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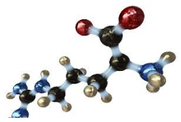


BioChemistry

وَلَقَدْ خَلَقْنَا الْإِنسَانَ وَنَعْلَمُ مَا تُوَسْوِسُ بِهِ نَفْسُهُ ۖ وَنَحْنُ أَقْرَبُ إِلَيْهِ مِنْ حَبْلِ الْوَرِيدِ

MID | Lecture #1

Introduction to biochemistry Pt.1

Written by : Nezar Alsabatin
Ali Alsharaeh

Reviewed by : Yamen Aljarrah

Color coding used in the modified:

- *Black: the original slides*
- *Navy Blue: the doctor’s explanation/words*
- *Gray: additional information and explanation*
- *Red: important information*

Introduction into Biochemistry

Prof. Mamoun Ahram

Course information

- Recommended textbooks
  - Marks' Basic Medical Biochemistry: A Clinical Approach 6th Edition, by Michael Lieberman (Author), Alisa Peet MD (Author), 2023
  - Biochemistry 8th edition by Mary Campbell (Author) and Shawn Farrell (Author)

- Online:

  https://themedicalbiochemistrypage.org/

- Instructors
  - Prof. Nafez Abu Tarboush
  - Prof. Mamoun Ahram

Outline

- Introduction
- Acids and bases, pH, and buffers
- Macromolecules:
  - Carbohydrates, lipids, amino acids, peptides, and proteins
- Protein structure-function relationship:
  I. Fibrous proteins: collagen, elastin, and keratins
  II. Globular proteins (plasma proteins, myoglobin, hemoglobin, and immunoglobulins)
  III. Regulation of hemoglobin
- Enzymes
  - structural features and classification, kinetics, mechanisms of regulation, cofactors
- Protein purification and analysis

Biochemistry & chemical composition of living organisms

Biochemistry = understanding life

Biochemistry covers the chemicals that are found in living beings.

- Know the chemical structures of biological molecules
- Understand the biological function of these molecules
- Understand the interaction and organization of different molecules within individual cells and whole biological systems
- Understand bioenergetics (the study of energy flow in cells)

- Bioenergetics focuses on the transfer and usage of energy in living cells.
- The difference between living and non living beings is the energy flow that the living beings have.

Biochemistry in medicine:

- ***explains all disciplines*** such as anatomy, biochemistry explains for us how a certain tissue or organ is built, formed , degraded and reformed.
- ***diagnose and monitor diseases,*** such as doing a lipid profile test which helps diagnose a deficiency or a disease.
- ***design drugs (new antibiotics, chemotherapy agents),*** which helped developing targeted therapy and precision medicine, these helped improving survival rate for diseases like leukemia (its success rate to cure 50 years ago was 40% and it's rate now is 95%)
- ***understand the molecular bases of diseases***

You do not have to know biochemistry to be a physician, but it makes you an elite physician if you do.

Chemical elements in living creatures

- The human body is composed mainly of ~30 elements.
- Four primary elements: carbon, hydrogen, oxygen, and nitrogen (96.5% of an organism's weight)
- Then, calcium and phosphorus (that's 98.5%).
- Others exist in trace amounts but are essential, elements (mostly metals.)

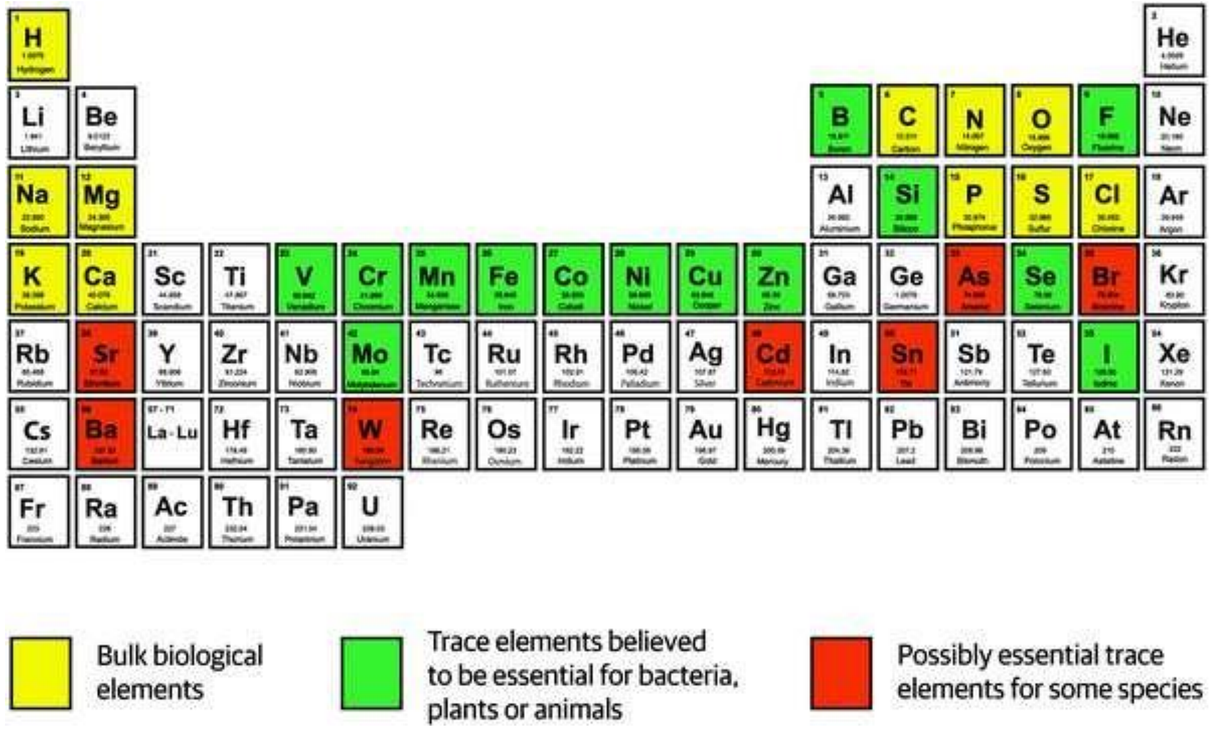


TABLE 2.1 Elements of the Human Body

Name	Symbol	Percentage of Body Weight
Major Elements (Total 98.5%)		
Oxygen	O	65.0
Carbon	C	18.0
Hydrogen	H	10.0
Nitrogen	N	3.0
Calcium	Ca	1.5
Phosphorus	P	1.0
Lesser Elements (Total 0.8%)		
Sulfur	S	0.25
Potassium	K	0.20
Sodium	Na	0.15
Chlorine	Cl	0.15
Magnesium	Mg	0.05
Iron	Fe	0.006

