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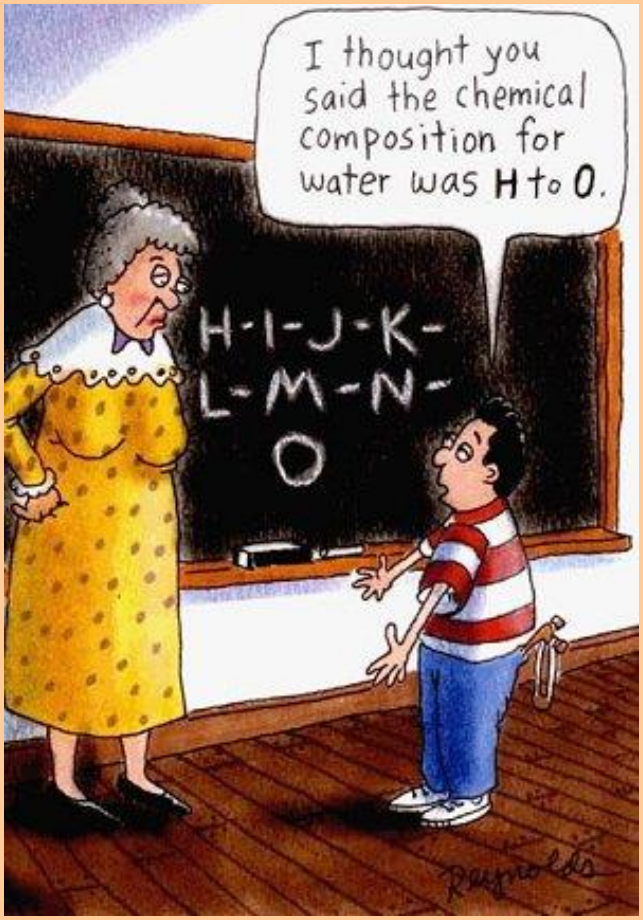
Click on "Play from Beginning"

Chapter 2: THE COMPOSITION AND CHEMISTRY OF LIFE



Lesson Objectives

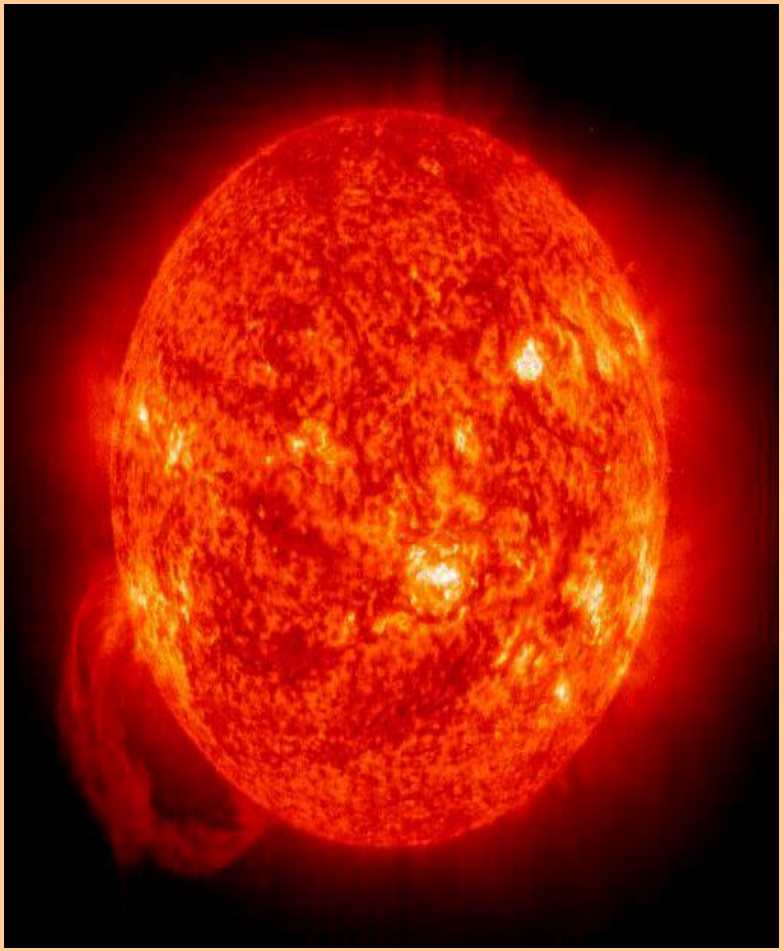
By the end of this lesson, you should be able to:

- Understand matter and how matter is affected (physical versus chemical changes).
- Describe atoms and molecules (subatomic particles, atomic number, atomic mass, isotopes).
- Explore types of bonds between atoms and molecules (covalent, ionic, hydrogen).
- Identify and explain hydrogen bonding and its relationship to the properties of water.
- Define solutions especially when water is the solvent.
- Describe acidic and basic solutions in terms of pH, ion concentration and examples.
- Explain buffers and their relevance to life.

- **Science Practice: Chemistry Overview Lab**

MATTER

- Living organisms are composed of **Matter.**
- **Matter** - anything that occupies space or has mass (weight).
- **Matter** is composed of chemical **Elements.**



Physical changes affect the state or structure, but do NOT change the chemical make-up of a substance.

