Biology 101

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DR.Ahmad Al Qawasmi

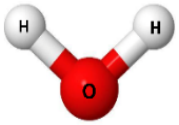
ARKAN
ACADEMY

Chapter 3: Chemistry of water

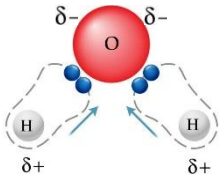
- Water covers ¾ of earth
- Water is the only common substance to exist in the natural environment in all 3 physical states of matter
- Most of water is in the liquid form

3.1: Polar covalent bonds in water molecules result in hydrogen bond

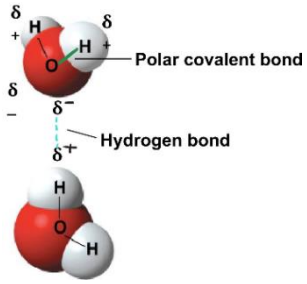
- The unique behavior & properties of water are due to its structure & interactions with other molecules
- Water molecule is *V-shape* in structure consisting of 2 H atoms and 1 O atom
  - Each H atom binds to O atom by a single covalent bond



- Oxygen atom is *more electronegative* than hydrogen the electrons of the covalent bond spend more time *closer* to oxygen atom, causing *unequal sharing* of electrons
  - The bond between O and H is a ***polar covalent bond***
  - O has 2 partially negative charge (-2)
  - Each H has 1 partially positive charge (+1)



- The partially *positive* charge of each H atom attracts with the partially *negative* charge of O atom of other water molecule forming ***Hydrogen bonds***
  - In liquid water its hydrogen bonds are fragile where they are formed and broken frequently
  - Covalent bond is much <u>stronger</u> than hydrogen bond (about 20 times)



Bonds between:

- ✓ H and O atoms in the ***same*** water molecule = *polar covalent bond*
- ✓ H and O atoms in the ***different*** water molecules = *Hydrogen bonds*

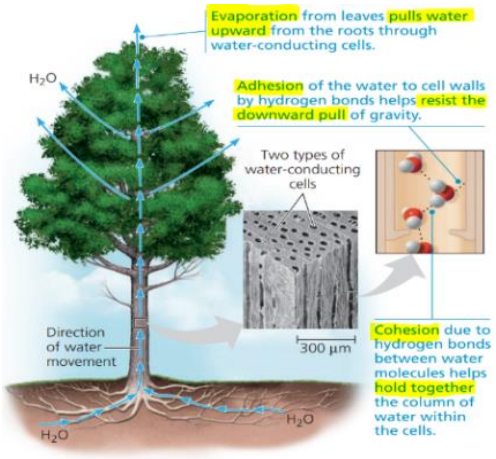
3.2: Properties of water that contribute to earth suitability for life

- There are 4 properties of water contribute to earth suitability for life:
  - Cohesion of water
  - Ability to moderate temperature
  - Expansion upon freezing
  - Versatility as a solvent

- All water properties are due to **hydrogen bonding** which is due to the **polarity** of water molecules

Cohesion of water

- ***Cohesion:*** Holding water molecules together by hydrogen bonding
- ***Adhesion:*** It is the clinging of one substance *to another*



- Transport of water in plants against gravity depends on:
  - Cohesion **holds** water molecules together from the roots to the leaves
  - Water adhesion with other molecules in the cell walls **resisting** (preventing) the downward pulling of gravity
  - Evaporation **pulls** water upward

Adhesion and cohesion are hydrogen bonding between:

- ✓ Water molecules to ***each other*** = *Cohesion*
- ✓ Water molecules with ***other molecule*** = *Adhesion*

- ***Surface tension:*** It is a property related to *cohesion*, and it is a measure of how difficult it is to stretch or break the *surface* of a liquid

- Water has a high surface tension due to hydrogen bonds between water below, but not to the air above, where water is coated with an invisible film allowing spider to walk on the pond surface

Ability to moderate temperature

- *Kinetic energy:* Energy of motion (not necessarily in any particular direction)
  - Faster movement = greater kinetic energy
- *Thermal energy:* Kinetic energy associated with the random movement of molecules and atoms
- Although thermal energy is related to temperature but they aren't the same, the difference:
  - *Temperature:* represent the **average** of Kinetic energy, regardless the volume of the material
  - *Thermal energy:* represent **total** kinetic energy, depends on the volume of the material
- *Heat:* It is thermal energy when transferred from one body to another
  - Heat passes from the warmer object to the cooler object until the two are the same temperature
  - An ice cube cools a drink by absorbing thermal energy from the liquid causing decrease in the thermal energy of the liquid and increase in the ice so melts
- Units of Heat
  - Calorie (cal): it is the amount of heat absorbed or released to raise or cool (change) the temperature of 1 g of **water** by 1^oC
  - Joule (J): [1 J = 0.239 cal], [1 calorie = 4.184 J]