Trace Elements (Total 0.7%)			
Chromium	Cr	Molybdenum	Mo
Cobalt	Co	Selenium	Se
Copper	Cu	Silicon	Si
Fluorine	F	Tin	Sn
Iodine	I	Vanadium	V
Manganese	Mn	Zinc	Zn

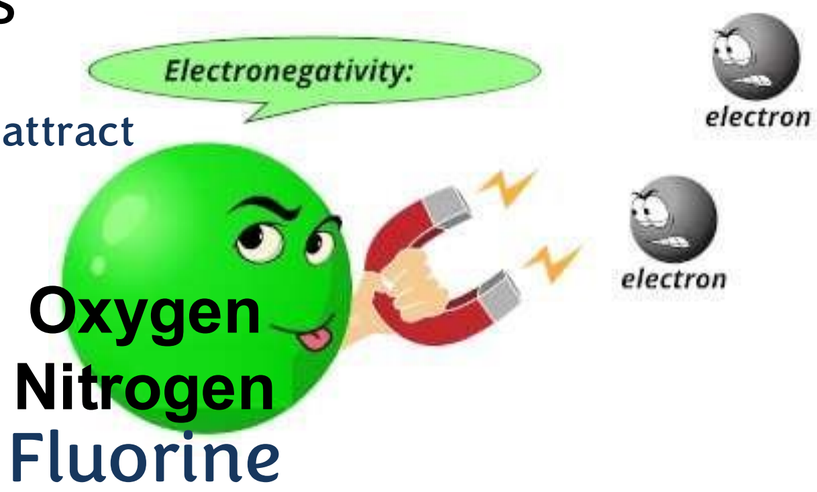
Ca and P are mostly found in bones.
While Fe is mostly found in rbc.

You don't have to memorize the numbers but you do have to know the major, lesser and trace elements.

You can't survive without trace elements in your body, even if their percentage is very low!!

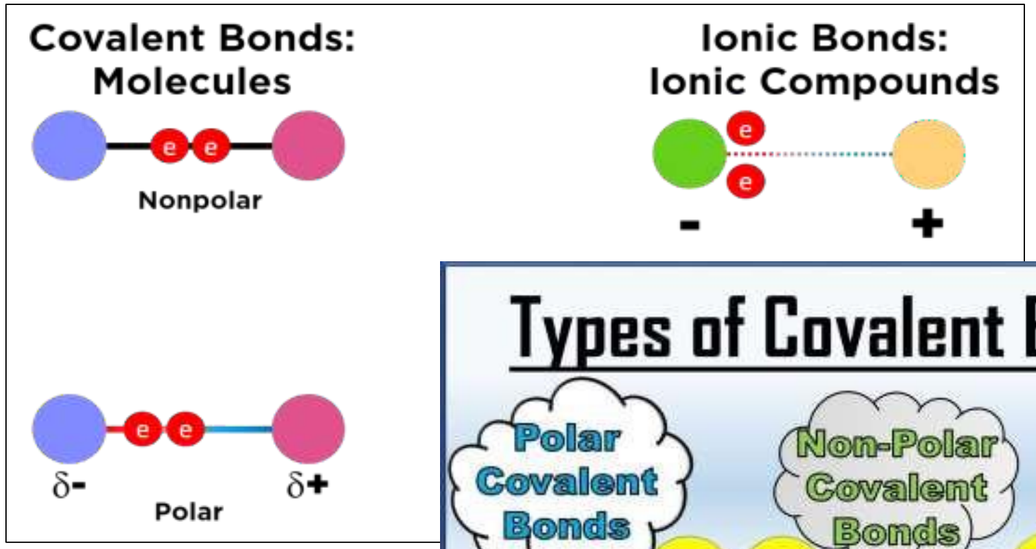
Important terms

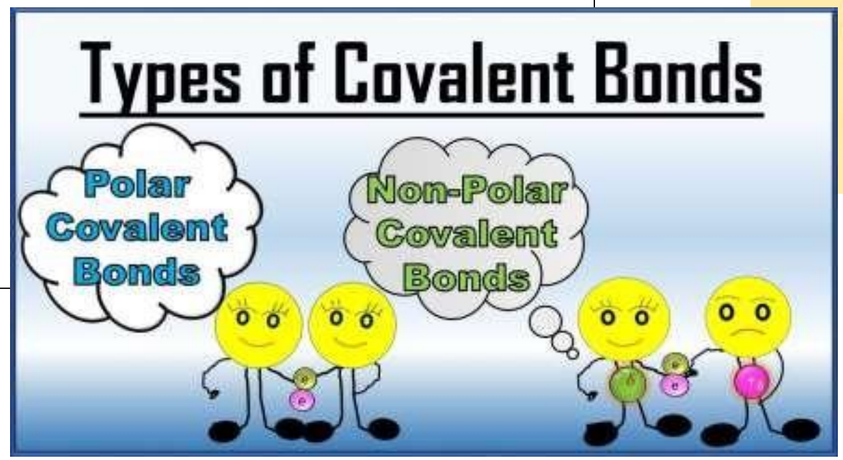
- Electronegativity The ability of an element to attract electrons easily.
- Covalent bonds
  - Polar vs. non-polar covalent bonds
  - Single vs. multiple
- Nucleophile vs electrophile

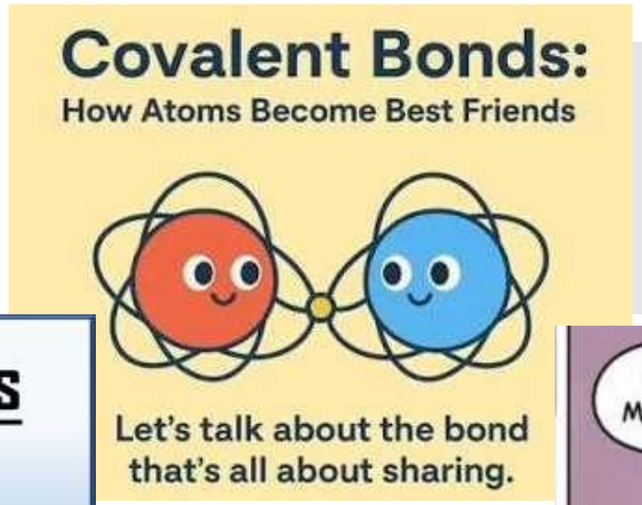


Hydrogen

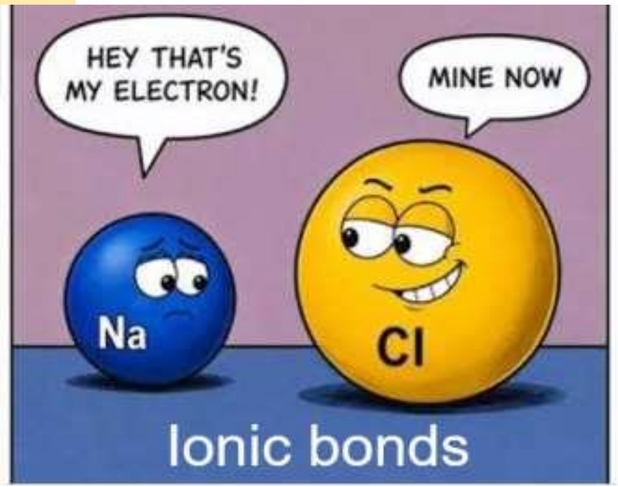
Carbon







Covalent bonds occurs when 2 atoms share valance electrons between them .

