Aboud Aldabobi + Shaima Karchoud

Contributed in the Scientific Correction

Obada Froukh

Contributed in the Grammatical Correction

Obada Froukh

Doctor

Prof. Mamoun Ahram

Biochemistry= Understanding of life

• Know the chemical structures of biological molecules.
• Understand the biological function of these molecules.
(Remember that always structure serves the function of any molecule and Biochemistry is going to explain this relationship).

• Understand interaction and organization of different molecules within individual cells and whole biological systems.

***Biochemistry is also important in medicine**

➢ Explains all disciplines.
➢ Understand the molecular bases of diseases.

EX: A patient with cold, so what causes the fever and the other Symptoms?

Ans: This is because he had a viral infection which causes the release of eicosanoids (Lipids), and this molecule is produced by another enzyme called cyclooxygenase, so to treat this disease you have to inhibit the cyclooxygenase and stop the production of eicosanoids, so you will stop the fever and the inflammation (this is the way in which the Panadol and aspirin work).

➢ diagnose and monitor diseases.
  • When you carry out a blood test for a patient, you try to

determine the concentration of molecules in his blood such as **vitamins and Liver Enzymes** so any change in such molecules could indicate a disease.

• Also, it is important in monitoring diseases by carrying out these tests on different periods of times, so you can observe the difference in the concentration of these molecules.

➢Design drugs (new antibiotics, chemotherapy agents)

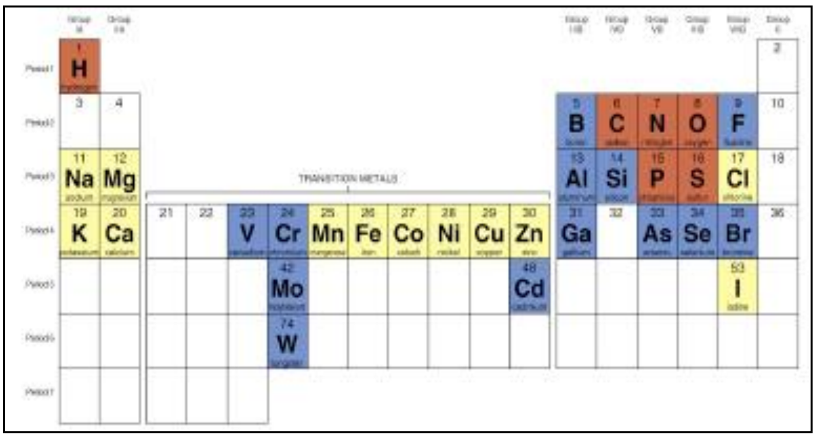
• By studying the protein structures, you can design a molecule that can bind to this protein as **activator or even as an inhibitor**.

• living organisms on earth are composed mainly of 31 elements and are classified in different tiers according to their abundance.

➢ First TIER:> 1-**Carbon** 2-**Hydrogen** 3-**Oxygen** 4-**Nitrogen**
form 96.5% of organisms weight.

➢ Second TIER: **>sulfur** and **phosphorus**
(most biological compounds are made of only 6 elements: C, H, O, N, P, S).

➢ THIRD/FOURTH TIERS: (minor but essential elements) **>**mostly **metals.**



Element	Comment
First Tier	
Carbon (C)	Most abundant in *all* organisms
Hydrogen (H)	
Nitrogen (N)	
Oxygen (O)	
Second Tier	
Calcium (Ca)	Much less abundant but found in *all organisms*
Chlorine (Cl)	
Magnesium (Mg)	
Phosphorus (P)	
Potassium (K)	
Sodium (Na)	
Sulfur (S)	
Third Tier	
Cobalt (Co)	Metals present in small amounts in *all organisms* and essential to life
Copper (Cu)	
Iron (Fe)	
Manganese (Mn)	
Zinc (Zn)	
Fourth Tier	
Aluminum (Al)	Found in or required by *some organisms* in trace amounts
Arsenic (As)	
Boron (B)	
Bromine (Br)	
Chromium (Cr)	
Fluorine (F)	
Gallium (Ga)	
Iodine (I)	
Molybdenum (Mo)	
Nickel (Ni)	
Selenium (Se)	
Silicon (Si)	
Tungsten (W)	
Vanadium (V)	

➢ **Important Terms:**

1-Electronegativity: **the tendency of an atom to attract electrons of the bond.**
2-Covalent bonds: **strong bonds that occur by sharing electrons**
➢ **form macromolecules.**

A) **polar** VS **non-polar** covalent bonds

2 atoms with almost the same E.N form a bond>>e- shared equally
2 atoms with different EN form a bond>>e- closer to the atom with higher E.N

➢ NOTE: the bonds in a molecule may be polar while the molecule itself is nonpolar; because of its geometry.

