Structure of Water and Hydrogen Bonding

Chemistry Review

Matter

Anything that takes up space and has mass

- Rocks, metals, oils, gases, organisms, etc. are all forms of matter

Element

A substance that cannot be broken down into other substances by chemical reactions

- 92 elements occur in nature
- Periodic table

Compound

A substance consisting of two or more different elements combined in a fixed ratio

- H_2O
- NaCl

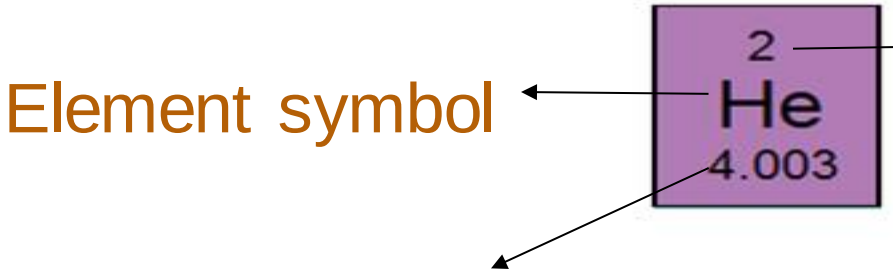
Essential elements: of the 92 naturally occurring elements 20-25% are essential to survive and reproduce. CHOPN make up 96% of living matter

Trace elements: of the 92 naturally occurring elements, these are required by an organism in very small quantities

Essential Elements

- Search up the essential elements. Why are they essential? (i.e. what major roles do these elements play in the human body?
- Search up trace elements. What are a few examples of trace elements and their purpose in the human body?

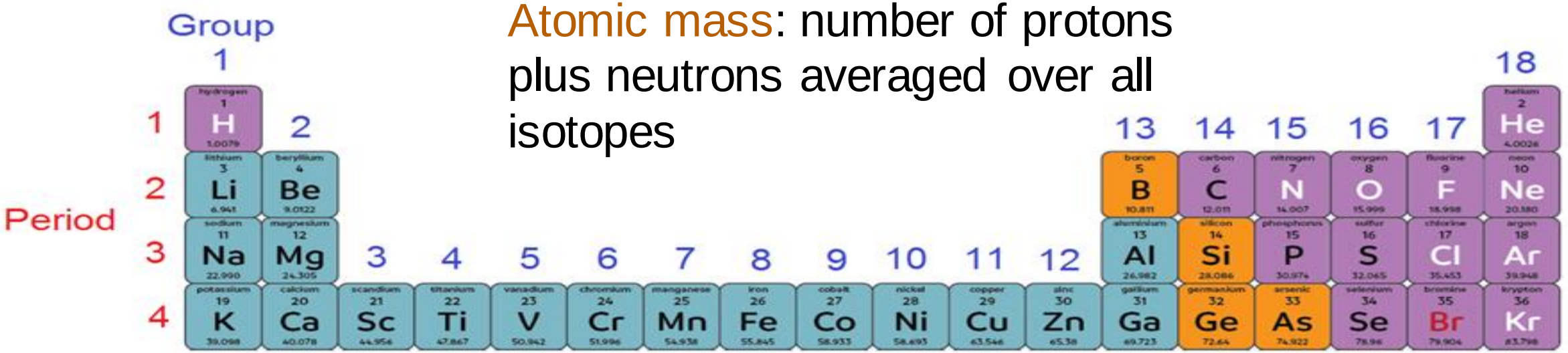
Chemistry Review



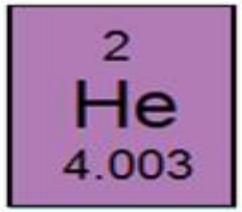
Element symbol

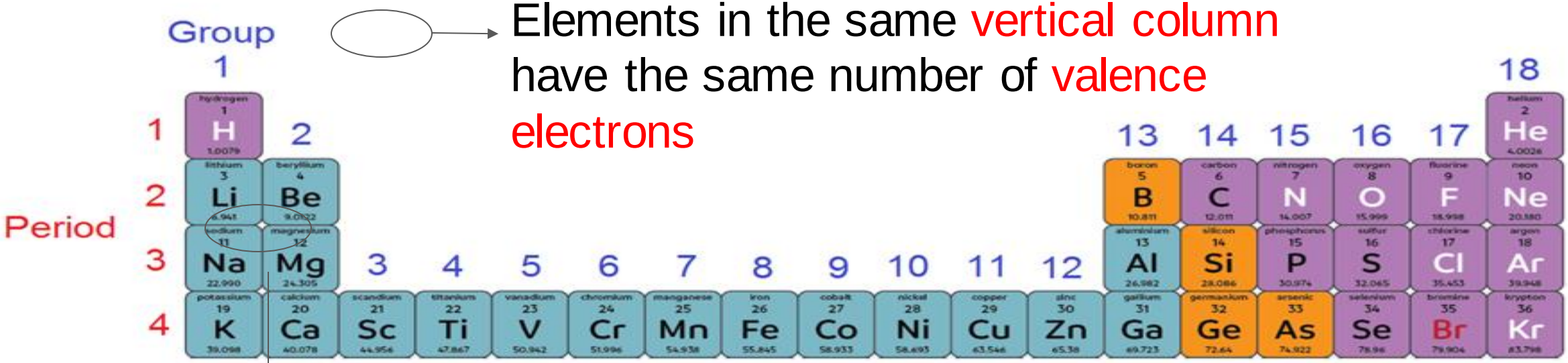
Atomic number: number of protons

Atomic mass: number of protons plus neutrons averaged over all isotopes



Chemistry Review



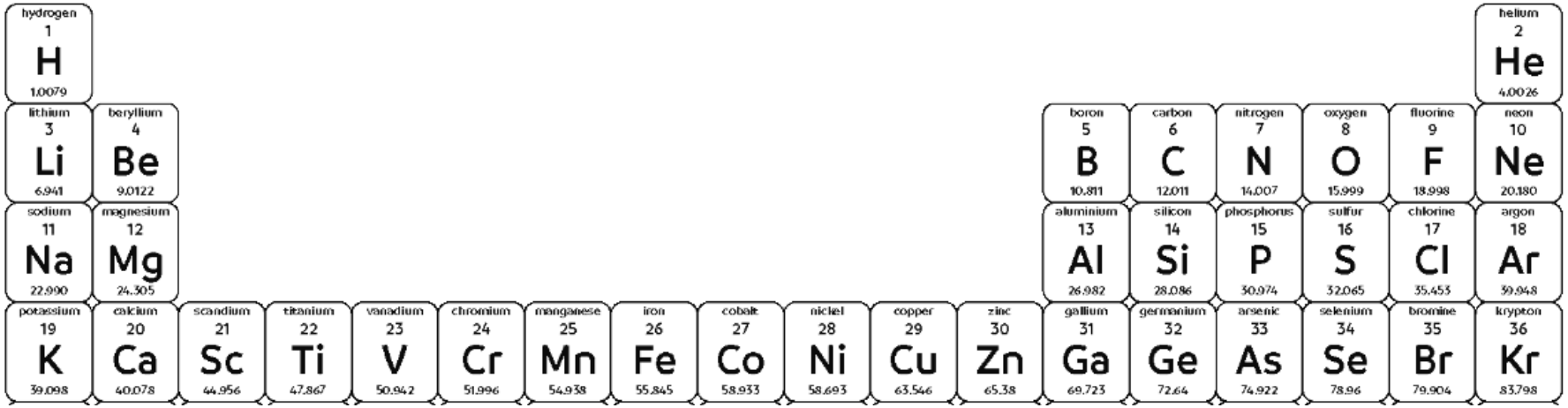


Elements in the same vertical column have the same number of valence electrons

Elements in the same horizontal row have the same total number of electron shells

The Periodic Table

- What else do you remember about the periodic table?