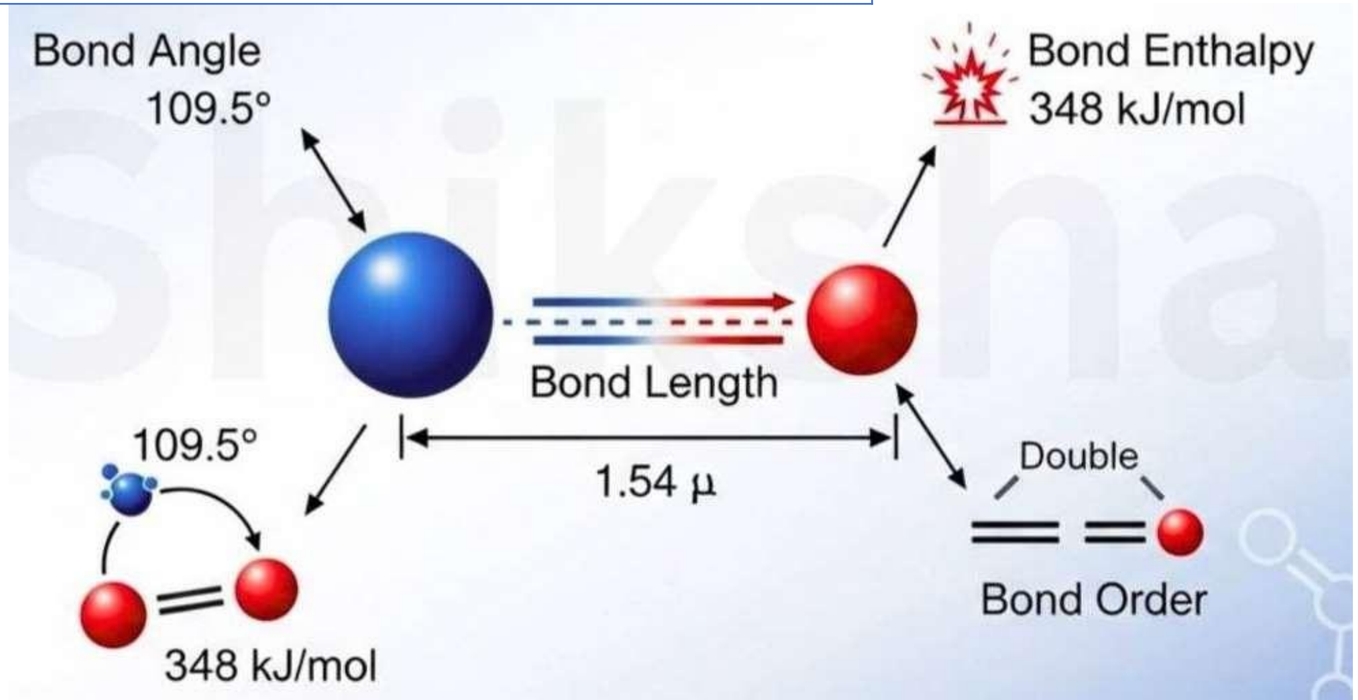


Important properties of covalent bonds

These properties of covalent bonds define the shape and characteristics of the molecule.

Bond Length	Distance between nuclei of bonded atoms
Bond Angle	Angle between two bonds at central atom
Bond Enthalpy	Energy to break one mole of bonds in gaseous state
Bond Order	Number of shared electron pairs (bonds) between atoms
Bond Polarity	Unequal sharing of electrons between atoms

- Electrons “spend more time” near the nucleus of the atom with the highest electronegativity .
- Because electrons “spend more time” near the atom with the higher electronegativity, this atom acquires a partial negative charge, and the other atom, which has a lower electronegativity, acquires a partial positive charge.



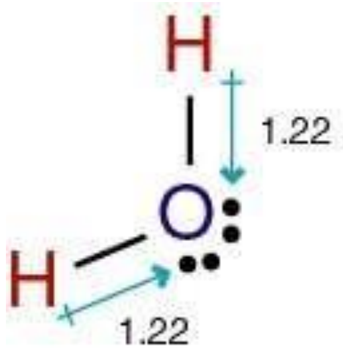
Polarity of covalent bonds

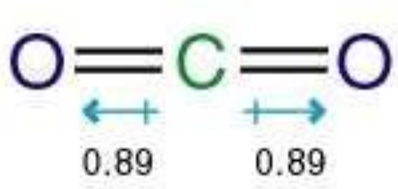
Depends on the electronegativity of the atoms in the covalent bonds.

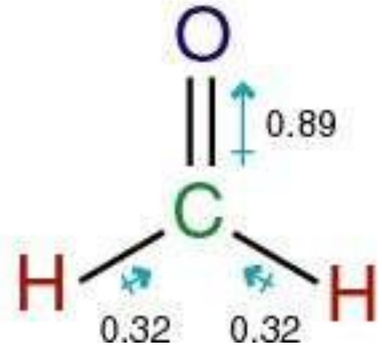
Non polar covalent bonds = equal sharing of electrons between atoms.

- Covalent bonds in which the electrons are shared unequally in this way are known as polar covalent bonds. The bonds are known as “dipoles”.
  - Oxygen and nitrogen atoms are electronegative
  - Oxygen and hydrogen
  - Nitrogen and hydrogen
  - Not carbon and hydrogen

Both water and CO_2 contain polar bonds, but only water is a polar molecule. Why?







Because of the bond angles.

We can decide if a molecule is polar or not by trying to divide it by an imaginary line. If there is a line which divides it into a part with net partial (+) charge and another part with a net partial (–) charge, the molecule is polar. Otherwise, it is nonpolar.