Ex: CO_2

→ the angle is Important in making the molecule polar. **Ex:** H_2O

B) **single** VS **multiple** >>depends on the number of the shared electrons (single bond, double bond or triple bond).

3- Non-covalent interactions: interactions between molecules (attraction or repulsion) that occur all the time >>> molecules can never function by themselves, instead, they function by interacting with other molecules, and these interactions are non-covalent (**Ex:** collagen)

a) **Electrostatic interactions**
b) **Hydrogen bonds**
c) **Van Der Waals interactions**
d) **Hydrophobic interactions**

→hydrophobic VS hydrophilic
→Making backbone of a molecules

4-Nucleophile Vs Electrophile

→Nucleophile is a negatively charged molecule which prefers the interaction with the Positively charged molecules **(Electron Donor)**.

→Electrophile is a positively charged molecule which prefers the interaction with the Negatively charged molecules **(Electron acceptor).**

→

Properties of bonds: ☺

1. Bond strength ✓the amount of energy that must be supplied to break a bond
   ✓depends on bond's length (inversely related)
   ✓covalent bonds are almost 20 times stronger than non-covalent

2. Bond length: ✓the distance between 2 nuclei of the sharing atoms
   ✓depends on many factors such as: a-EN
   b-Atoms' size
   c-Bond type; single, double or triple

NOTE: As the bond length increases, atoms go far away from each other, so the bond strength decreases ☺

3. Bond orientation:

   ✓Bond angles and length determine the overall geometry of atoms

   ✓It gives the shape to the molecule, creating the 3D structure that affects the molecule's function.

   ✓ Any change in the structure could change the function of proteins (sometimes leading to a mutation).

→ These 3 properties create diversity in the formation of organisms.

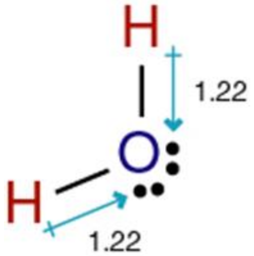
polarity of covalent bond:

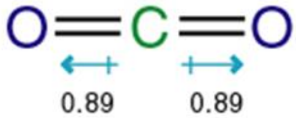
✓Covalent bonds in which the electrons are shared unequally in this way are known as polar covalent bonds. The bonds are known as “dipoles”.

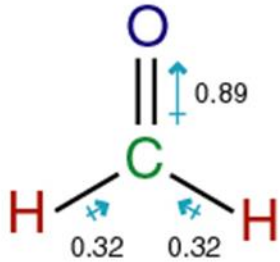
Ex : . Oxygen and nitrogen atoms are electronegative
. Oxygen and hydrogen
. Nitrogen and hydrogen
. Not carbon and hydrogen

➢not every polar bond forms a polar molecule. Ex: CO2
➢to say that a molecule is polar, you should be able to divide it to positive and negative parts by some line
➢You cannot draw such line in linear molecules, so obviously the angle of the

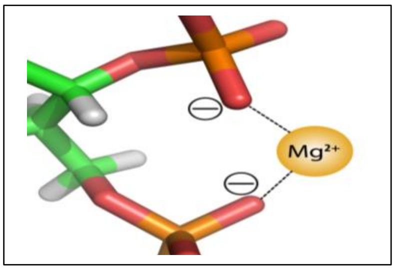
bonds affects the polarity as mentioned before. Ex: H2O







noncovalent interactions: (they are reversible and relatively weak)



1- Electrostatic interactions:☺

→charge-charge interactions:

→They are formed between two charged particles.

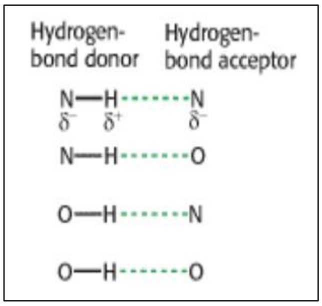
→These forces are quite strong in the absence of water

Extra

For example: Mg $^{2+}$ ions associate with the negatively charged phosphates of nucleotides and nucleic acids.