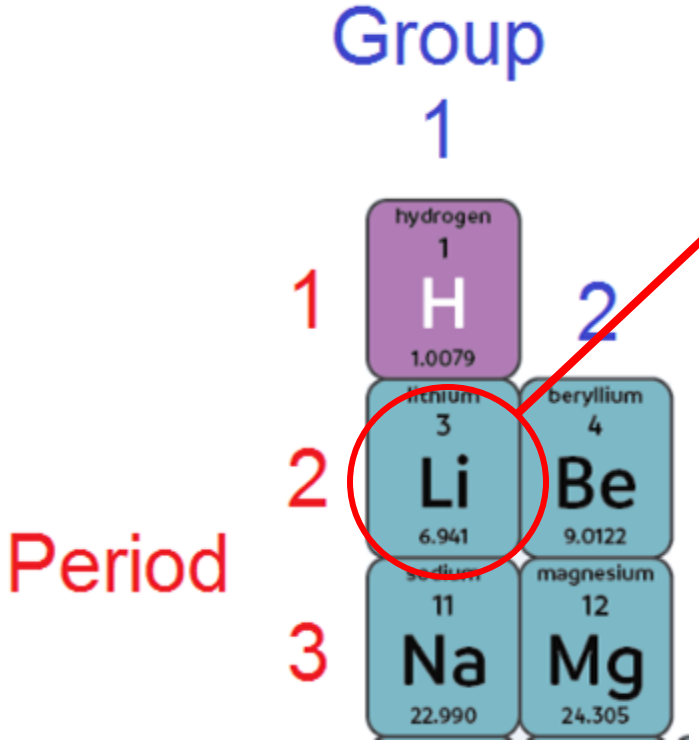


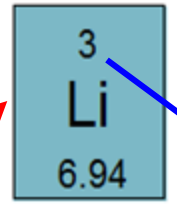
Bohr Model

- **Bohr Model**: shows electrons orbiting the nucleus of an atom
  - Electrons are placed on shells around the nucleus
  - Each shell is a different energy level and can hold up to a certain number of electrons
    - 1st shell: 2 e^-
    - 2nd shell: 8 e^-
    - 3rd shell: 18e^-

Bohr Models

Example: Lithium

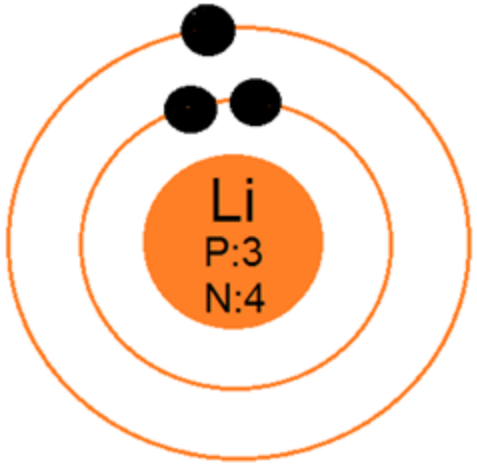




Period 2 = 2 shells

Group 1 = 1 valence e^-

3 protons = 3 electrons

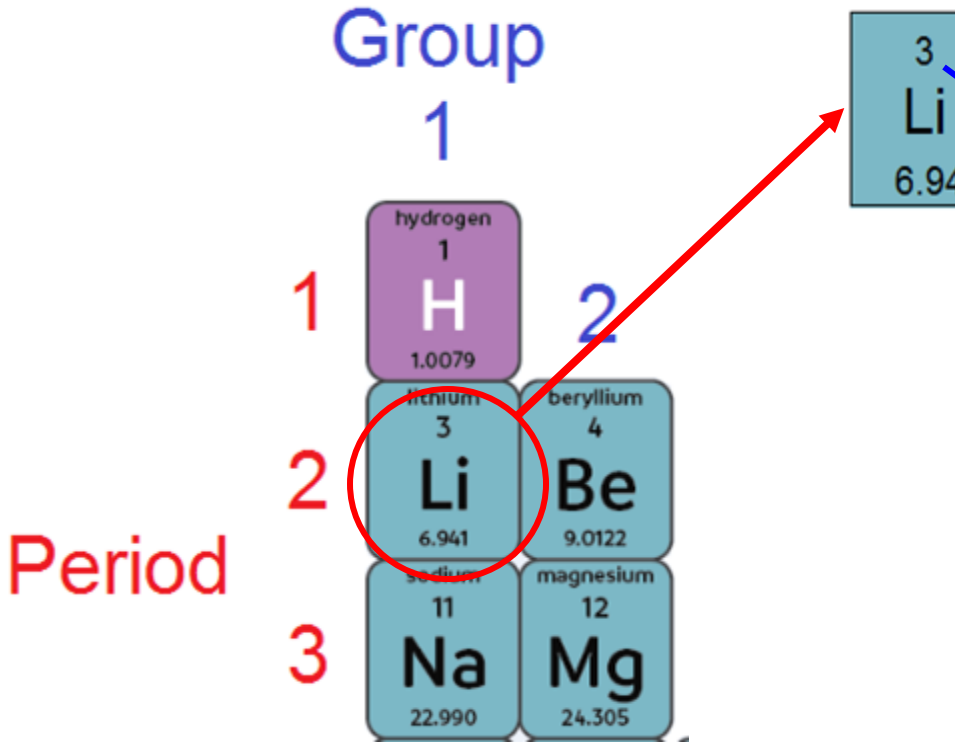


Lewis Dot Model

- **Lewis dot model**: simplified Bohr diagrams
  - Does not show energy levels
  - Only shows electrons in the valence shell (outermost shell)
  - Electrons are placed around the element symbol

Lewis Dot Model

Example: Lithium



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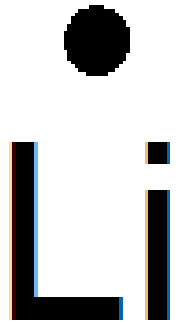


Types of Bonds

- Elements want to be **stable**
  - Achieve this by forming chemical bonds with other elements
  - **Octet rule**: elements will gain, lose, or share electrons to complete their valence shell and become stable (like noble gases)