Non-covalent interactions

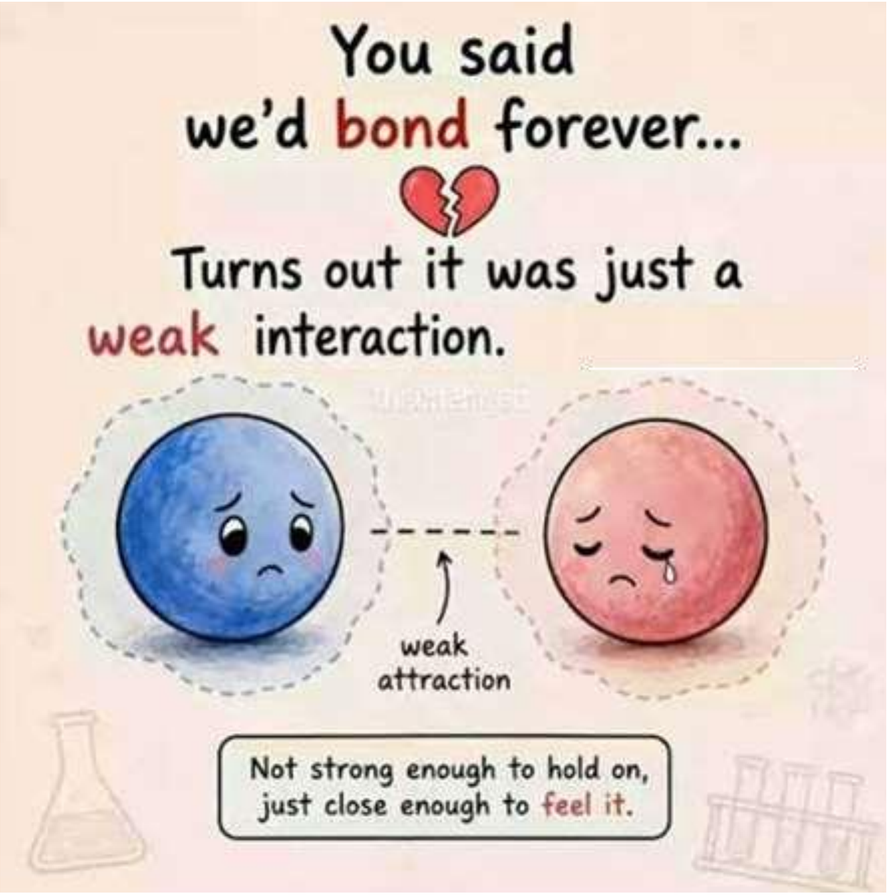
- These interactions are the major player in biochemistry.
- They are reversible and generally weak.

I. Electrostatic interaction

II. Hydrogen bonds

III. Van der Waals

IV. Hydrophobic interactions

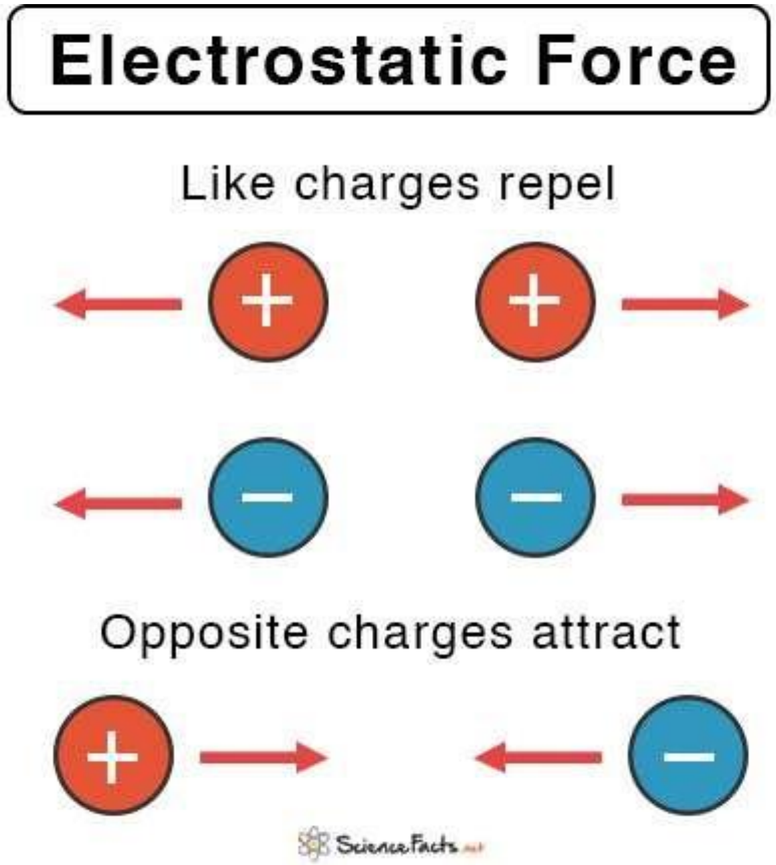


Electrostatic interactions

An interaction between a molecule with a positive charge and a molecule with a negative charge.

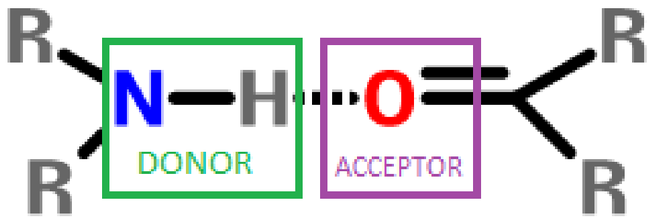
- Also called, **charge-charge interactions**:
  - They are formed between two charged particles.
  - These forces are quite strong in the absence of water.

There is a difference between a bond and an interaction , you can think of a bond like 2 people who are walking together holding each other hands , while an interaction would be like 2 people who walk together and have some interaction between them like a chat but not holding each others hands.

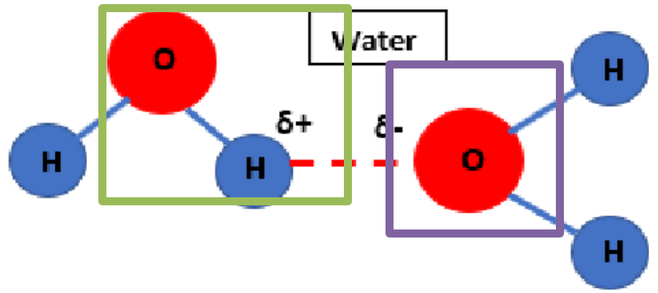


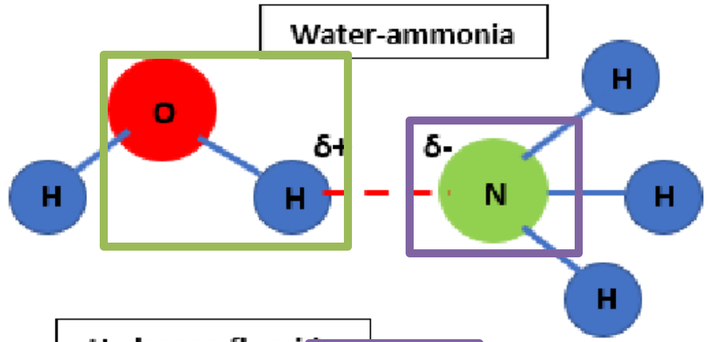
Hydrogen bonds

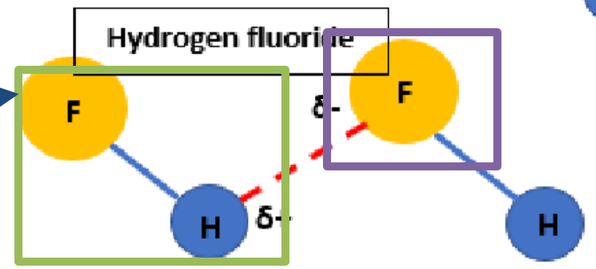
They're called "bonds" But they're actually interactions.