These electrostatic interactions make an especially large contribution to the folded structure of nucleic acids, because the monomers each carry a full negative charge.

2-Hydrogen bonds: ☺



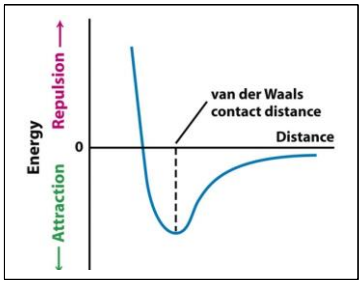
➢must involve a hydrogen atom which is donated

➢this hydrogen must be associated with a highly EN atom (ex; O/N)

➢the molecule which has this hydrogen is called "DONOR" and the other is called the "ACCEPTOR".

3-Van Der Waals interactions:☺ (the weakest)

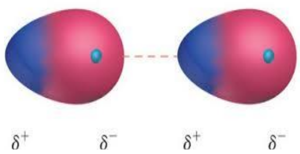
➢Arises from the Unequal distribution of electronic charge around an atom which causes the molecule to have 2 charges at the same time



➢The strength of the attraction is affected by distance.

➢The more Van Der Waals interactions, the stronger it gets

➢They mostly give the protein its shape.



4- Hydrophobic interactions:☺

➢Not true interactions

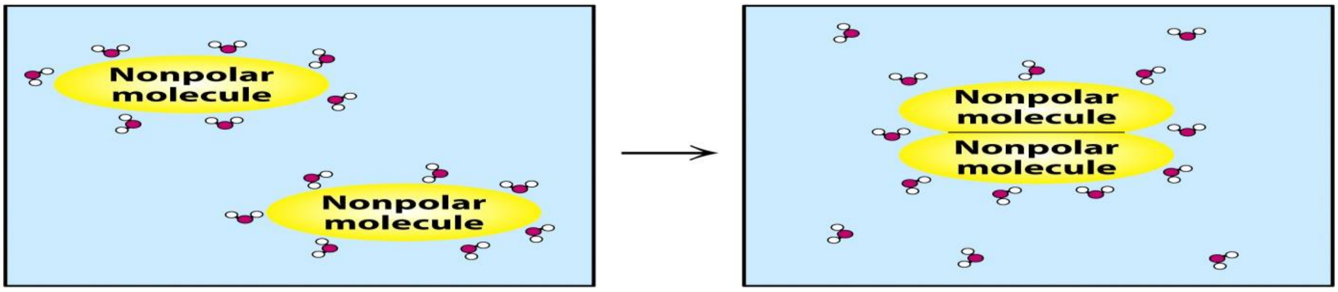
➢What makes it different is that we are talking here about the interactions between atoms which are involved in nonpolar bonds (carbon and hydrogen)

➢Self-association of nonpolar compounds in an aqueous environment

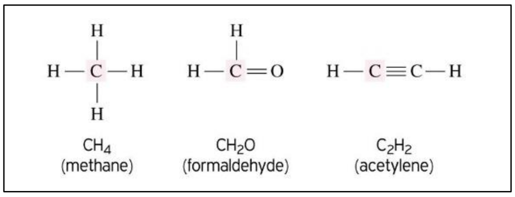
➢ let's take an example:

- Consider we have 2 separate droplets of oil in a bowl of water, they will eventually

come together to form one big drop.
Now try to pull them apart, you will notice that they immediately come back together. Why? ☺
Ans: Because they are more stable together, since it helps reduce the unfavorable interactions between nonpolar groups and water by decreasing the surface area composed to hydrophilic solution☺



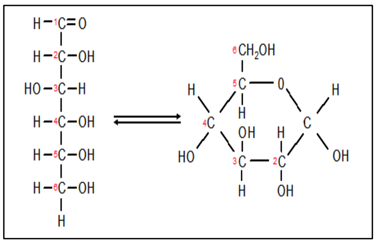
properties of noncovalent interactions:
Reversible
✓Relatively weak. 1-30 kj/mole vs. 350 kj/mole in C–C bond.
✓Molecules interact and bind specifically.
✓ Noncovalent forces significantly contribute to the structure, stability, and functional competence of macromolecules in living cells.
✓Can be either attractive or repulsive.
✓Involve interactions both within the biomolecule and between it and the water of the surrounding environment. (remember, molecules cannot function by themselves, they need to interact with other molecules and even with the environment itself).