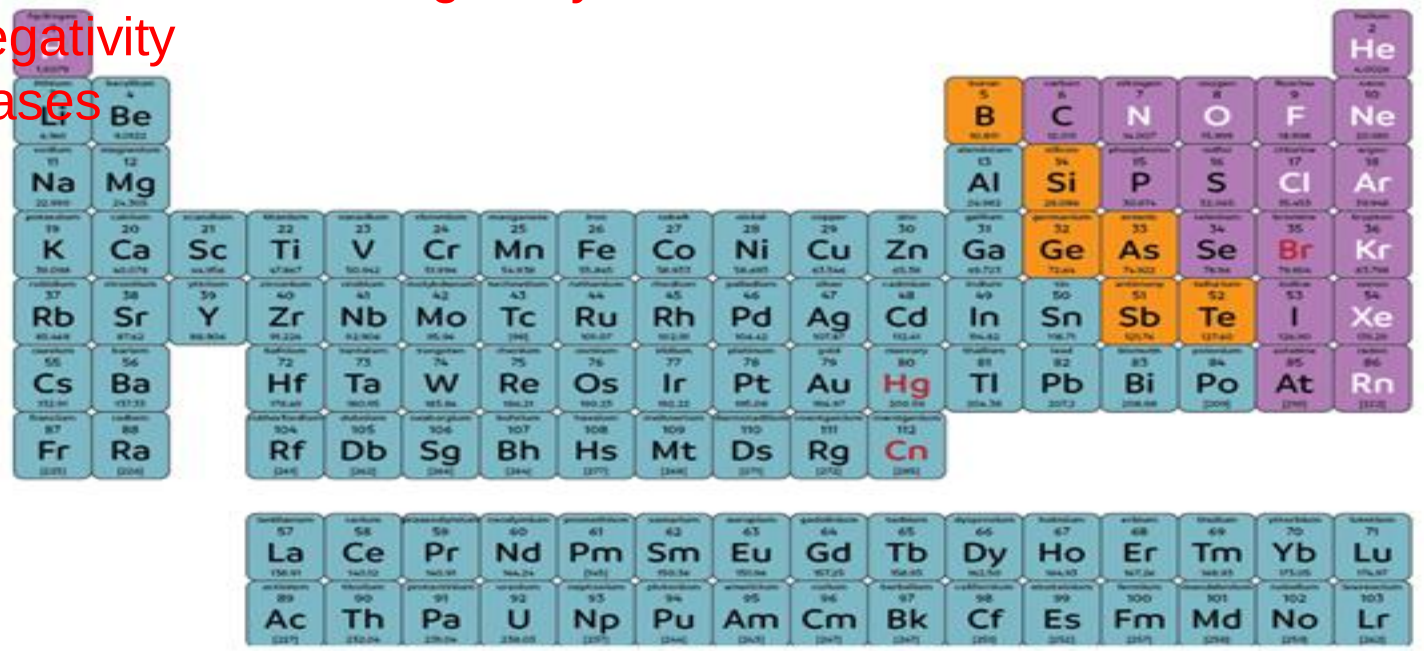
Types of Bonds

Chemical Bonds: an attraction between two atoms, resulting from the sharing or transferring of valence electrons

Electronegativity: the measure of an atom's ability to attract electrons to itself

Electronegativity increases →

Electronegativity decreases ↓

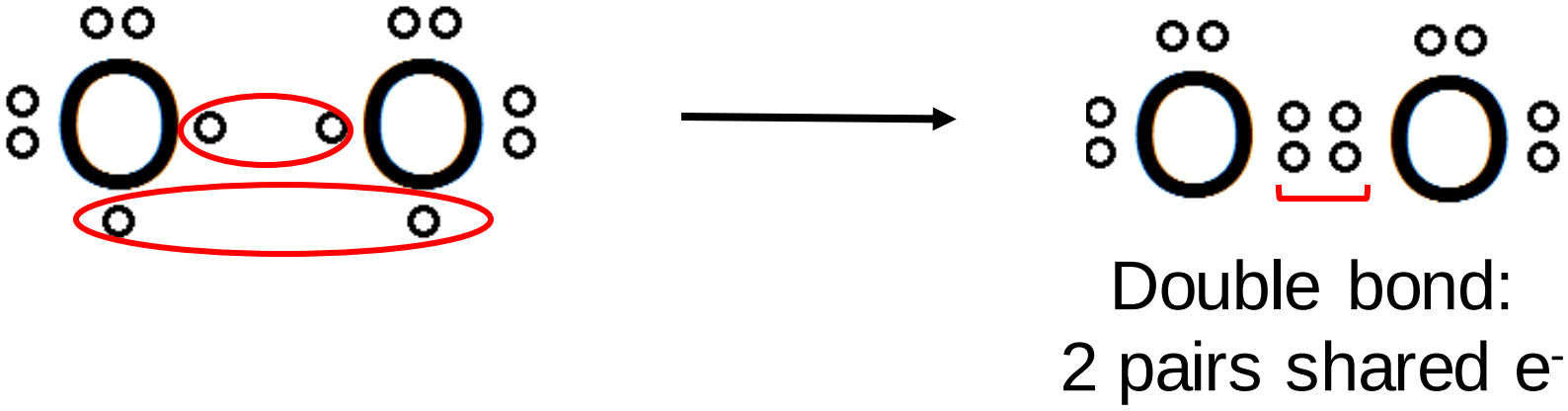


Types of Bonds

- **Covalent bonds**: when two or more atoms **share** electrons (usually between two nonmetals)
  - Forms molecules and compounds
    - Single bond: 1 pair of shared e-
    - Double bond: 2 pairs of shared e-
    - Triple bond: 3 pairs of shared e-
  - There are **two** types of covalent bonds: **nonpolar covalent** and **polar covalent**

Types of Bonds

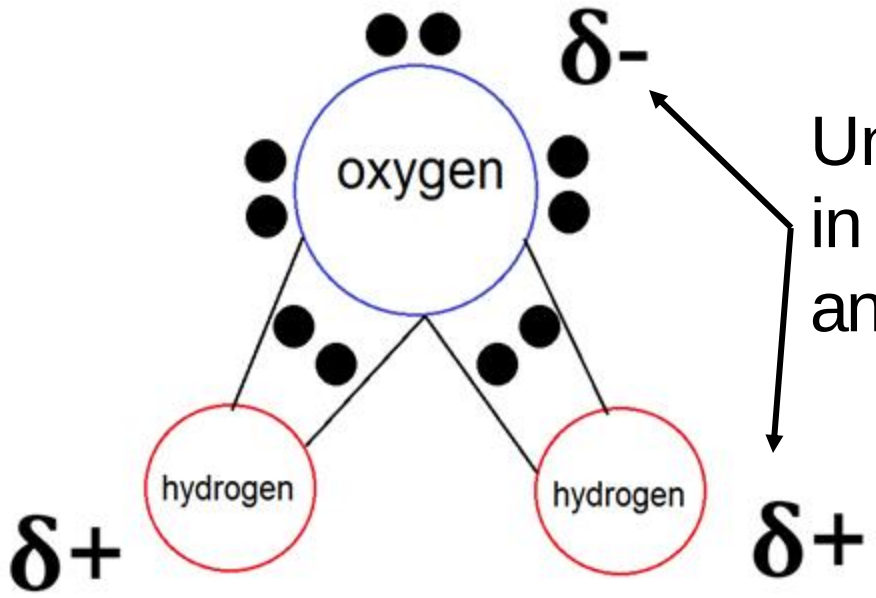
- **Nonpolar covalent**
  - Electrons are shared equally between two atoms
    - Example: O_2