Chemical Changes

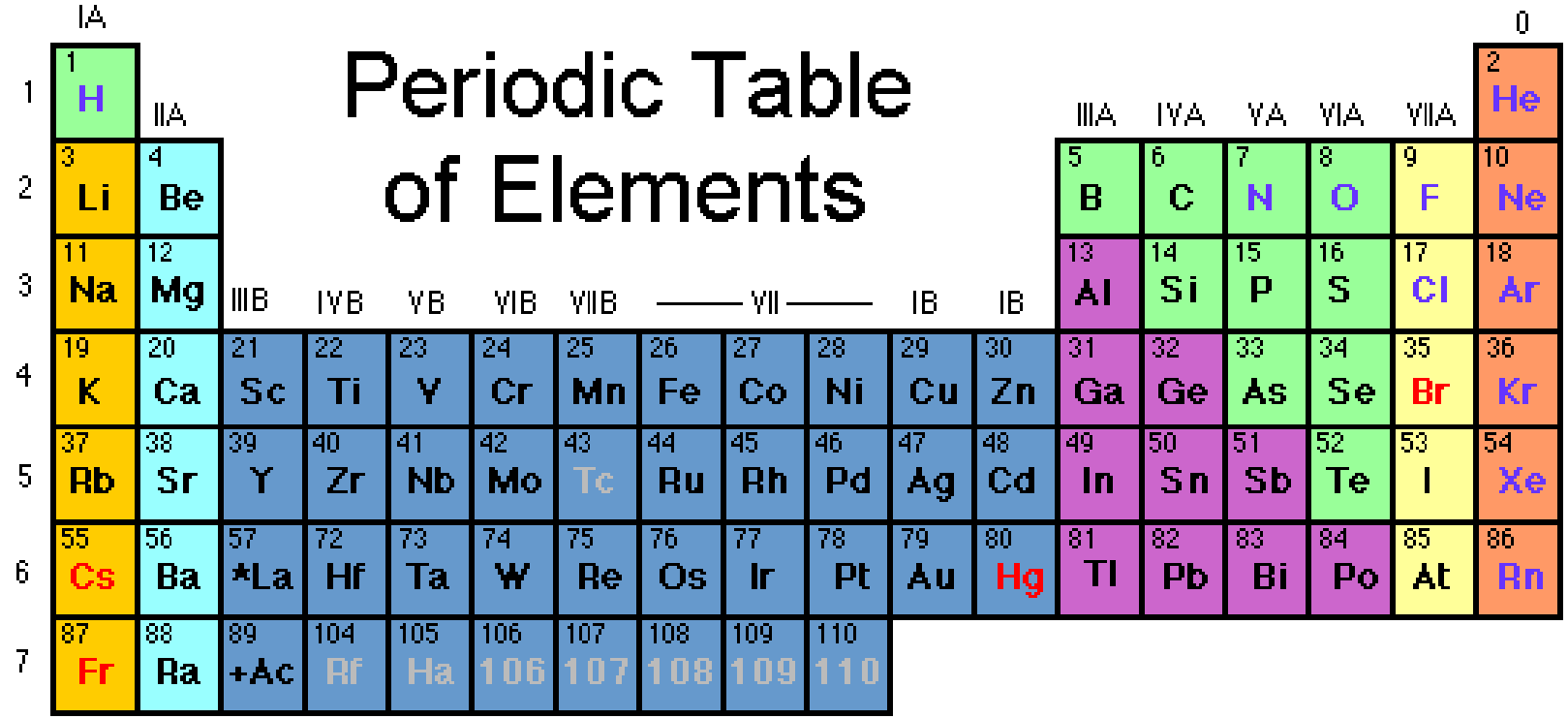
- alter the *chemical composition* of a substance.
- produce NEW substances with physical & chemical properties DIFFERENT from the constituents.

e.g. Sodium (Na) explodes in air, Chlorine gas (Cl_2) is lethal
But table salt (NaCl) tastes great!

Elements

- Substances that cannot be broken down chemically into simpler kinds of matter.
- Composed of only one type of **ATOM.**
- More than 110 elements (92 naturally- occurring)
- **Essential elements** in living organisms include
  - **C**arbon
  - **H**ydrogen
  - **O**xygen
  - **N**itrogen
- **CHON**

Periodic Table of Elements



* Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+ Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

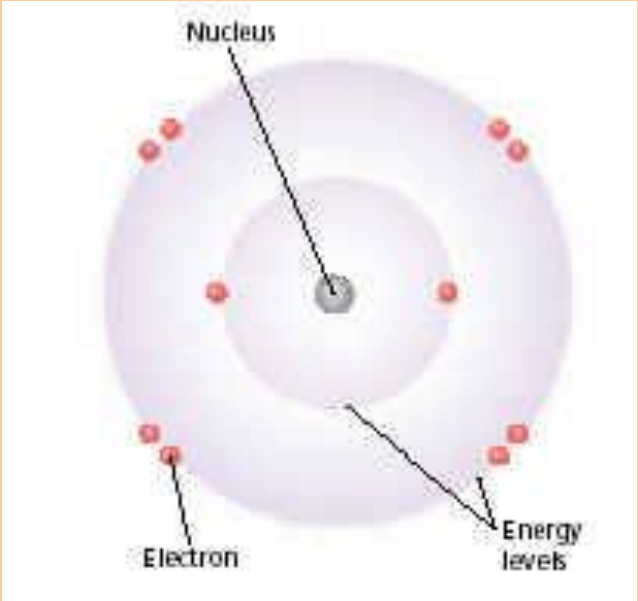
Legend - click to find out more...

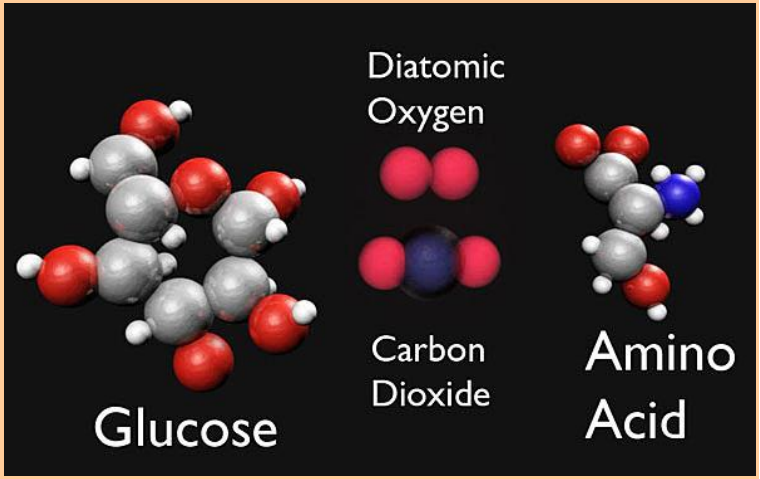
H - gas **Li - solid** **Br - liquid** **Tc - synthetic**

Non-Metals
Transition Metals
Rare Earth Metals
Halogens
Alkali Metals
Alkali Earth Metals
Other Metals
Inert Elements

Atoms and Molecules

- **ATOMS** are the simplest particle of an element that retains all the properties of that element.
  - **Smallest building blocks of Matter**
- Properties of atoms determine the structure and properties of the matter they compose.
- **MOLECULES** are groups of atoms connected together.