- A hydrogen bond is a strong, non-covalent dipole-dipole attraction between a **hydrogen atom** (called a donor, **has a partial positive charge**) that is covalently bonded to a highly electronegative atom, and another electronegative atom (called an acceptor, **has a partial negative charge**) with a lone pair of electrons.
- These bonds typically form with the elements nitrogen, oxygen, or fluorine.
- **Hydrogen bonds are an example of dipole-dipole interactions.**



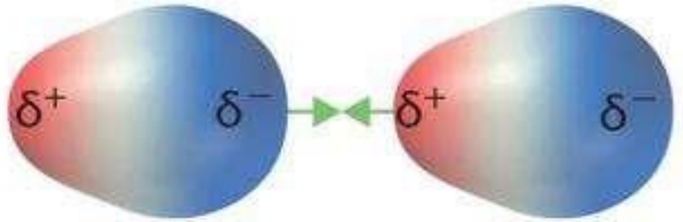




Green square = donor
Purple square = acceptor

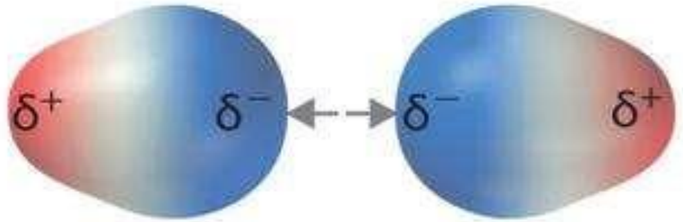
van der Waals attractions

- Very weak and transient interactions (changes all the time).
- Could be either an attraction or repulsion interaction.

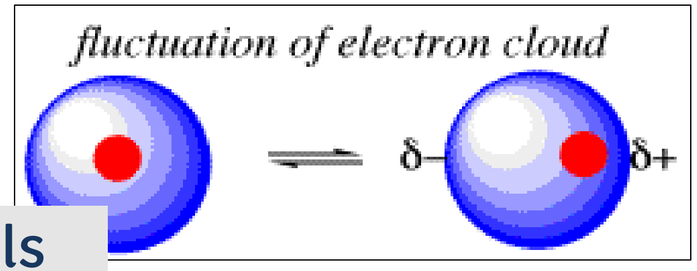


(b) Attraction

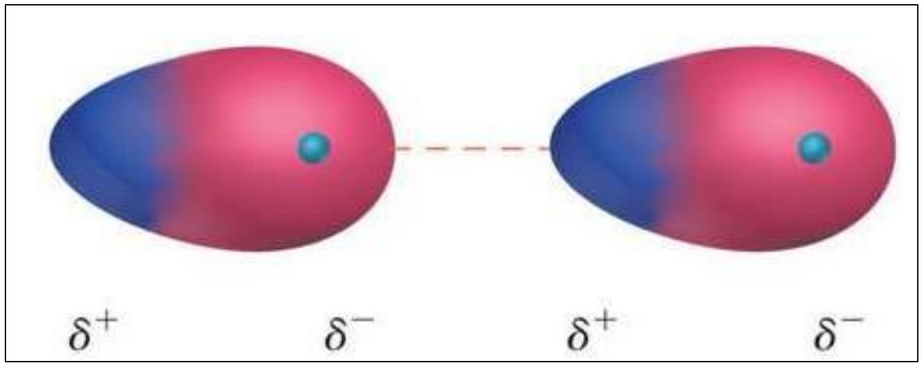
- Unequal distribution of electronic charge around an atom at any time resulting in attractive and repulsive forces.
- The strength of the attraction is affected by distance.



(d) Repulsion



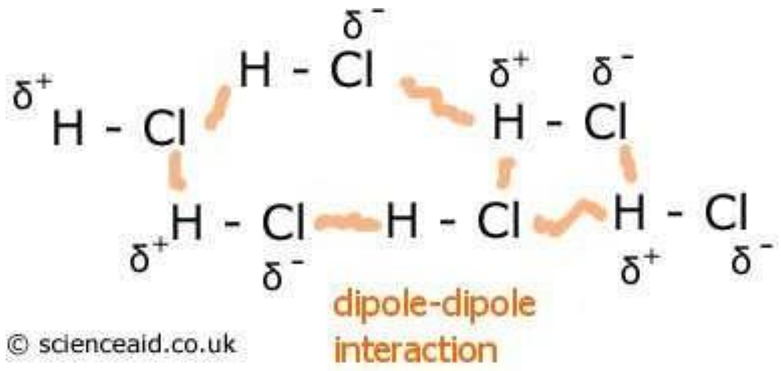
When you have a lot of van der waals interactions acting together, they will be very significant in determining the structure of the molecules.

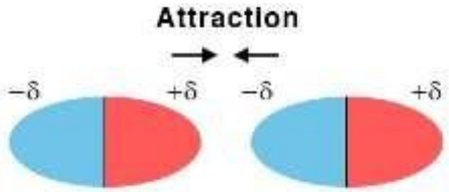


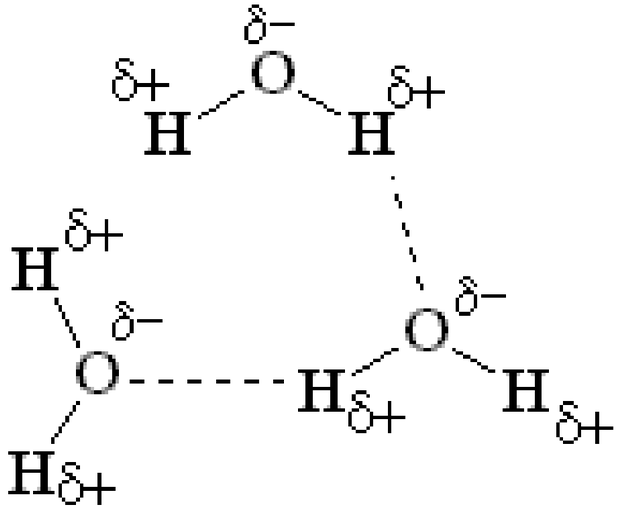
Note others:

- Dipole – dipole interactions occurs between 2 polar molecules that has partial positive and negative charges.
- Hydrogen bonds are dipole-dipole interactions.
- Dipole-charge interactions happens when a partial charge interacts with a **REAL** charge (not partial charge).