Double bond:
2 pairs shared e^-

Types of Bonds

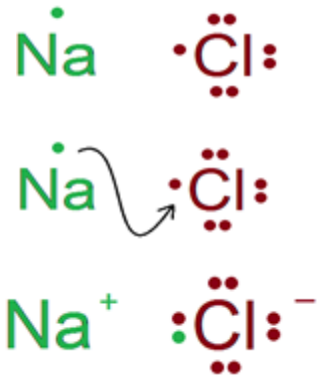
- **Polar covalent**
  - Electrons are not shared equally between two atoms
    - Example: H_2O



Unequal sharing of e- results in partial charges on oxygen and hydrogen

Types of Bonds

- **Ionic bonds**: The attraction between oppositely charged atoms (**ions**)
  - Usually between a metal and nonmetal (metal transfers electrons to nonmetal)
  - Forms ionic compounds and salts
    - NaCl
    - LiF
  - Occurs when there is a **transfer** of electrons from one atom to another atom forming ions
    - Cation: positively charged ion
    - Anion: negatively charged ion



Types of Bonds

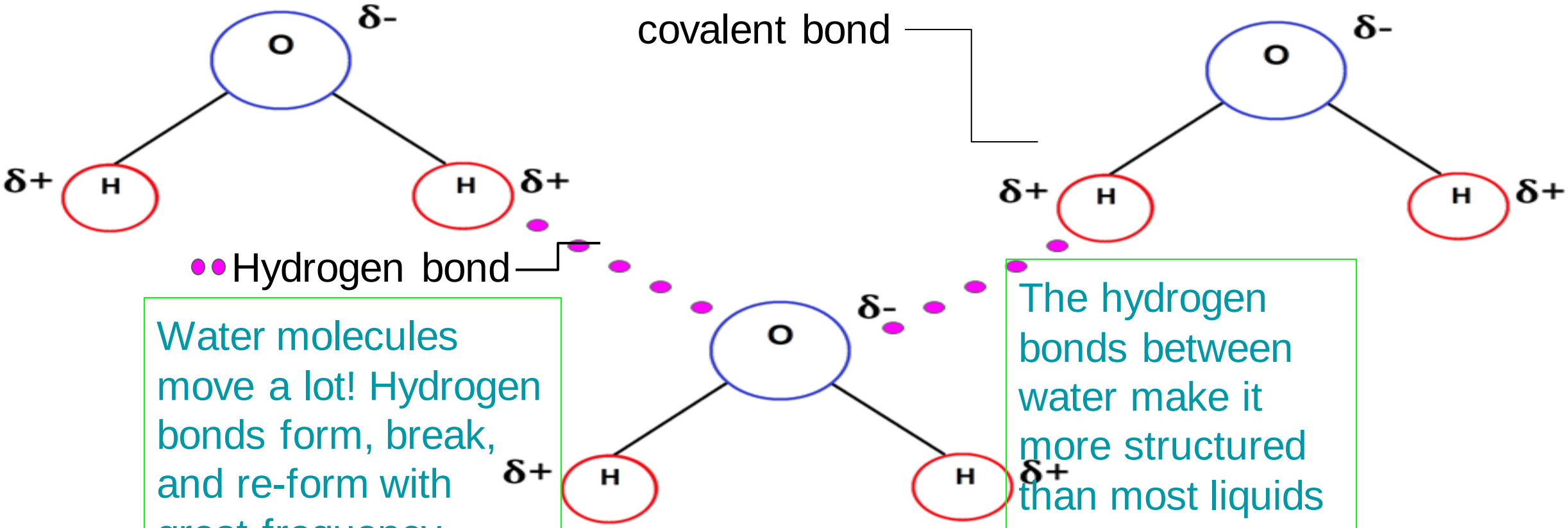
- **Hydrogen bonds**: the partially positive hydrogen atom in one polar covalent molecule will be **attracted** to an electronegative atom in another polar covalent molecule
  - **Intermolecular bond**: bond that forms **between** molecules

Types of Bonds

- **Why does this happen?**
  - When a hydrogen atom is bonded to an electronegative atom (usually O, N, or F) the electrons are <u>not being shared equally</u> between atoms (remember: this is a **polar covalent bond**)
    - This causes the **hydrogen** to have a partial positive charge and the electronegative atom to have a partial negative charge

Hydrogen Bonding

Example: hydrogen bonds between water molecules



Water molecules move a lot! Hydrogen bonds form, break, and re-form with great frequency

The hydrogen bonds between water make it more structured than most liquids

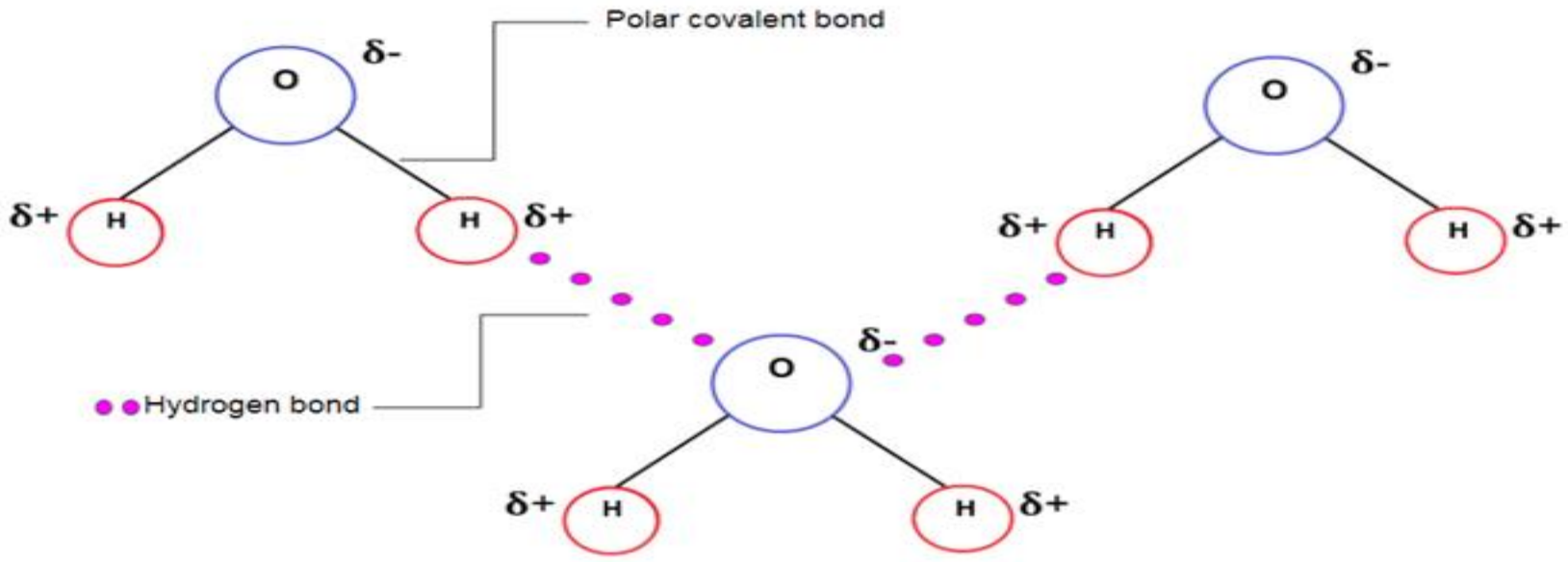
Properties of water

Properties of Water

Overview of the properties of water:

1. *Polarity*
2. *Cohesion*
3. *Adhesion*
4. *Capillary action*
5. *Temperature control*
    a. *High specific heat*
    b. *Evaporative cooling*
6. *Floating ice*
7. *Solvent*

Properties of Water

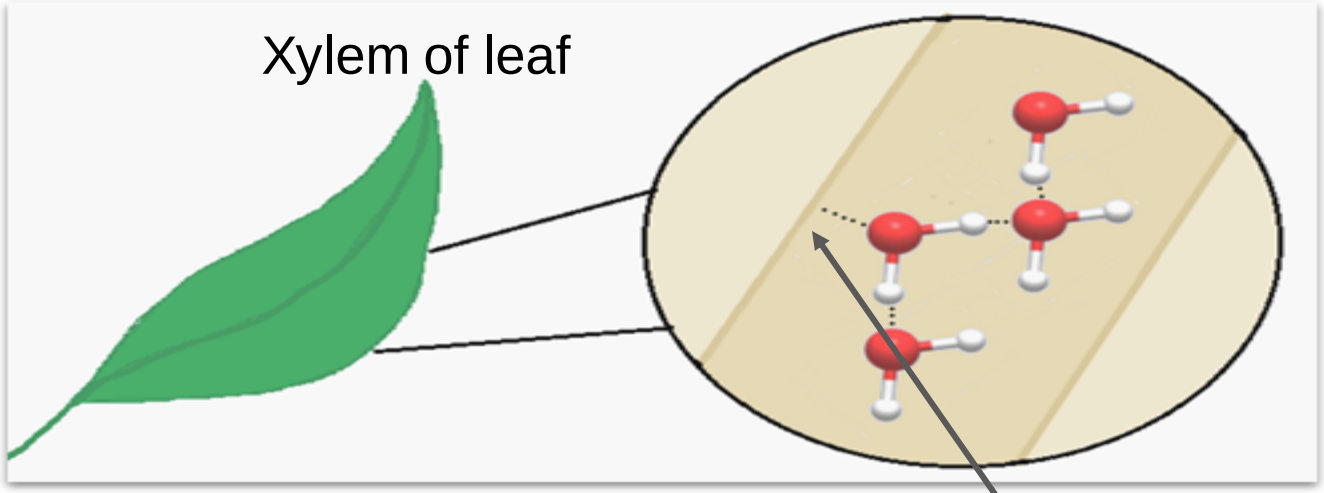


1. **Polarity**: unequal sharing of the electrons make water a polar molecule

Properties of Water

2. **Cohesion**: attraction of molecules for other molecules of the same kind

- Hydrogen bonds between H_2O molecules hold them together and increase cohesive forces



Cohesion: H_2O molecules stick together

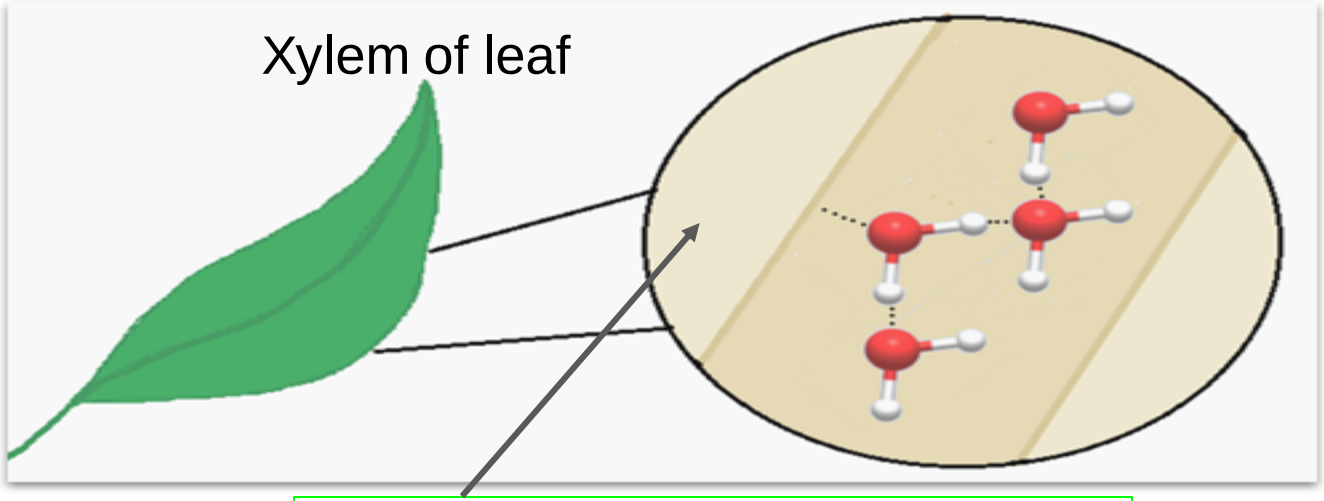
- Allows for the transport of H_2O and nutrients against gravity in plants
- Responsible for surface tension