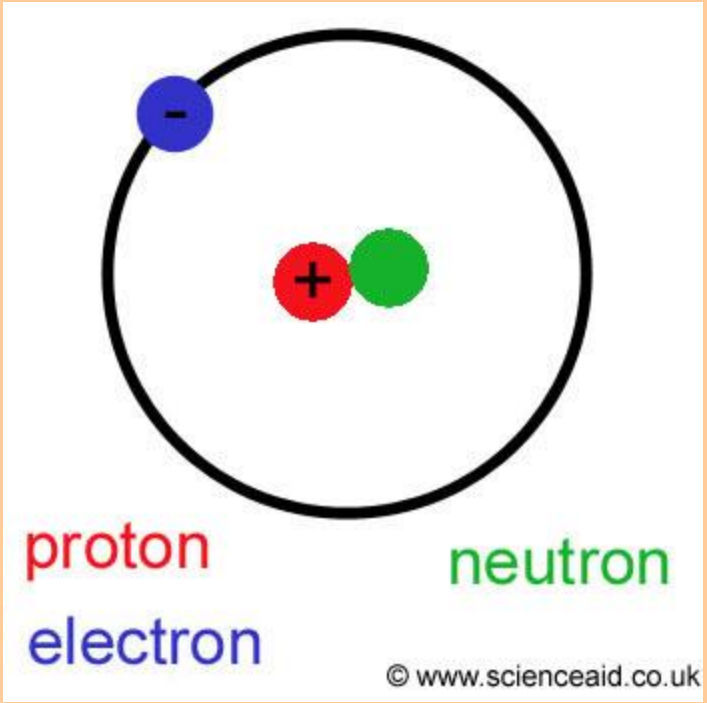




SUBATOMIC PARTICLES

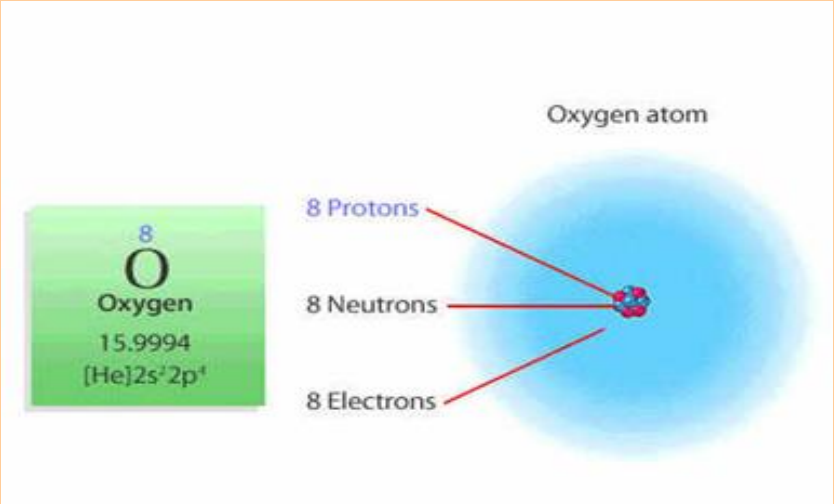
Atoms of each element are composed of even smaller parts called **Subatomic Particles:**

- **Neutrons**, which have no electrical charge (in nucleus).
- **Protons**, which are positively charged (in nucleus).
- **Electrons**, which are negatively charged (around the nucleus in a "cloud").



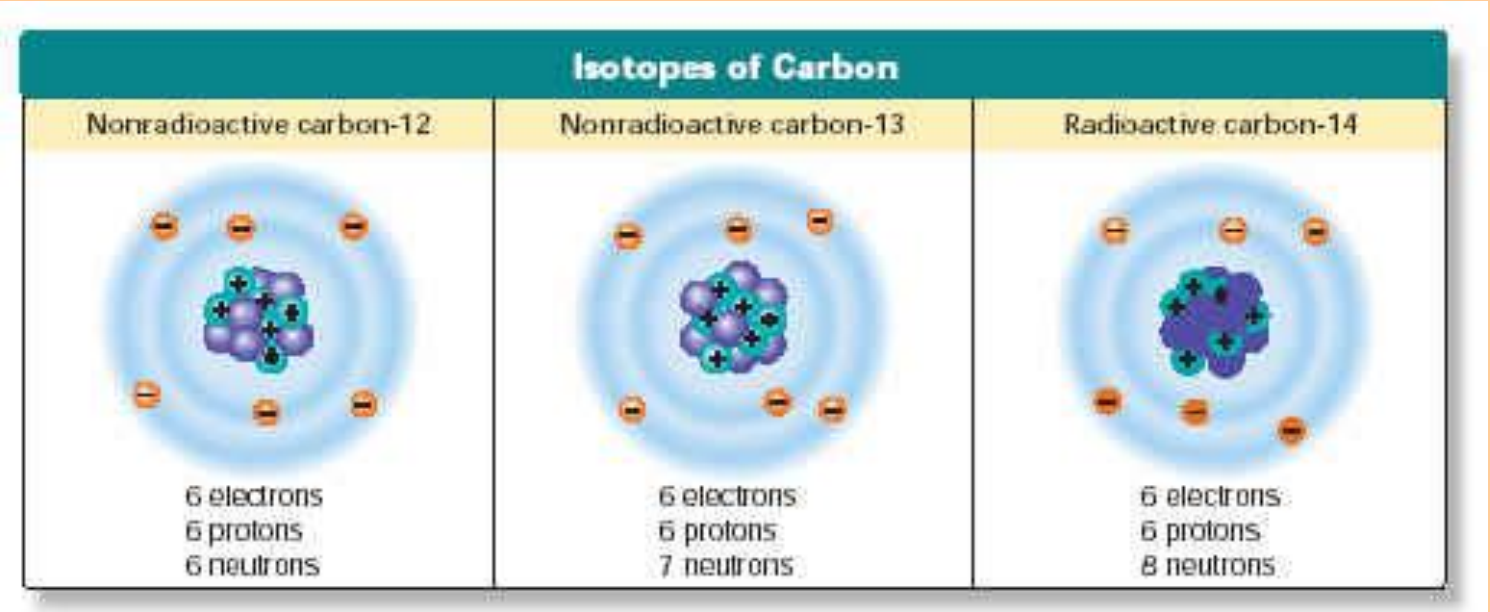
Atomic Number and Mass

- Number of protons of an atom of a particular element is called the **Atomic Number.**
- The number of protons + neutrons = **Atomic Mass.**
- Number of protons is normally balanced by an equal number of negatively charged electrons.