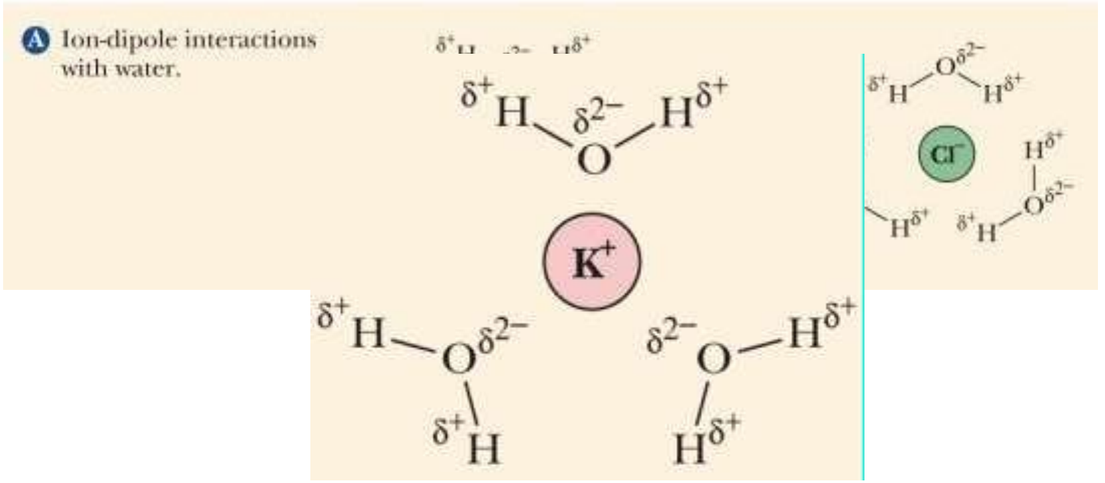
Dipole-dipole interaction







Dipole-charge interaction

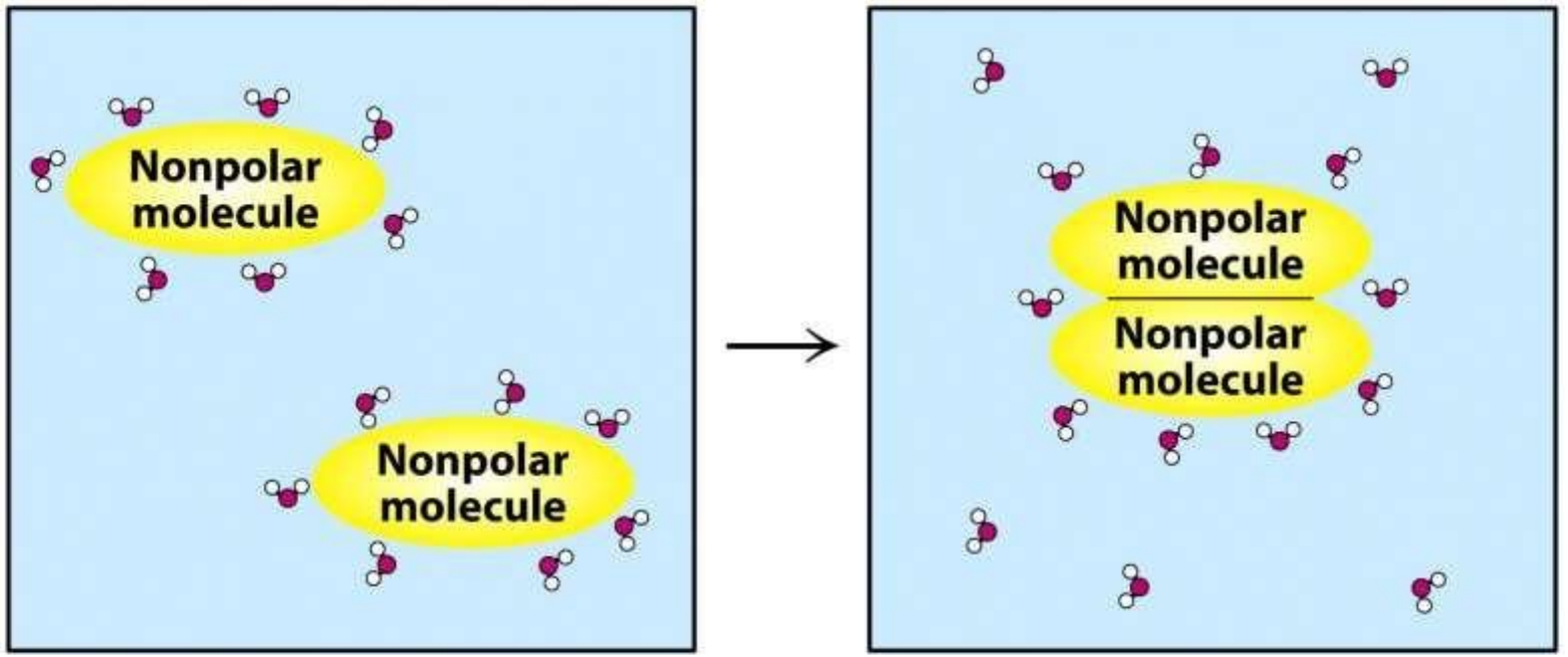


Hydrophobic interactions

the most important force in determining the structure of molecules.

- Self-association (cluster) of nonpolar compounds in an aqueous environment to minimize the unfavorable interaction with water molecules. (Non polar compounds are hydrophobic).
- It is not that nonpolar molecules are attracted to each other; it is driven by water molecules naturally bonding with one another, excluding the nonpolar substances.

Example: when you put 2 drops of oil in water, they will move until they cluster together so they have the least interaction with water.



Properties of noncovalent interactions

- Reversible
- Relatively weak
- Can be either attractive or repulsive
- Molecules interact and bind specifically.
- Noncovalent forces significantly contribute to the structure, stability, and functional competence of macromolecules in living cells.
- Involve interactions both within the biomolecule and between it and the water of the surrounding environment. (the surrounding atmosphere and solution that surrounds the molecule are important in determining the stability and structure of the molucule) , (example : in a glucose molecule, you are going to find : Interactions between oxygen, hydrogen and carbon within the glucose molecule itself. And if you dissolve the glucose in water, there will be interactions between water and glucose molecules aswell).

Carbon

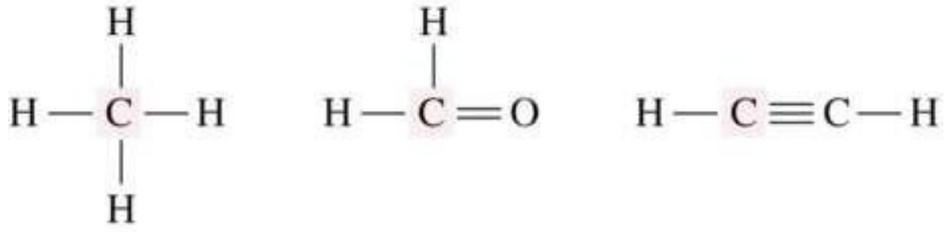
The road to diversity and stability

Carbon is very important to life to the point that scientists consider it the best indicator of life in the outer space, then comes water as the 2nd indicator of life.