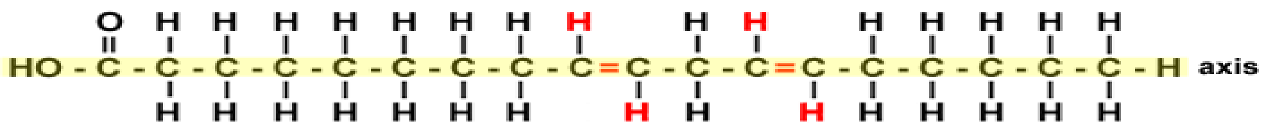
Carbon: (The road to diversity and stability)

Properties of carbon:

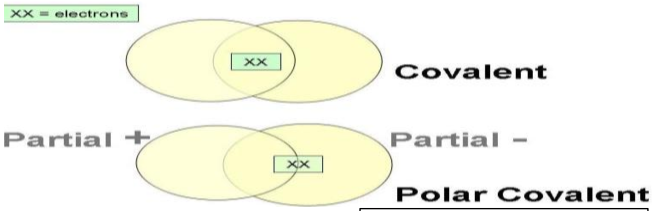
- Can form 4 bonds



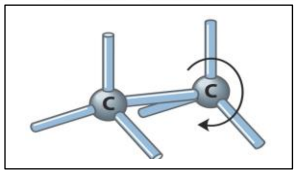
✓may be with the same atom or different atom
✓can form single, double, or triple bonds.
(Remember, our bodies don't contain triple bonds)
✓Each bond is very stable.
(Strength of bonds: triple > double > Single)
✓They link C atoms together in chains and rings.
(These serve as backbones)



- Has an intermediate E.N→ It can form a bond with hydrogen forming a nonpolar bond, as well, it may form a bond with oxygen creating a polar bond ⟹ This facilitates diversity.

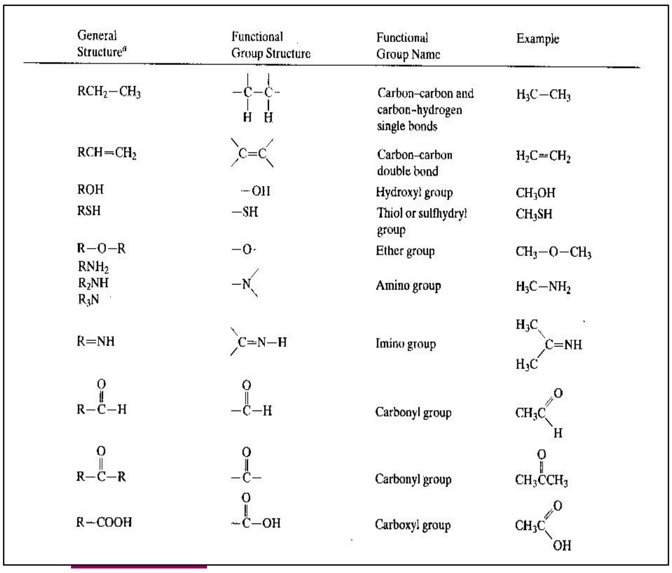


- Can form bonds with different angles, forming molecules with different 3D shapes and these bonds can rotate, again, increasing the level of diversity inside our bodies.