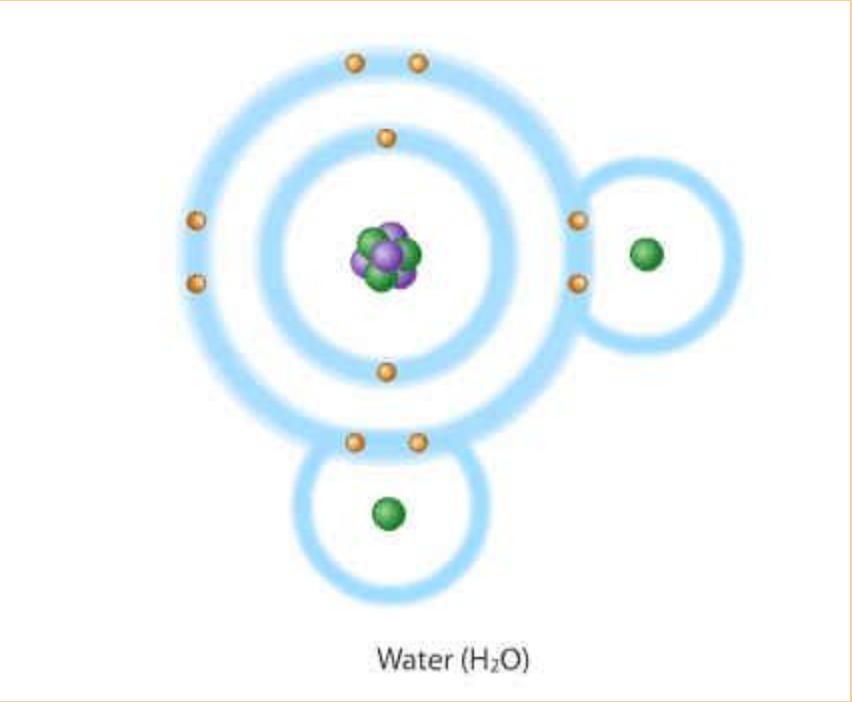
Isotopes

- Different forms of the same element.
- Have the **same number of protons**, but **different number of neutrons.**
- May be radioactive, spontaneously giving off particles and energy.
- May be used to date fossils or as medical tracers.



Chemical Bonds: Covalent

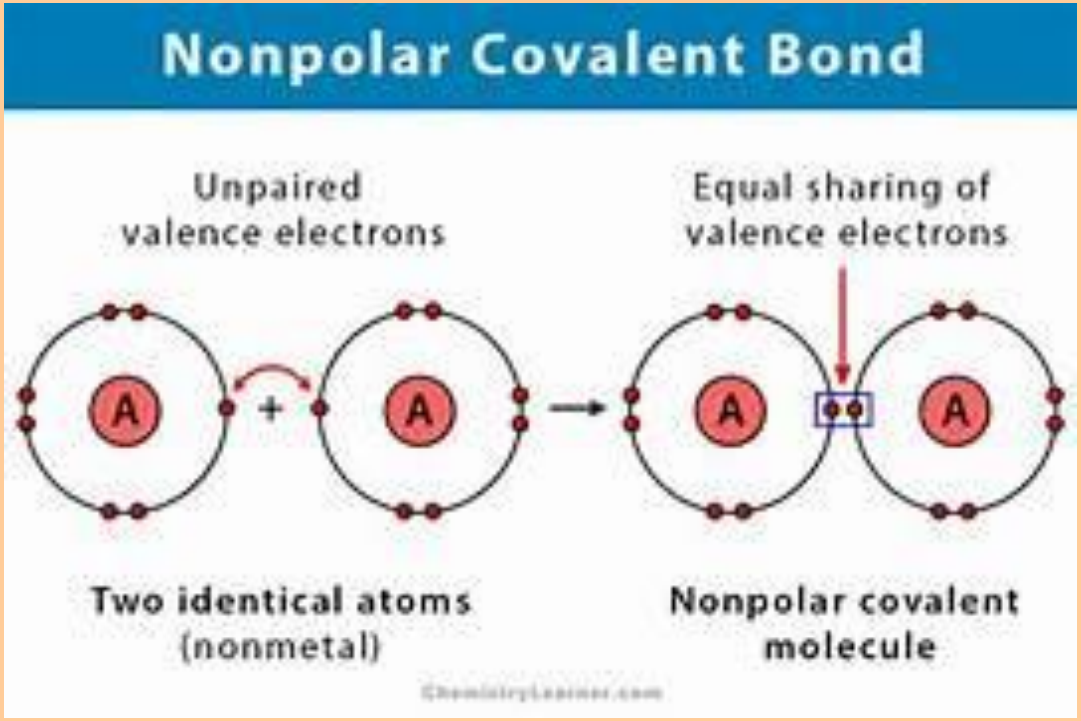
- Formed when two atoms **share** one or more pairs of electrons.
- Often the **Strongest** type of chemical bond.
- Types:
  - **Non-Polar**
  - **Polar**



Water (H_2O)

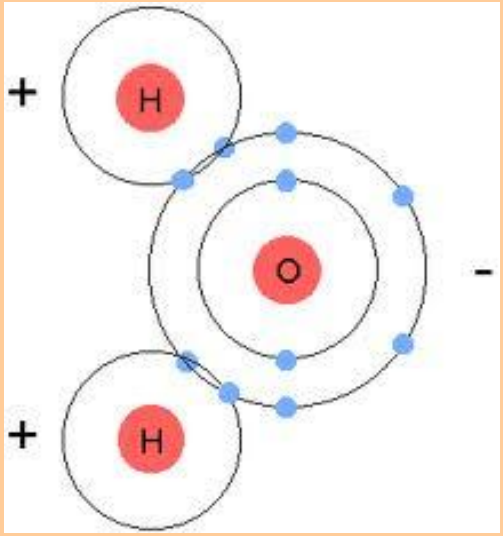
Non-Polar Covalent Bonds

- In **non-polar covalent bonds**, sharing of electrons is **equal**, i.e. the electrons are not attracted to either atom to a greater degree.