Kilocalorie (kcal) = 1,000 Cal

- ***Specific heat:*** It is the amount of heat that must be absorbed or lost for 1 g of that **substance** to change its temperature by 1°C
  - It is a measure of how well a substance resists changing its temperature when absorbs or release heat

- Water has a *high specific heat* = 1 cal/(g. ^{o}C), which causes:
  - *High resistance* of water to change its temperature
  - If water absorbed or released a certain amount of heat it would change its temperature *slightly* (in a degree less than other substances)

- Why does the water have a High specific heat?
  - Due to H-bonds which causes the requirement of large amount of heat to disrupt them

Notes:

- ✓ Absorbing heat = molecules move faster = breaking (disrupting) H-bonds
- ✓ Releasing heat = molecules move slower = forming (stabilizing) H-bonds

To conclude

- Water can moderate the temperature due to hydrogen bonding which causes High specific heat and a very slight change in the temperature when it absorbs or releases a large amount of heat
- It is beneficial to:
  - It absorbs a huge amount of heat from coastal areas, during summer & daytime water then releasing it during winter & night so moderating the temperature
  - Stabilize ocean temperatures (creating a favorable environment for marine life)
  - Water covers most of Earth and keeps temperature fluctuations on land and water within limits that permit life
  - Organisms resist changes in their own temperature because they are made primarily of water

- ***Vaporization:*** The transformation of material from liquid to gas
- Generally, water molecules are moving & they differ in their speed
  - The fastest molecules have the greatest kinetic energy (hottest), so they are the most likely to overcome the attraction and escape from liquid as a vapor even at low temperature
  - Some evaporation occurs ***at any temperature***, why?
    - ✓ Temperature is the average kinetic energy of the molecules, some molecules can have kinetic energy much more than this average (molecules vary in their speed) and escape the liquid

- ***Heat of vaporization:*** It is the amount of heat a liquid must absorb for 1 g of it to be converted from liquid to gas
  - Water has a high heat of vaporization relative to most other liquids due to the strength of its H-bonds they must be broken to form water vapor
  - Heat of vaporization of water = double the heat of vaporization of alcohol & ammonia

- The effects of the high heat of vaporization of water:
  - On a global scale solar heat absorbed by tropical seas causes evaporation of surface water which moist tropical air which moves poleward releasing heat as it condenses forming rain (***moderate*** Earth's climate)
  - On an organismal scale when steam condenses into liquid on the skin heat energy released resulting in severity of steam ***burns***

- Evaporative Cooling
  - When liquid evaporates the surface of the liquid that remains behind cools down because the **hottest** (greatest kinetic energy) molecules **leave** as gas decreasing the average kinetic energy (temperature)

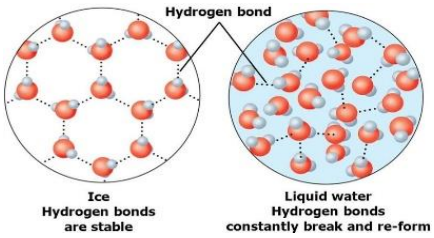
- Evaporative cooling of water contributes in:
  - Stability of temperature in lakes & ponds and prevents terrestrial organisms from overheating
  - Evaporation from the leaves of plants prevents them from being too warm from sunlight
  - Prevents human from overheating by evaporation of sweat from human skin

Expansion upon freezing

- As water freezes *H-bonds rearrange* and water expands become *less dense* as freezing than liquid water so ice *floats* above liquid water
  - Other materials contract and become denser when they solidify BUT water expands (less dense)

- At temperatures **above 4°C**: water behaves <u>like other liquids</u> (expanding as warms, contract as cools)
- As the temperature falls **from 4°C to 0°C**: water begins to freeze more and more of its molecules are moving too slowly no breaking of hydrogen bonds
- At **0°C**: the molecules become locked into a <u>crystalline lattice</u> *each water molecule hydrogen-bonded to four partners*

  - ✓ Liquid water: Hydrogen bonds break and reform
  - ✓ Ice: Hydrogen bonds are stable and kept a part from each other (it is less dense about 10%)