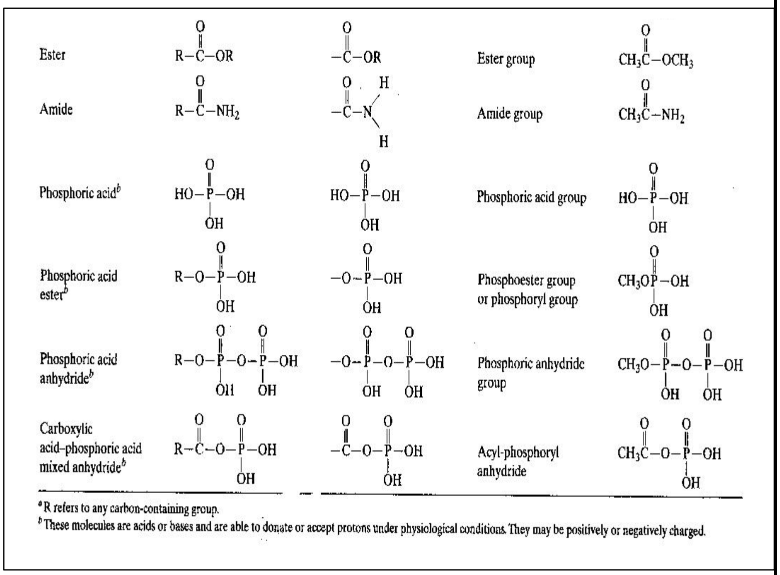


- Pure carbon is not water soluble, but when carbon forms covalent bonds with other elements like O or N; the molecule as a whole is what makes the carbon compounds to be soluble.

Functional groups (Groups of atoms attached to a carbon skeleton):



General Structure[a]	Functional Group Structure	Functional Group Name	Example
RCH_2-CH_3	$-C(H)-C(H)-$	Carbon–carbon and carbon-hydrogen single bonds	H_3C-CH_3
$RCH=CH_2$	$>C=C<$	Carbon–carbon double bond	$H_2C=CH_2$
ROH	$-OH$	Hydroxyl group	CH_3OH
RSH	$-SH$	Thiol or sulfhydryl group	CH_3SH
$R-O-R$	$-O-$	Ether group	CH_3-O-CH_3
RNH_2, R_2NH, R_3N	$-N<$	Amino group	H_3C-NH_2
$R=NH$	$>C=N-H$	Imino group	$(H_3C)_2C=NH$
$R-C(=O)-H$	$-C(=O)-H$	Carbonyl group	$CH_3C(=O)H$
$R-C(=O)-R$	$-C(=O)-$	Carbonyl group	$CH_3C(=O)CH_3$
$R-COOH$	$-C(=O)-OH$	Carboxyl group	$CH_3C(=O)OH$



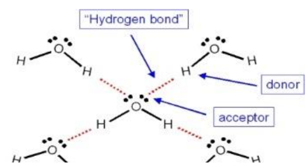
Ester	$R-C(=O)-OR$	$-C(=O)-OR$	Ester group	$CH_3C(=O)-OCH_3$
Amide	$R-C(=O)-NH_2$	$-C(=O)-N(H)H$	Amide group	$CH_3C(=O)-NH_2$
Phosphoric acid[b]	$HO-P(=O)(OH)-OH$	$HO-P(=O)(OH)-OH$	Phosphoric acid group	$HO-P(=O)(OH)-OH$
Phosphoric acid ester[b]	$R-O-P(=O)(OH)-OH$	$-O-P(=O)(OH)-OH$	Phosphoester group or phosphoryl group	$CH_3OP(=O)(OH)-OH$
Phosphoric acid anhydride[b]	$R-O-P(=O)(OH)-O-P(=O)(OH)-OH$	$-O-P(=O)(OH)-O-P(=O)(OH)-OH$	Phosphoric anhydride group	$CH_3O-P(=O)(OH)-O-P(=O)(OH)-OH$
Carboxylic acid–phosphoric acid mixed anhydride[b]	$R-C(=O)-O-P(=O)(OH)-OH$	$-C(=O)-O-P(=O)(OH)-OH$	Acyl-phosphoryl anhydride	$CH_3C(=O)-O-P(=O)(OH)-OH$

[a] R refers to any carbon-containing group.
[b] These molecules are acids or bases and are able to donate or accept protons under physiological conditions. They may be positively or negatively charged.

Properties of water:

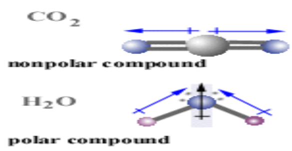
→Water is a polar molecule as a whole because of 1-the different of E.N between Hydrogen and oxygen. 2- It is angular.

→Water is highly cohesive.