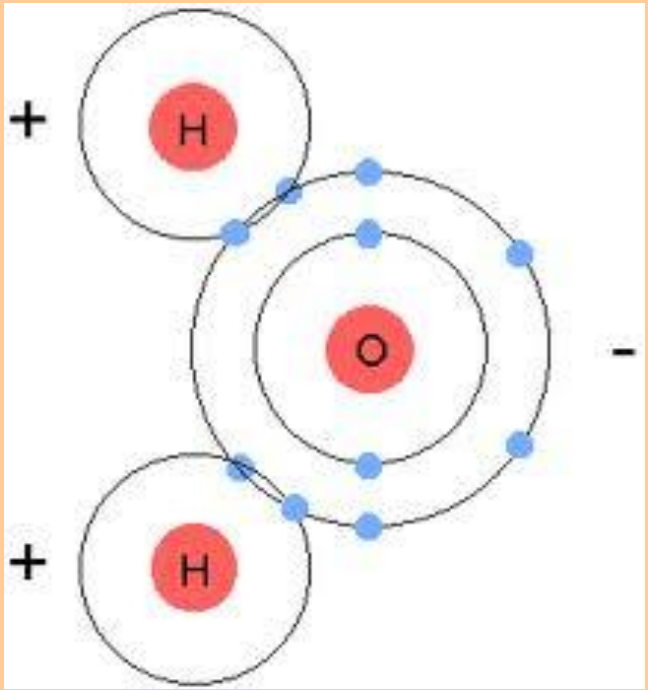
Polar Covalent Bonds

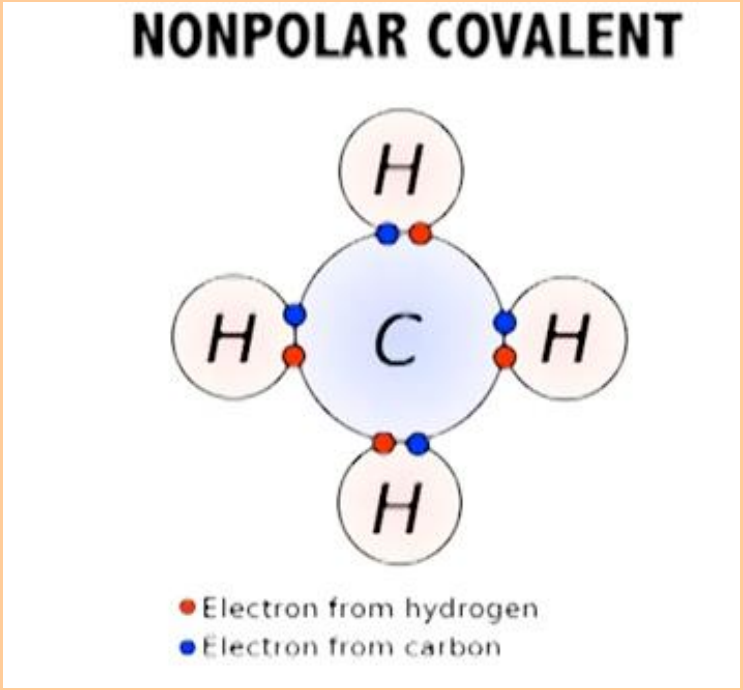
- With **polar covalent bonds**, the sharing of electrons is **unequal** i.e. electrons involved in the bond are slightly more attracted to one atom of the bond than to the other.
- **Example:**
  - **Water** (H_2O) is a polar molecule.
  - Electrons spend more time with Oxygen than Hydrogens.
  - **Hydrogens** become slightly **positive**, **Oxygen** slightly **negative.**