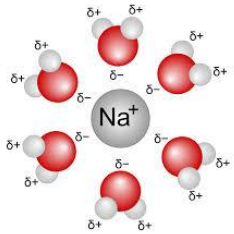
- When ice absorbs heat and it *rises above 0°C* hydrogen bonds are disrupted, crystal collapses and ice melts (molecules have fewer hydrogen bonds) then molecules become closer to each other and *density increases* until reaching 4^oC
  - The greatest density of water at **<u>4°C</u>**
- As temperature *rises above 4^oC*, molecules are moving faster and expands (*density decreases*)

- Floating of ice above liquid ice is important:
  - Suitability of the environment for life (If ice sank then ponds, lakes, and oceans would freeze solid)
  - The floating ice insulates the water below so preventing it from freezing & allowing life to exist under the ice
  - Ice also provides a solid habitat for some animals (such as polar bears and seals)

- ***Global warming:*** caused by increasing carbon dioxide and greenhouse gases in the atmosphere
  - ➢ It affects icy environments around the globe where ice forms later, melts earlier, covers smaller area

Versatility as a solvent

- *Solvent:* The dissolving *agent* of a solution
- *Solute:* The substance that is *dissolved*
- *Solution:* A liquid that is a completely homogeneous *mixture* of two or more substances
  - ➢ *Aqueous solution:* A solution in which the solvent is <u>water</u>
- Water is a very versatile solvent due to the **polarity** of water molecules
- Dissolving an ionic compound (such as NaCl) in water:
  - ➢ Ions are *attracted* to the partially charged regions of water molecules) due to their opposite charges
    - ✓ Partially negative oxygen atoms attract the cations (Na^+)
    - ✓ Partially positive Hydrogen atoms attract the anions (Cl^-)
  - ➢ ***Hydration shell:*** The sphere of water molecules *around* each dissolved ion
    - ✓ Water molecules *surround* the individual sodium and chloride ions and the solutes will be homogeneously mixed with water



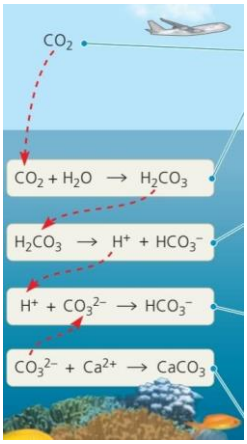
- A compound does not need to be ionic to dissolve in water also nonionic polar molecules can dissolve in water, such as:
  - ➢ Sugars are water-soluble (forming hydrogen bonds with water molecules)
  - ➢ Proteins are large molecules that can dissolve in water if they have ionic or polar regions on their surface

Hydrophilic and Hydrophobic

- ***Hydrophilic Substances:*** Substances have *affinity* for water
  - ➢ Some hydrophilic substances don't actually dissolve in water (because they could be too large and so can't dissolve in water) such as ***cotton***
    - ✓ Cotton is a plant product that contains cellulose and has many partial positive and negative charges forming H-bonds
- ***Hydrophobic substances:*** Substances *don't have affinity* for water
  - ➢ They are <u>nonionic</u> and <u>nonpolar</u> so no H-bonds and repel water
  - ➢ Such as ***Vegetable oil*** because of the nonpolar covalent bonds (H-C) repel with water and vinegar

3.3: Acidic and basic conditions affect living organisms

- Acidification: A Threat to Our Oceans
  - Human activities such as burning fossil fuels threaten water quality because of CO_2 (the main product of fossil fuel combustion) is absorbed by the oceans causing Ocean acidification
  - CO_2 dissolved in seawater forms carbonic acid which produces proton
  - H^+ from carbonic acid combines with carbonate ions to produce bicarbonate which causes the lack of carbonate
    - ✓ Carbonate is required for ***calcification*** (production of calcium carbonate) by many marine organisms, including reef-building corals



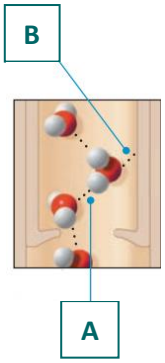
Past Papers

1) The oxygen atom in a water molecule due to its high electronegativity:
   - A) One negative charge
   - B) Two negative charges
   - C) One positive charge
   - D) Two positive charges
   - E) None of the above

2) Water is able to form hydrogen bonds because
   - A) oxygen has a valence of -1
   - B) the water molecule is shaped like a tetrahedron
   - C) the bonds that hold together the atoms in a water molecule are polar covalent bonds
   - D) the oxygen atom in a water molecule has a weak positive charge
   - E) each of the hydrogen atoms in a water molecule is weakly negative in charge

3) Each water molecules can form hydrogen bond with other _____ molecules
   - A) 4
   - B) 3
   - C) 2
   - D) 1

4) According to the figure which letters represent adhesion and which represent cohesion?
   - A) A: Cohesion, B: Cohesion
   - B) A: Adhesion, B: Adhesion
   - C) A: Cohesion, B: Adhesion
   - D) A: Adhesion, B: Cohesion



5) Which of the following effects is produced by the high surface tension of water?