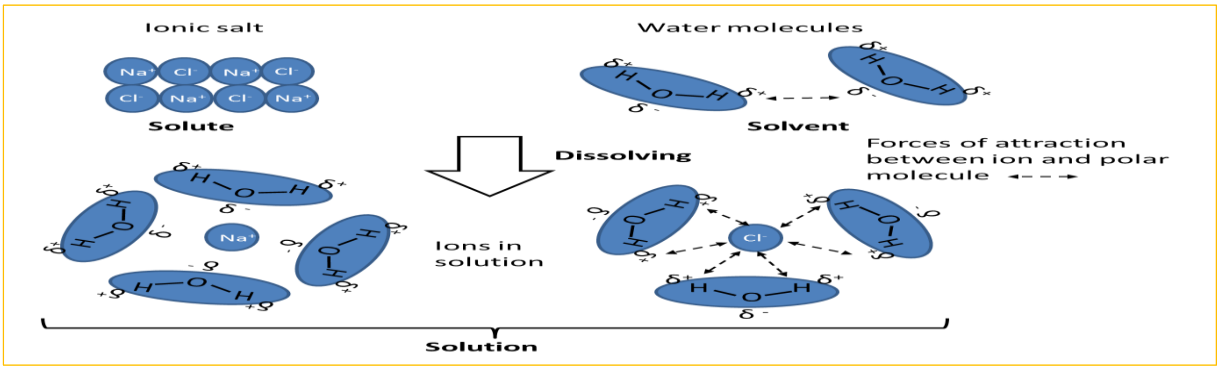


→Water molecules produce a network thus increasing boiling point.
→It is reactive because it is a nucleophile.
→Water molecules are ionized to become a positively charged hydronium ion (or proton), and a hydroxide ion:

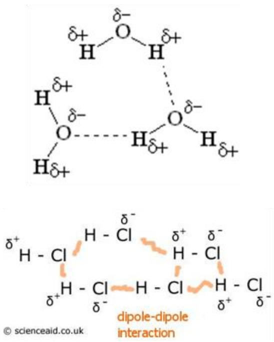
$$H_2O + H_2O \rightleftharpoons H_3O^{\oplus} + OH^{\ominus}$$



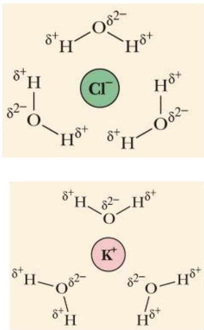
→Water is an excellent solvent since it's small and is able to weaken electrostatic forces and hydrogen bonding between polar molecules.

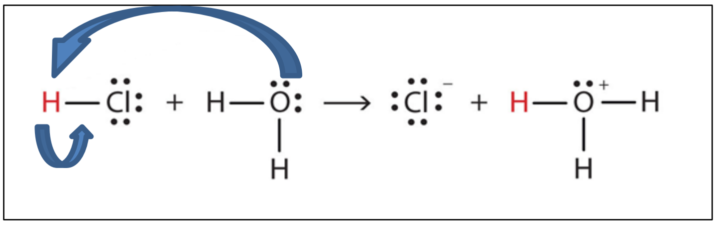


Dipole-dipole interaction



Dipole-charge interaction





Brønsted-Lowry acids and bases: ^_^

Acid ➢ A substance that produces H+ when dissolved in water

➢ H+ Reacts with water producing hydronium ion (H3O+).

➢ Remember there is no naked protons (free hydrogen ions in the solution), instead they will be hydrated.

$$H{-}Cl + H{-}\ddot{O}{:}{-}H \longrightarrow [H{-}\ddot{O}(H){-}H]^+ + Cl^-$$

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

$$H{-}\ddot{N}H{-}H(g) + H_2O(l) \rightleftharpoons H{-}N^+H_2{-}H(aq) + OH^-(aq)$$

This OH^- ion comes from H_2O.

❖ Types of acids and bases:

The Brønsted-Lowry acid: Any substance (proton donor) able to give a hydrogen ion (H+ - a proton) to another molecule.

→Monoprotic acid: HCl, HNO3, CH3COOH

→Diprotic acid: H2SO4

→Triprotic acid: H3PO3

Brønsted-Lowry base: any substance that accepts a proton (H+) from an acid.

→NaOH, NH3, KOH.

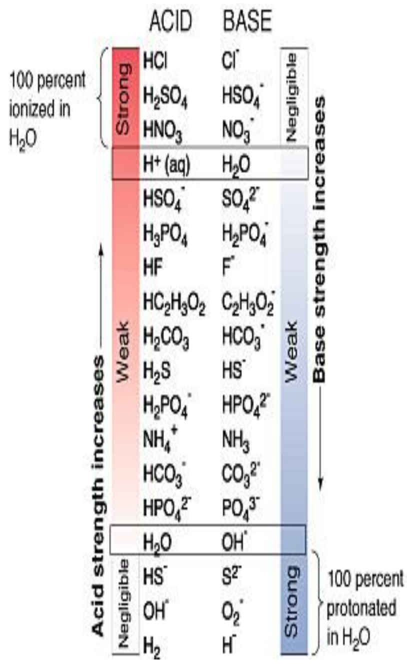
➢ Substances that can act as an acid in one reaction and as a base in another are called **amphoteric substances** (ampho= dual, both).