Polar & NonPolar Covalent Molecules

Polar Molecule

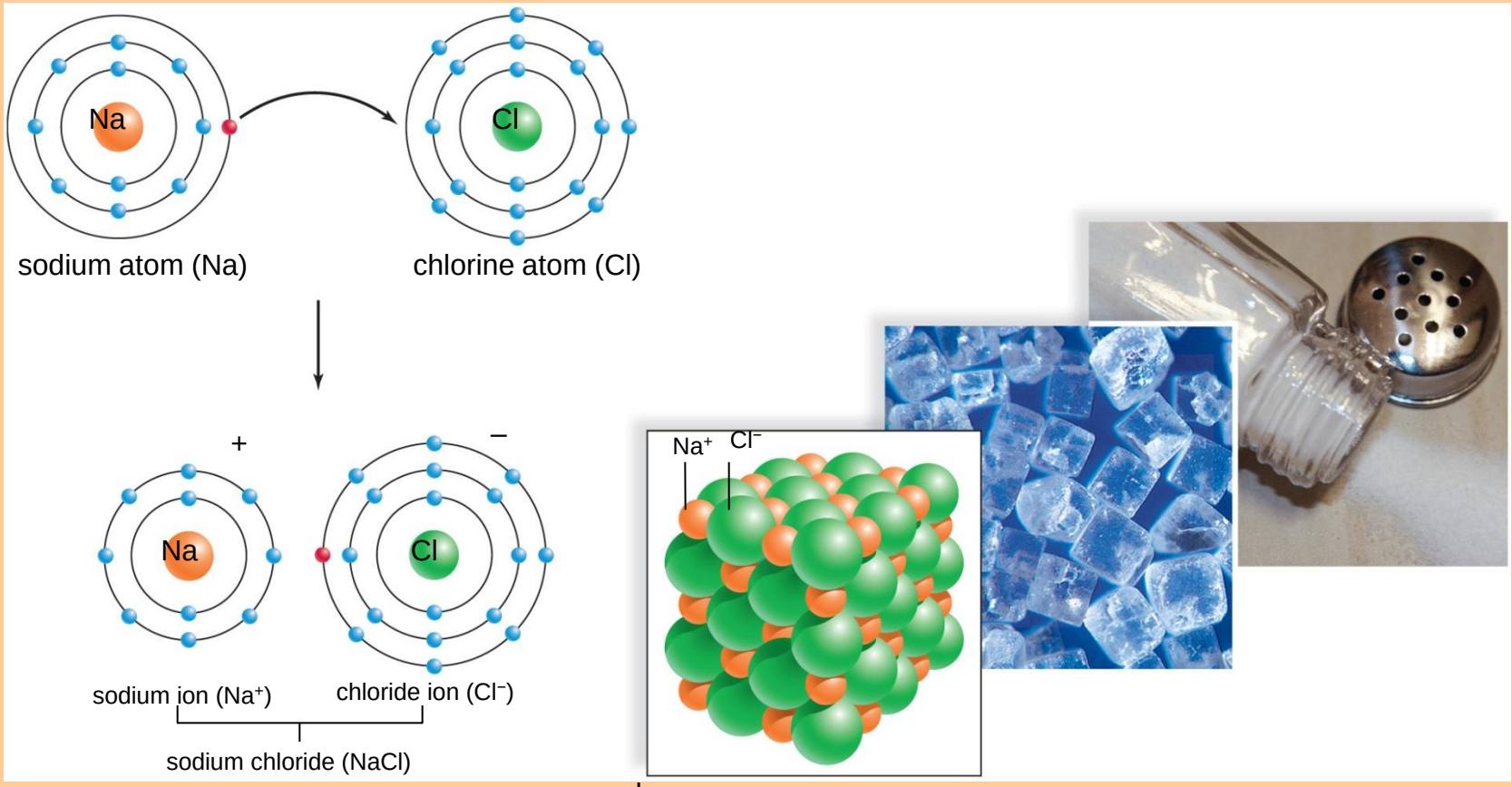




Chemical Bonds: Ionic

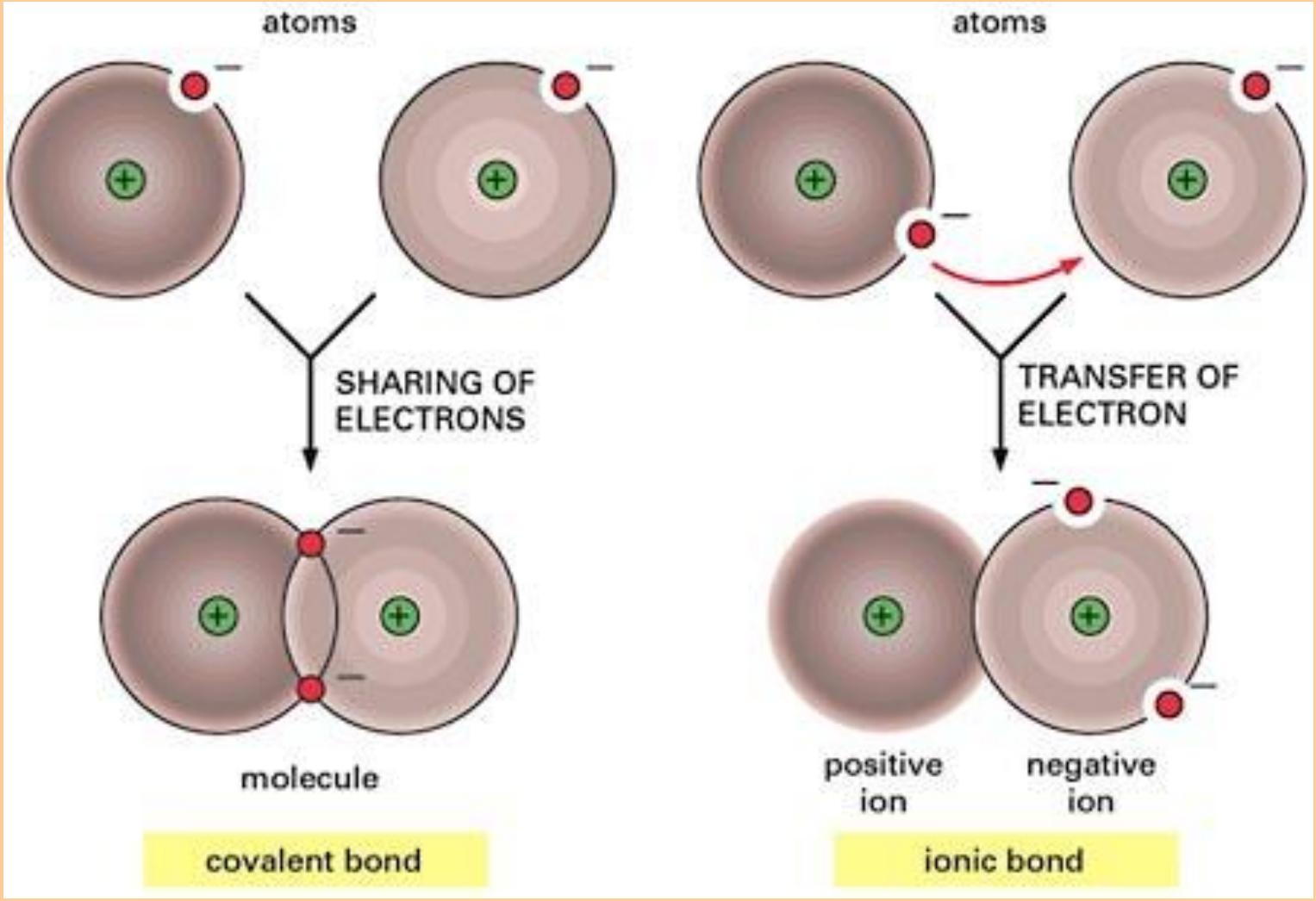
- **Ion:** Atom that has a negative or positive charge.
- Some atoms become stable by losing or gaining electrons.
- Atoms that lose electrons are called positive ions.
- Atoms that gain electrons are called negative ions.
- Because positive and negative electrical charges attract each other, **ionic bonds** form.
- Ionic bonds are often **weaker** than covalent bonds.

Formation of Sodium Chloride (NaCl)



a. b.

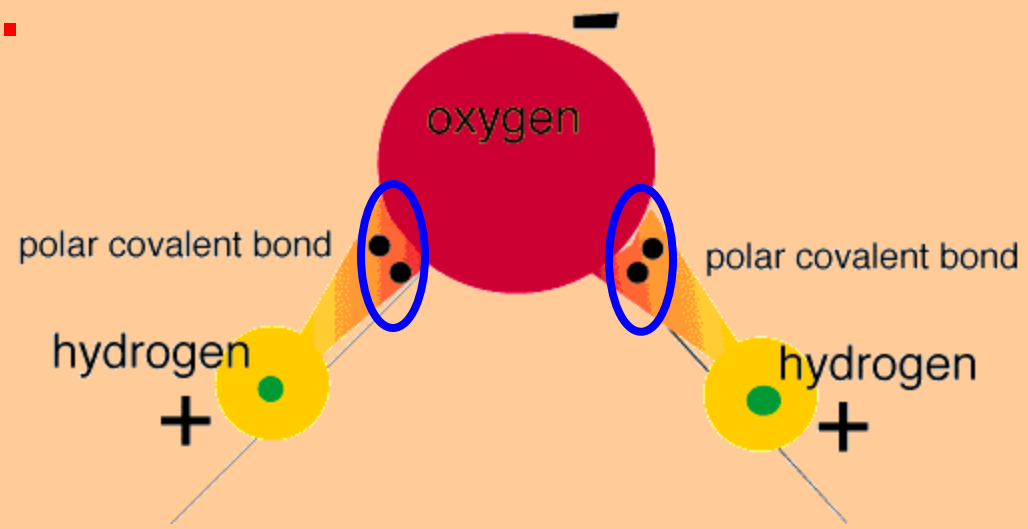
Summary of Ionic and Covalent Bonds



Polarity of Water

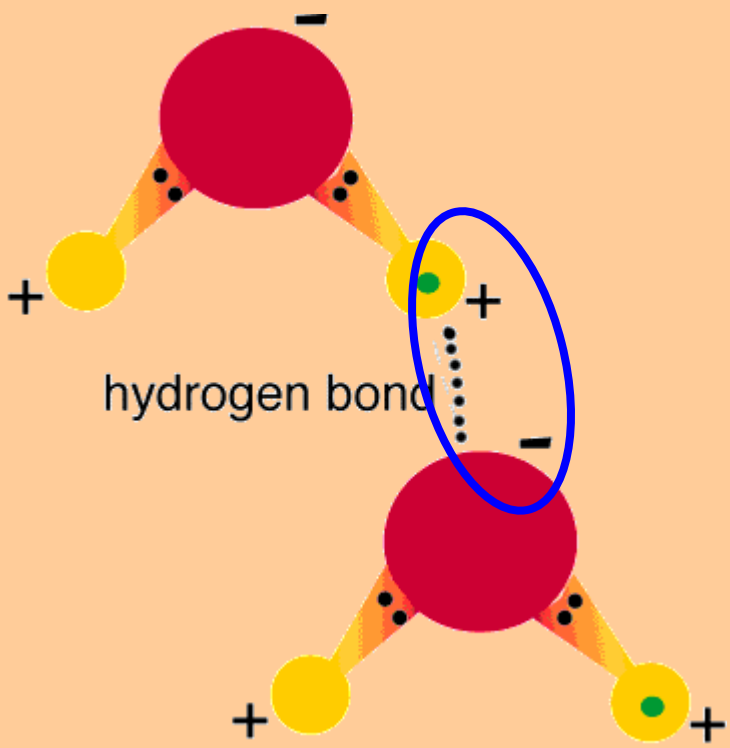
Can't have life without it!