Properties of carbon (1)

- It can form four **covalent** bonds **(it could form these bounds with the same molecules or different ones)**, which can be single, double, or triple bonds **(changeable for diversity). (silicone also has this ability to make 4 covalent bonds but carbon is the best.)**
- Each bond is very stable.*(requires a lot of energy to be broken)*
  - strength of bonds: triple > double > Single)
- They link C atoms together in chains and rings.***(chains and rings can have branches which also increase the diversity of C atom)***
  - These serve as a backbones.

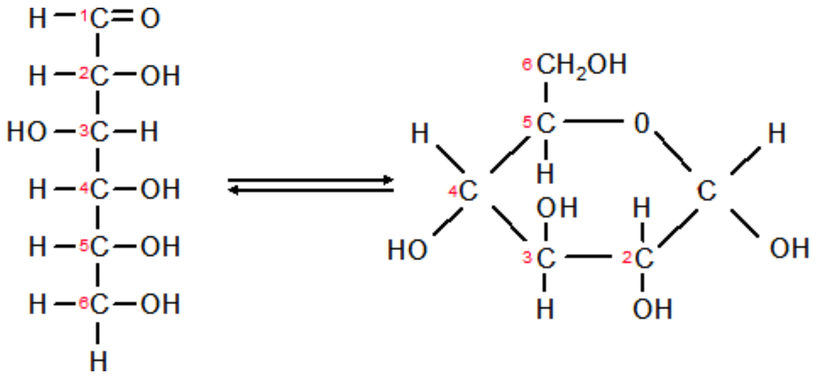
The three points above explain how diverse a carbon atom can be in life.

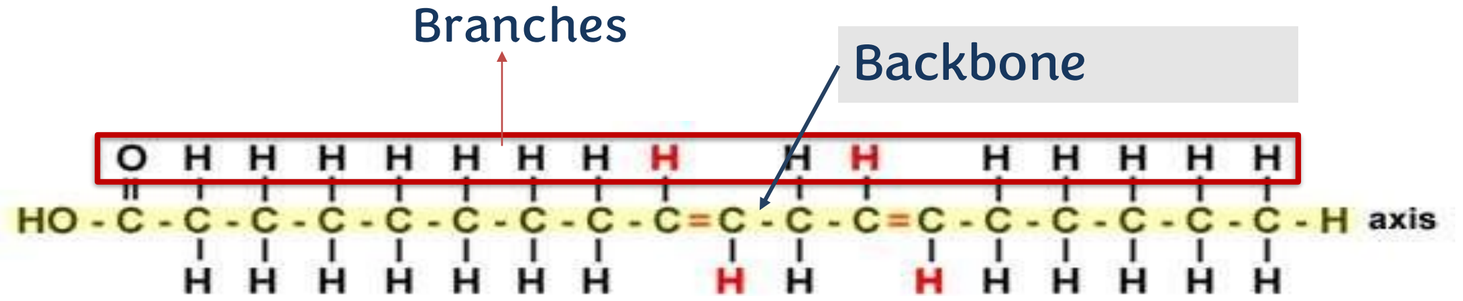


CH_4 (methane)

CH_2O (formaldehyde)

C_2H_2 (acetylene)



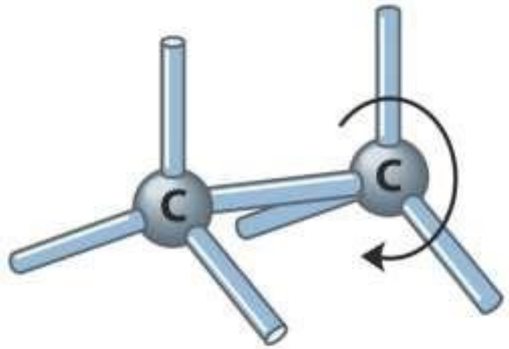


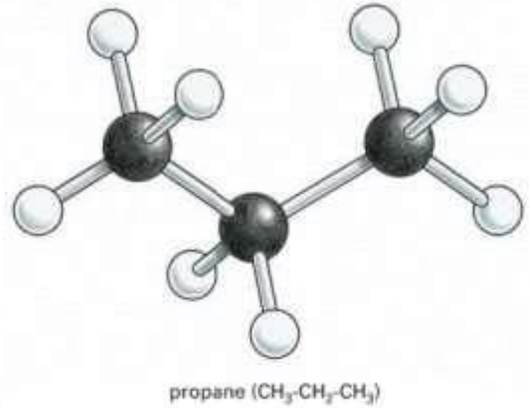
Properties of carbon (2)

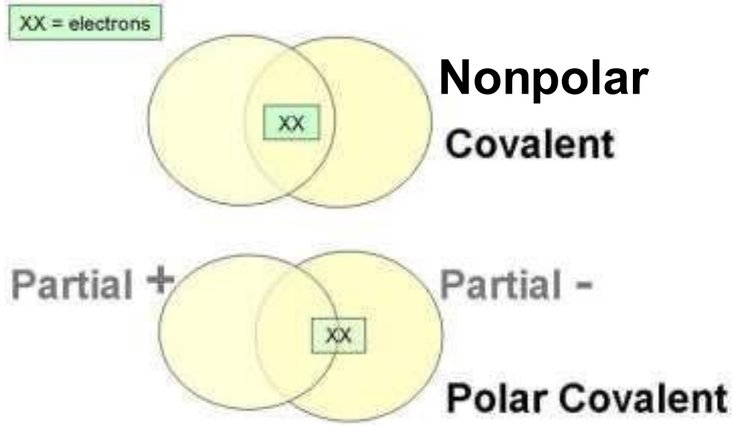
- Carbon bonds have angles giving molecules three-dimensional structures.
- In a carbon backbone, **some carbon atoms rotate around a single covalent bond** (flexibility) producing molecules of different shapes.
- The **electronegativity** of carbon is between other atoms. (it is intermediate)
  - It can form polar and non-polar(C–C or C–H) molecules.
- Pure carbon is not water soluble, but when carbon forms covalent bonds with other elements like O or N, the molecule that makes carbon compounds is soluble.