Ex: water: →With ammonia (NH3), water acts as an acid because it donates a proton (hydrogen ion) to ammonia.

NH3 + H2O ↔ NH4+ + OH–

→ With hydrochloric acid, water acts as a base.

HCl+ H2O → H3O+ + Cl-



Acid/Base strength: ❖

Acids differ in their ability to release protons

→ Strong acids dissociate 100%

Bases differ in their ability to accept protons.

→ Strong bases have strong affinity for protons

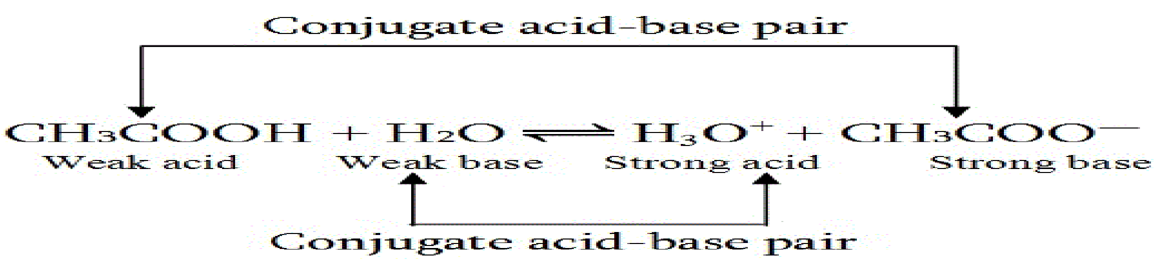
For **multi-protic acids** (H2SO4, H3PO4), each proton is donated at different strength.

For example, H3PO4 is a weak acid, now notice something that H3PO4 can release a proton forming (H2PO4-), this can also act as an acid as well so that it can donate a proton to form (HPO4-2) that can as well act as an acid and donate another proton. Yet, the second proton donation will not be as easy as the first donation.

>>> Why protons are donated at different strengths? ANS: simply due to the acid dissociation constant (Ka) which gonna decrease after the loss of the first hydrogen

Strong acid: H2SO4 + H2O → HSO4- + H3O+ Ka → 1*10^3

Weak acid: HSO4- + H2O → HSO4 -2 +H3O+ Ka → 1.2*10^-2



➢ Whenever you have an acid, it releases a proton to form a conjugate base.

➢ The stronger the acid, the weaker the conjugate base.

Strong vs. weak acids:

1) Strong acid and bases are one way direction

HCl → H+ + Cl-

NaOH → Na+ + OH-

2) Weak acids and bases do not ionize completely

HC2H3O2 ↔ H+ + C2H3O2-

NH3 + H2O ↔ NH4+ + OH-

Equilibrium constant (Keq) : ☺

Acid/base solutions are at constant equilibrium.

We can write equilibrium constant (Keq) for such reactions.

➢ The strength of acids can be measured by dissociation constant (Ka), which is basically concentration of products over concentration of reactants.

HA <--> H+ A-

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

The value of the Ka indicates direction of reaction:

- When Ka is greater than 1 the product side is favored.
- When Ka is less than 1 the reactants are favored.

<u>pKa is a measure of acid's strength</u>

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

➢The larger the Ka, the lower the pKa, the stronger the acid, the easier for it to dissociate into proton and conjugate base (and vice versa).

➢Formic acid for example, Ka is equal to 1.77 * 10-4, this mean: for one molecule of formic acid, you have 1.77 * 10-4 of products.

What does “Ka = 1*10^7” mean? you get 10 million protons and chloride ion for each molecule.

Remember: Scientists are sooo lazy□ and they found out the pKa to ease the reading of Ka values.

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

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

THE ONLY WAY OF FINDING THE LIMITS OF THE POSSIBLE IS GOING BEYOND THEM RIGHT INTO THE IMPOSSIBLE