- **Water** (H_2O) is a **POLAR** molecule.
  - **Polar Covalent Bonds** WITHIN each molecule.
- **Shared Electrons** spend **more time with Oxygen** than with Hydrogens.
- **Hydrogens** become slightly **positive**, **Oxygen** slightly **negative.**



Hydrogen Bonds Exist Between Water Molecules

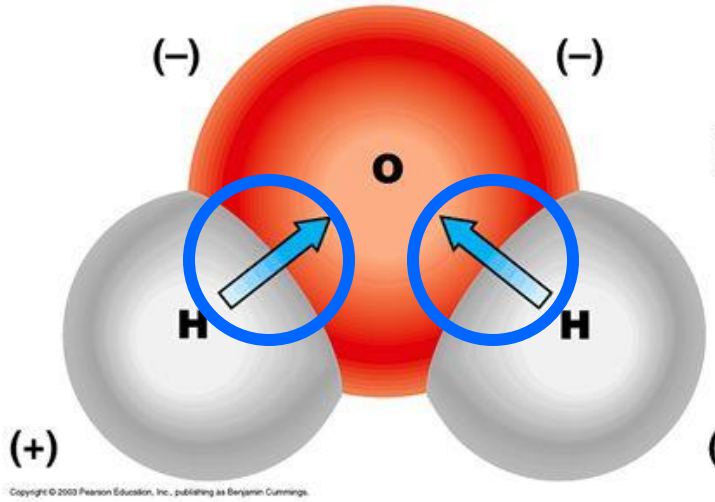
- The positive Hydrogens of water molecules are attracted to the negative Oxygens of other water molecules and form a **HYDROGEN BOND.**



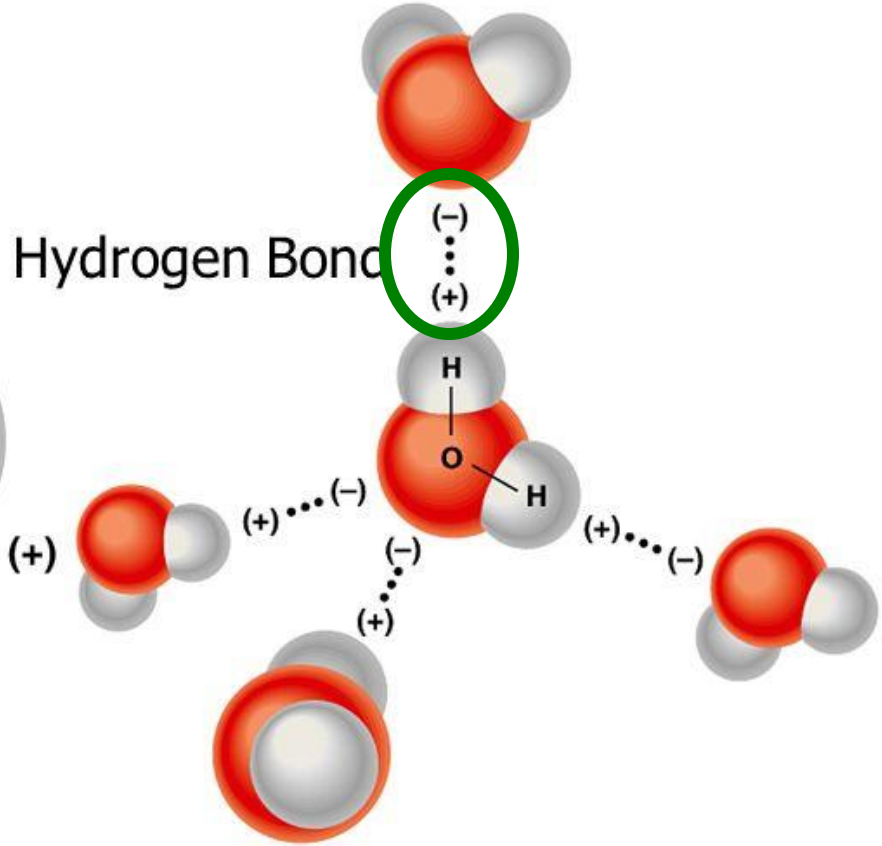
- One hydrogen bond is weak, but many hydrogen bonds are strong.

Properties of Water

Covalent bonding vs. Hydrogen bonding



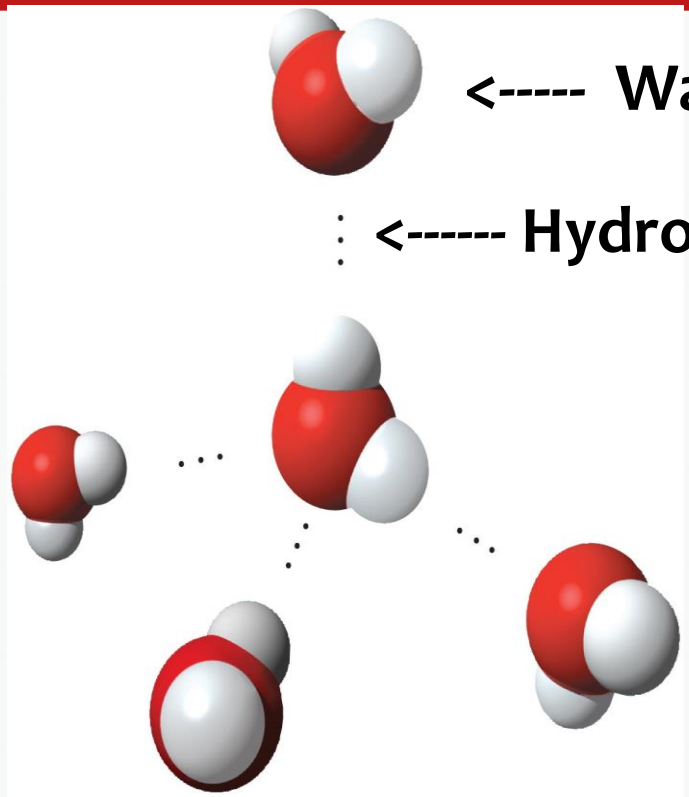
Covalent Bond



Hydrogen Bonding

The opposite charges of the molecules attract one another.