A) Lakes don't freeze solid in winter, despite low temperatures
B) A water strider can walk across the surface of a small pond
C) Organisms resist temperature changes, although they give off heat due to chemical reactions
D) Water can act as a solvent
E) The pH of water remains exactly neutral

6) Which of the following takes place as an ice cube cools a drink?

A) Molecular collisions in the drink increase
B) Kinetic energy in the drink decreases
C) A calorie of heat energy is transferred from the ice to the water of the drink
D) The specific heat of the water in the drink decreases
E) Evaporation of the water in the drink increases

7) Which of the following statements correctly defines a kilocalorie?

A) the amount of heat required to raise the temperature of 1 g of water by 1°F
B) the amount of heat required to raise the temperature of 1 g of water by 1°C
C) the amount of heat required to raise the temperature of 1 kg of water by 1°F
D) the amount of heat required to raise the temperature of 1 kg of water by 1°C
E) the amount of heat required to raise the temperature of 1,000 g of water by 1°F

8) The property that can make water resistant to changing in its temperature?

A) High surface tension
B) High specific heat
C) High heat of evaporation
D) Its V-like shape
E) Covalent bond between water molecules

9) How much heat must be absorbed by 10 grams of water to raise its temperature by 5 ° C? (Specific heat of water ~ 4 J) :

A) 200 J
B) 40 J
C) 4 J
D) 1000 J
E) 500 J

10) When water vaporizes, which of the following bonds is broken?

A) Hydrogen
B) Ionic
C) Polar covalent
D) Non polar covalent

11) Temperature usually increases when water condenses. Which behavior of water is most directly responsible for this phenomenon?

A) the change in density when it condenses to form a liquid or solid
B) reactions with other atmospheric compounds
C) the release of heat by the formation of hydrogen bonds
D) the release of heat by the breaking of hydrogen bonds
E) the high surface tension of water

12) At what temperature is water at its densest?

A) 0°C
B) 212°C
C) 32°C
D) 100°C
E) 4°C

13) The sphere of water molecule around an ion is known as:

A) Hydration shell
B) Cohesion
C) Adhesion
D) Surface tension

14) Why does ice float in liquid water?

A) The liquid water molecules have more kinetic energy and thus support the ice
B) The ionic bonds between the molecules in ice prevent the ice from sinking
C) Ice always has air bubbles that keep it afloat
D) Hydrogen bonds stabilize and keep the molecules of ice farther apart than the water molecules of liquid water
E) The crystalline lattice of ice causes it to be denser than liquid water

15) Hydrophobic substances such as vegetable oil are:

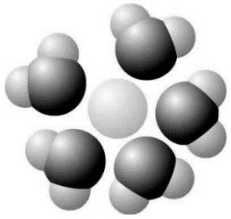
A) nonpolar substances that repel water molecules.
B) nonpolar substances that have an attraction for water molecules.
C) polar substances that repel water molecules.
D) polar substances that have an affinity for water.
E) charged molecules that hydrogen-bond with water molecules.

16) The tendency of water molecules to stay close to each other as a result hydrogen bonding:

A) Acts to moderate temperature
B) Keeps water moving through the vessels in tree trunk
C) Is called cohesion
D) Provide the surface tension that allows leaves to float on water
E) All of the listed responses are correct

17) Based on your knowledge of the polarity of water molecules, the solute molecule is most likely:

A) positively charged
B) negatively charged
C) without charge
D) hydrophobic
E) nonpolar



18) Some evaporation can occur at————-

A) High temperature B
B) Low temperature
C) Any temperature
D) At 100C
E) None of the above

19) Which of the following helps in the transporting of water against gravity

A) Cohesion
B) Adhesion
C) Evaporation
D) Condensation
E) All of them except D

20) Hydration shell can be form around

A) Ion
B) Sugar
C) Oil
D) Glucose
E) All of them except C

21) Transformation of material from liquid to gaseous state is known as

A) Evaporation
B) Vaporization
C) Boiling
D) Condensation
E) A+B

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