Property allowing liquid to resist external force

Properties of Water

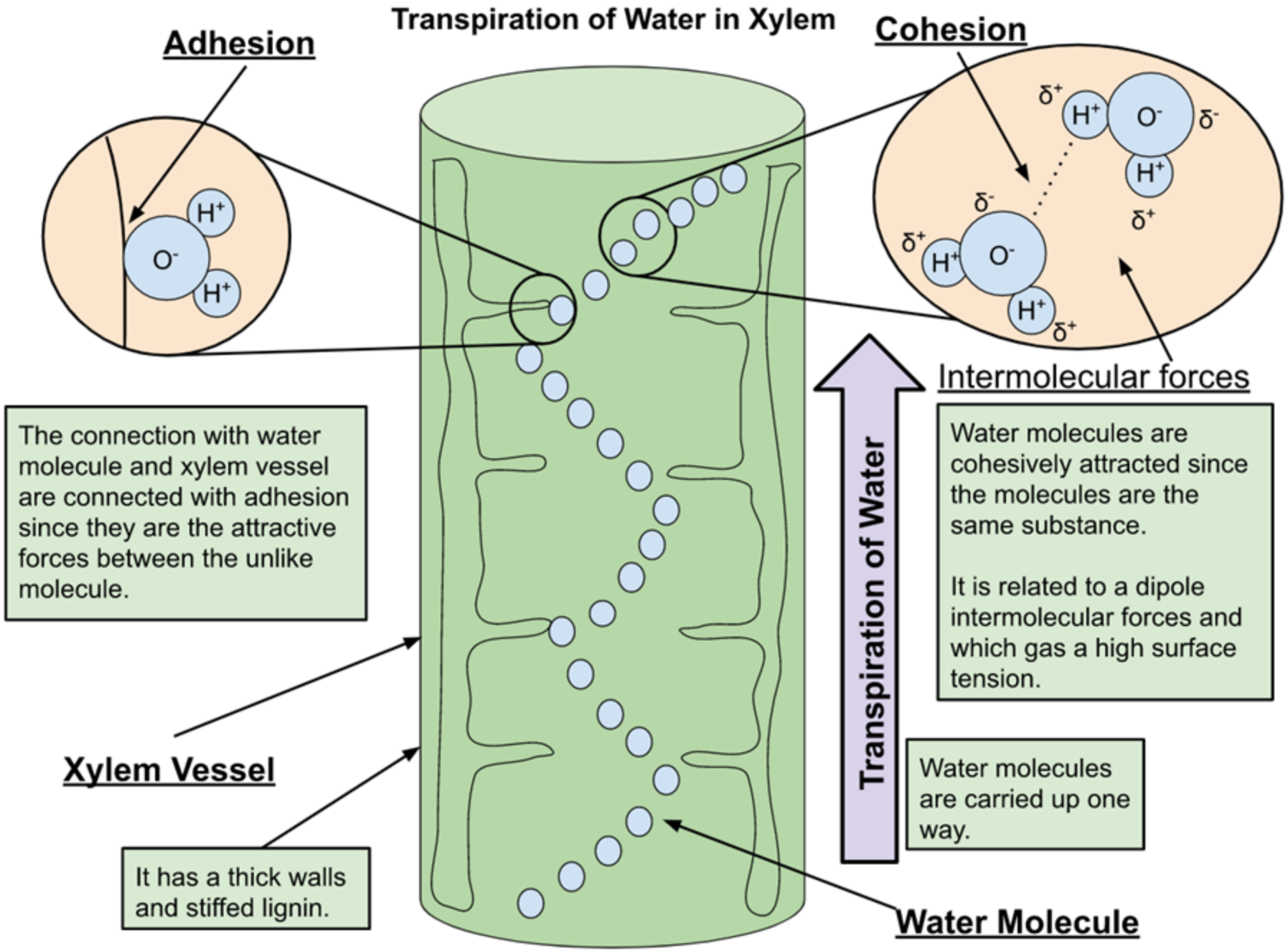
3. **Adhesion**: the clinging of one molecule to a different molecule

- Due to the polarity of H_2O
  - In plants, this allows water to cling to the cell walls to resist the downward pull of gravity



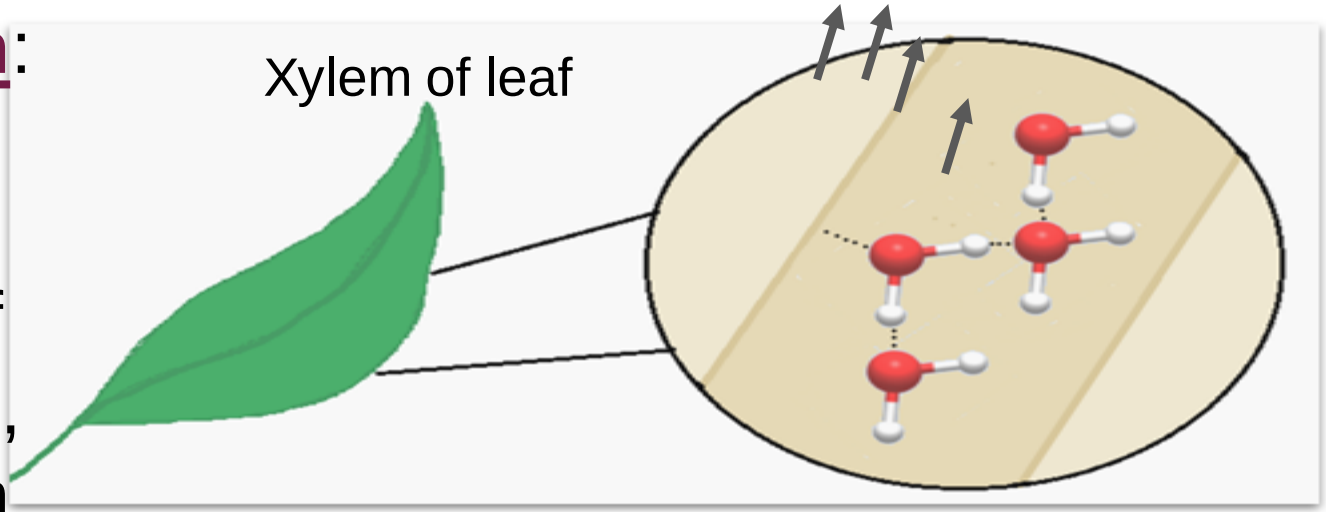
Adhesion: H_2O molecules stick to the xylem wall

Transpiration of Water in Xylem



Properties of Water

4. **Capillary Action**: the **upward** movement of water due to the forces of cohesion, adhesion, and surface tension



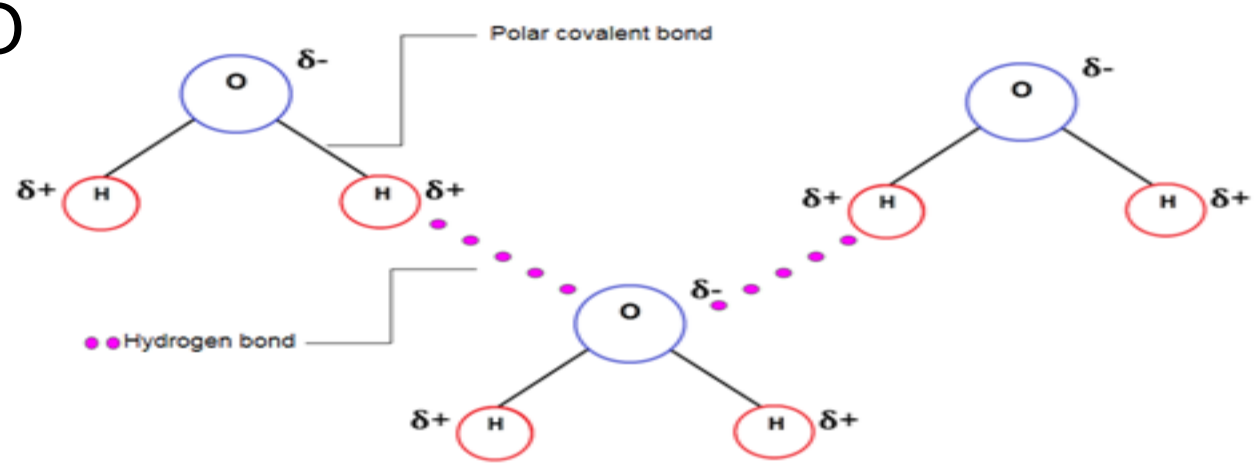
- Occurs when adhesion is greater than cohesion
  - Important for transport of water and nutrients in plants