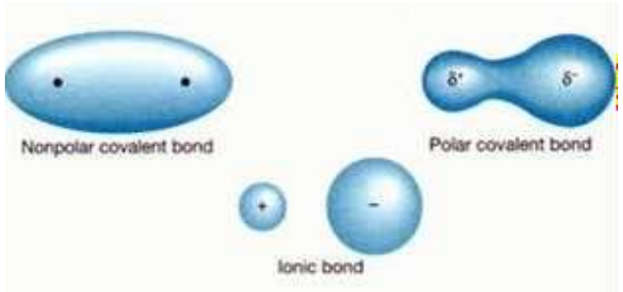
An example of diversity of carbon is coal and diamond

points mentioned above explain how diverse a carbon atom can be (in addition to the ones in the previous slide)









Water

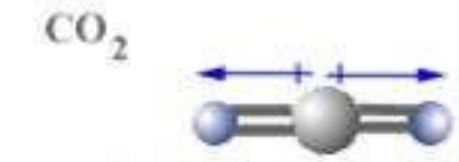
قال تعالى: (وجعلنا من الماء كل شيء حي)

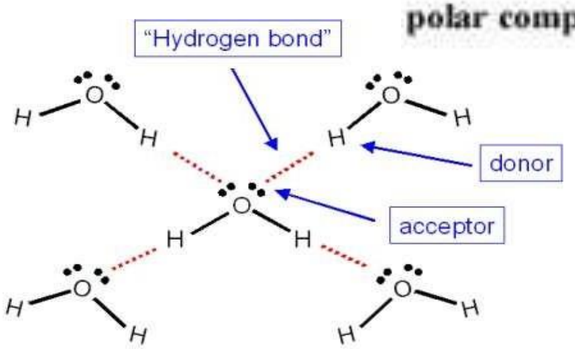
- All living beings need water to live (water has to be present in order to find life).

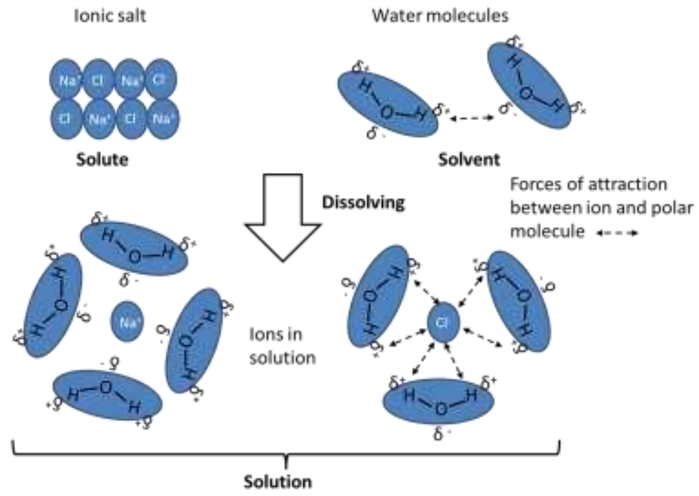
Properties of water (1)

- Water is a polar molecule as a whole because of:
  - the different electronegativities between Hydrogen and oxygen
  - It is angular.
- It can form dipole-dipole interactions and dipole-charge interactions.
- Water is highly cohesive **because every water molecule can form 4 hydrogen bonds** . **(the reason for water defying gravity inside plants is that water is highly cohesive. When the water in the leaves evaporates, all of the water molecules in the plants will go up against gravity).**
- Water molecules produce a network.**(Waters boiling point is high because it can form networks of 4 hydrogen bonds which requires a lot of energy to break it apart)**
- Water is an excellent solvent because It is: small and it weakens electrostatic forces and hydrogen **(and ionic)** bonding between polar molecules.

Enzymes catalyze reactions on an area inside the molecule away from water (called an active site) to prevent water molecules to get in because they are highly reactive because of the partial positive and negative charges it has



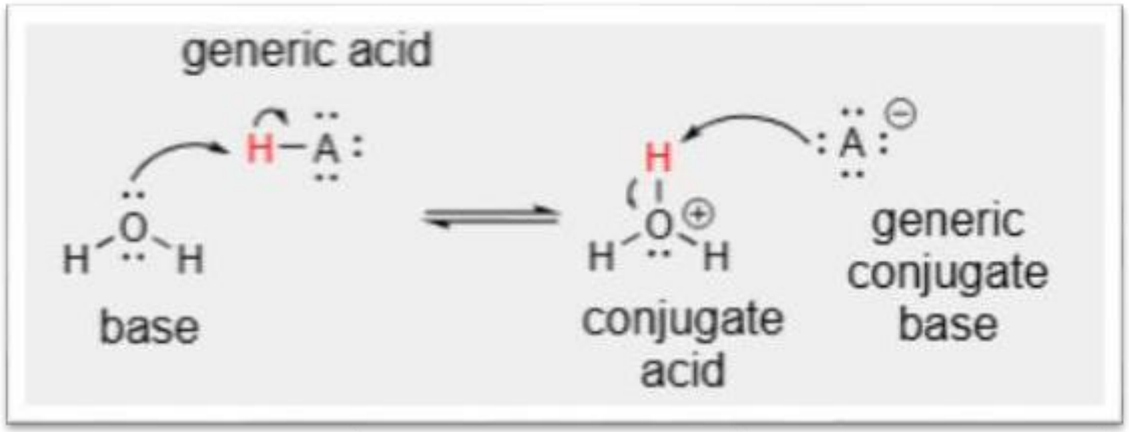




Properties of water (2)

Water can act as an acid or a base (dual nature).

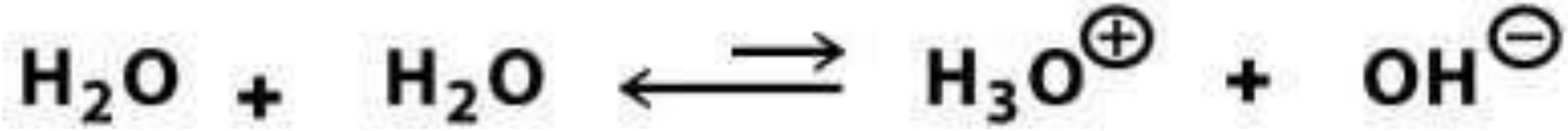
- It is reactive because it is a nucleophile *(base)* and an electrophile *(acid)*.
  (it has two pairs of electrons which makes molecules more reactive)
  - A nucleophile is an electron-rich molecule that is attracted to positively-charged or electron-deficient species (electrophiles).



Properties of water (3)

- Water molecules are ionized to become a positively-charged hydronium ion (or proton), and a hydroxide ion:

These are real charges



Note: $H_3O^+ = H^+$

For simplicity , you can write :

Quiz!

Good luck!!

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			

Additional Resources:

رسالة من الفريق العلمي:

قال تعالى: ﴿وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ﴾ [هود: 88]

مع بداية الفصل الصيفي ، نذكركم بإخلاص النية في الدراسة والسعي لله، عسى الله أن يوفقنا في الدنيا ويرفعنا درجاتٍ في الآخرة. 💙💙

References Used:

1. Prof.Mamoun Ahram live lecture.