Capillary action occurs moving water upwards

Properties of Water

5. **Temperature Control**

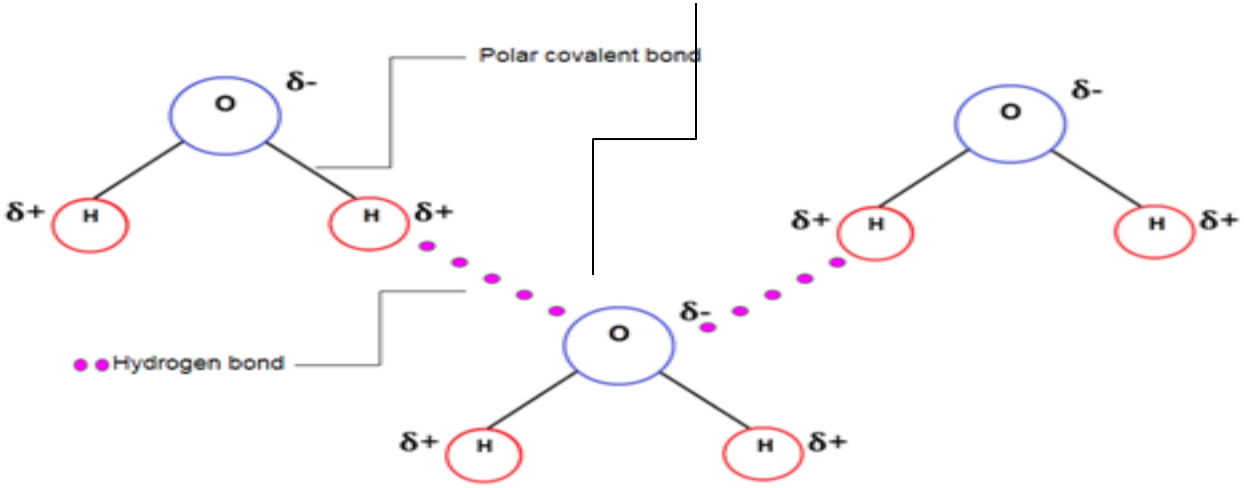
High Specific Heat: H_2O resists changes in temperature



- How?
- Hydrogen bonds!
  - Heat must be absorbed to break hydrogen bonds, but heat is released when hydrogen bonds form

Properties of Water

Temp control properties of H_2O stem from these hydrogen bonds

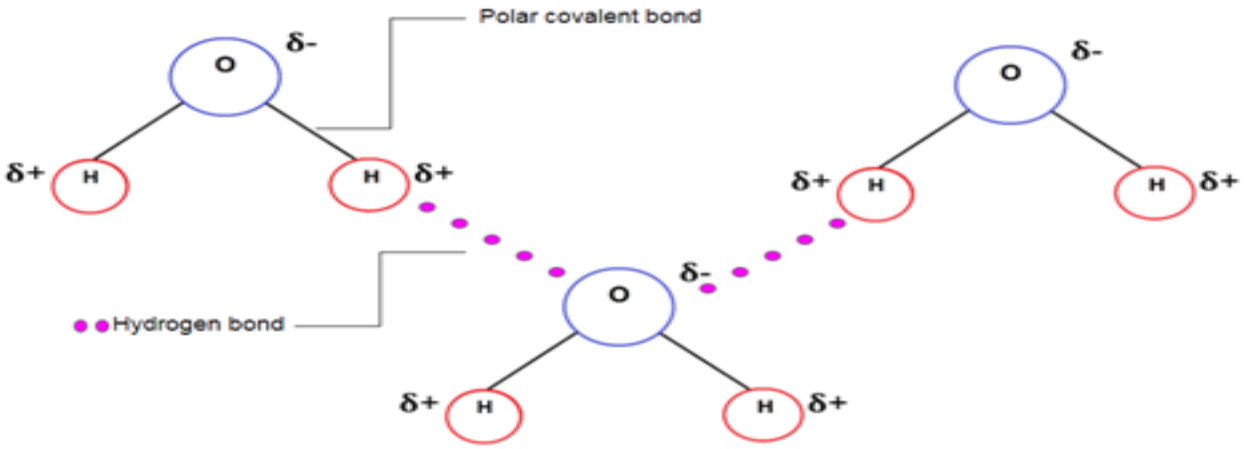


Importance of high specific heat:

- Moderates air temperature
  - Large bodies of water can absorb heat in the daytime and release heat at night
- Stabilizes ocean temp
  - Benefits marine life
- Organisms can <u>resist</u> changes in their own internal temp

Properties of Water

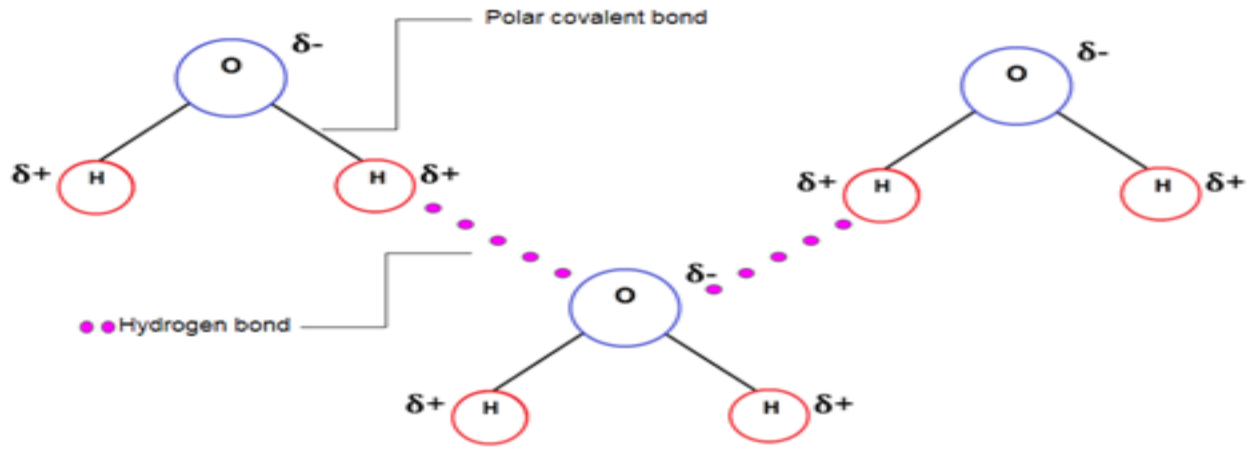
- **Evaporative Cooling**: water has a high heat of vaporization
  - The molecules with the highest kinetic energy leave as gas



Properties of Water

Importance of evaporative cooling:

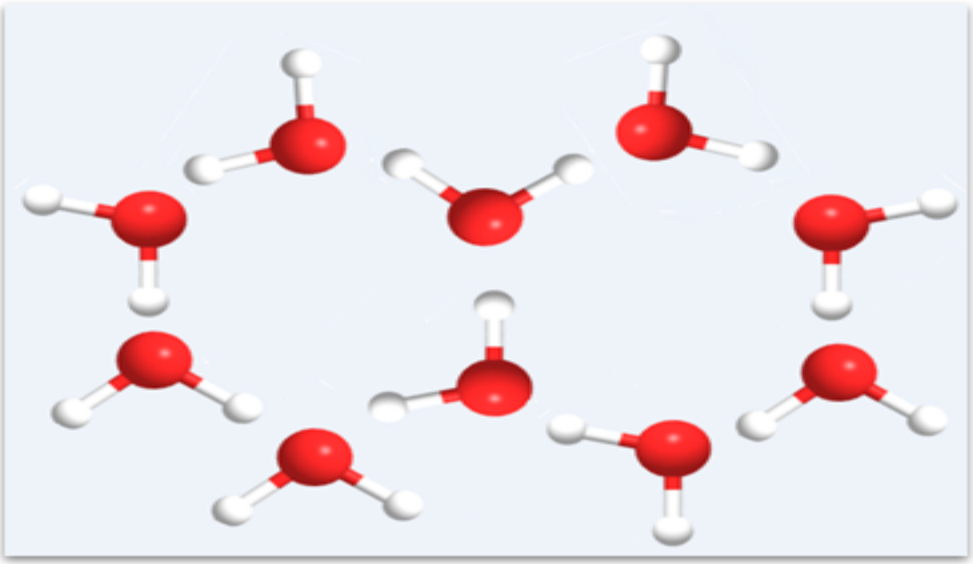
- Moderates Earth's climate
- Stabilizes temp in lakes and ponds



- Prevents terrestrial organisms from overheating (think sweating in humans)
- Prevents leaves from becoming too warm in the sun

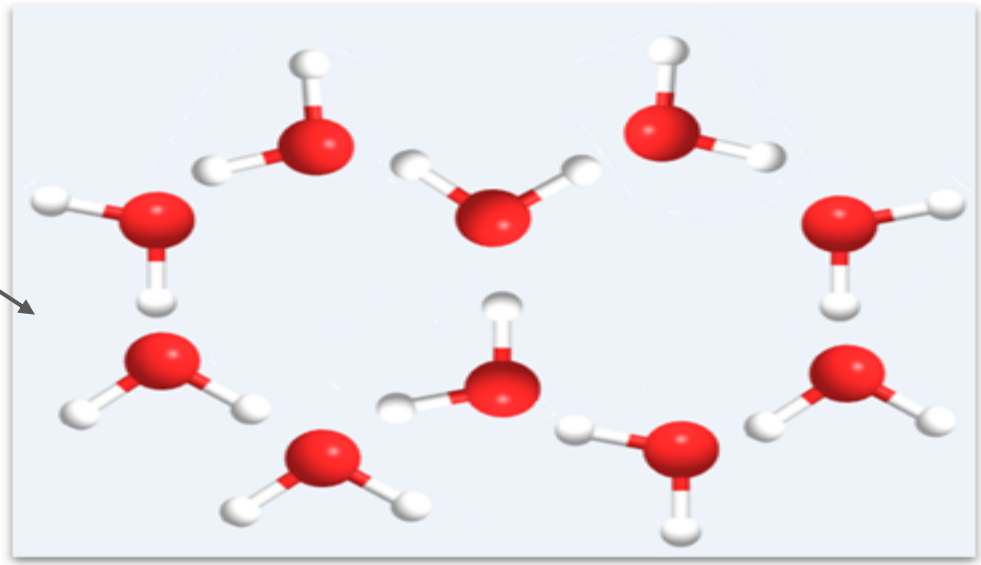
Properties of Water

6. **Density (floating ice)**: as water solidifies it expands and becomes less dense
   - Due to the hydrogen bonds
   - When cooled, H_2O molecules move too slowly to break the bonds
     - Allows marine life to survive under floating ice sheets



Properties of Water

Hydrogen bonds cause water molecules to form a crystalline structure



Quick! Think, Pair, Share

Imagine the 3D crystalline structure of ice. How many hydrogen bonds can one molecule of water make with its neighboring water molecules?

Answer: four

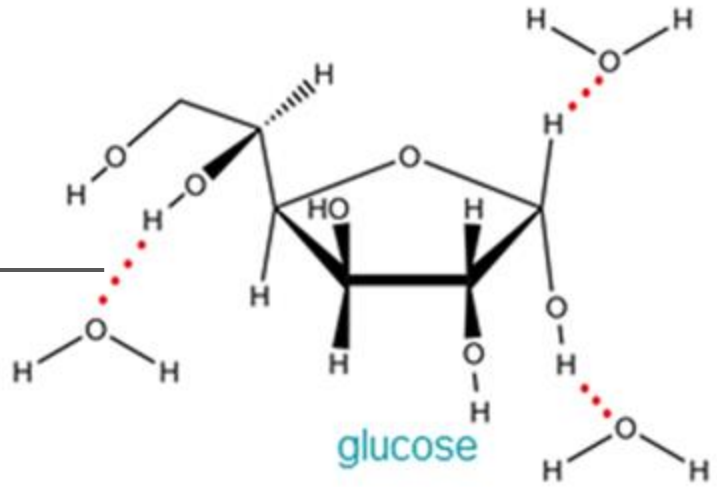
Properties of Water

7. **Solvent**: dissolving agent in a solution
- Water is a versatile solvent
  - Its polar molecules are attracted to ions and other polar molecules it can form hydrogen bonds with

Solution: homogenous mix of 2+ substances
Solvent: dissolving agent in a solution
Solute: substance that is dissolved

Properties of Water

- “Like dissolves like”
- Water can interact with sugars or proteins containing many oxygen and hydrogen
- Water will form hydrogen bonds with the sugar or protein to dissolve it



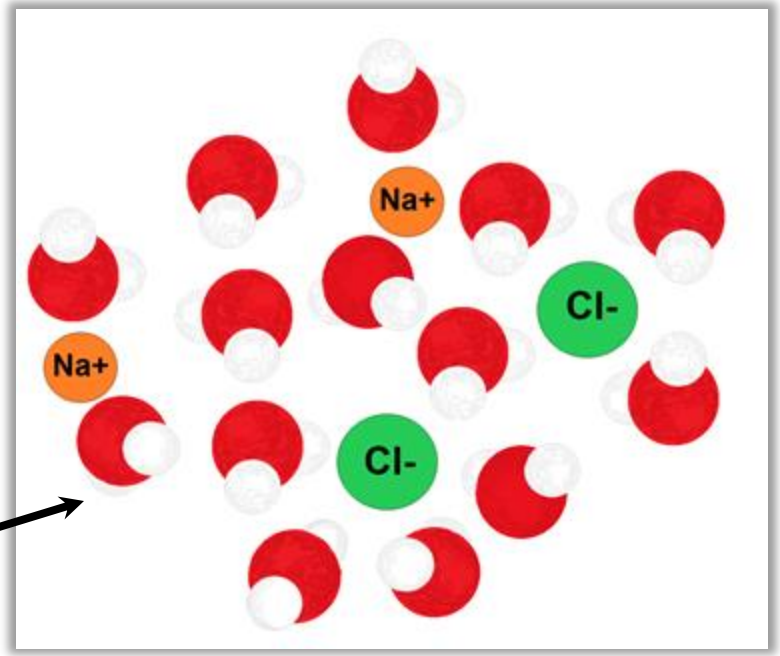
Properties of Water

Ionic compounds

- The partially negative oxygen in water will interact with a positive atom
- The partially positive hydrogen in water will interact with a negative atom
- Dissolves ions

Cl-

Na+



Na+ surrounded by oxygen

Cl- surrounded by hydrogen