The force of attraction forms hydrogen bonds.



The oxygen of one water molecule and the hydrogen of a different water molecule forms a hydrogen bond.

A single water molecule can form up to **4** hydrogen bonds with other water molecules at the same time. This is responsible for many of the unusual properties found in water.

PROPERTIES OF WATER

Hydrogen Bonds give Water many unique properties, which makes it critical to the functioning of all life forms

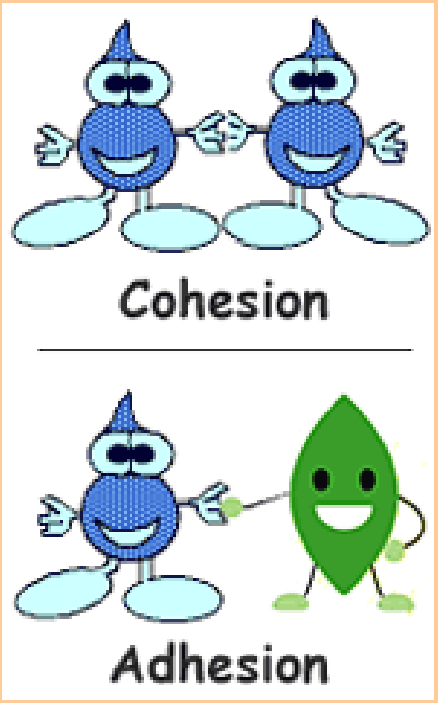
1) Cohesion
2) Adhesion
3) Temperature Moderation
4) Less Dense as a Solid than as a Liquid
5) Solvent of Life

1) Cohesion

- Attraction between water molecules.
- Results in **Surface Tension** (a measure of how difficult it is to break the surface of a liquid).
- Produces a surface film.

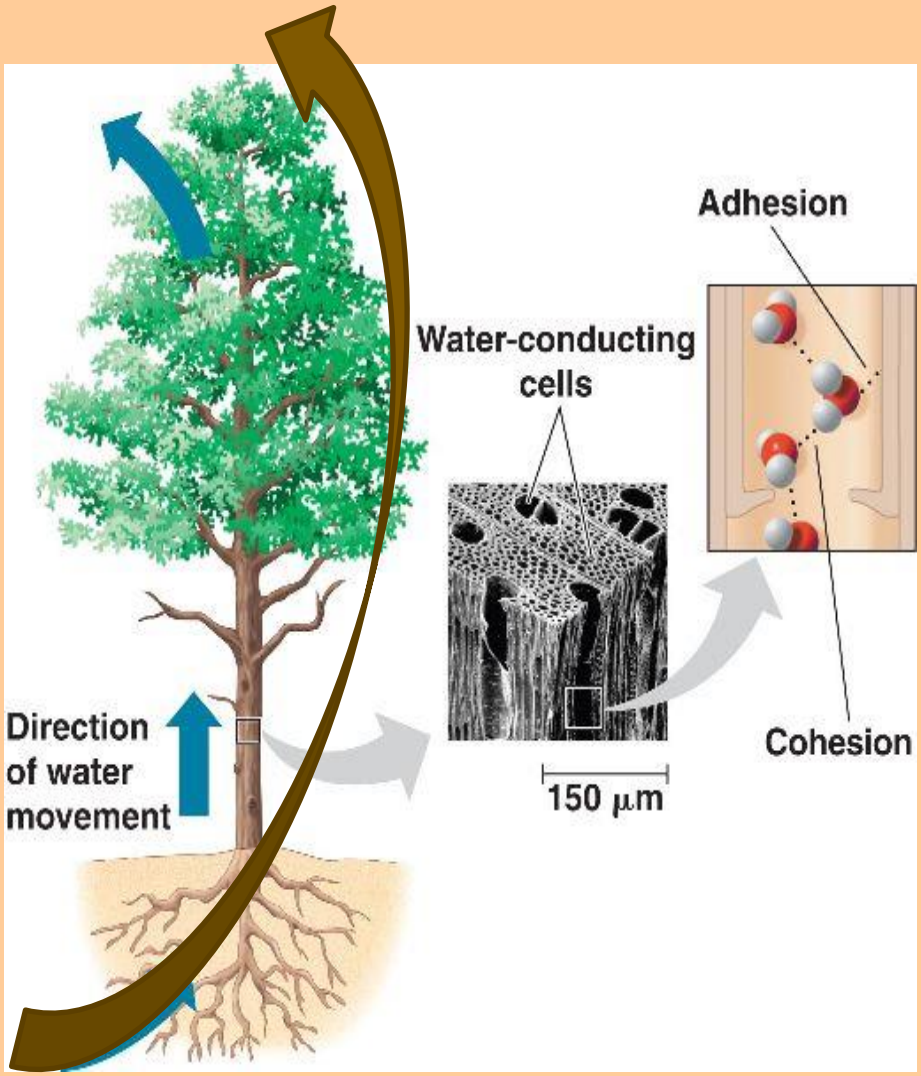
2) Adhesion

- Attraction between water and another substance.
- Water will make hydrogen bonds with other surfaces such as glass, soil, plant tissues, and cotton.



Cohesion and Adhesion

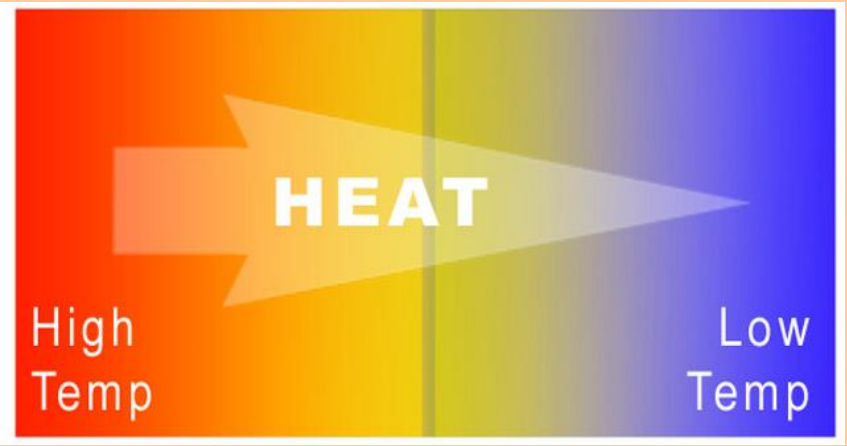
- Most plants depend upon **cohesion** and **adhesion** to help transport water and nutrients from their roots to their leaves.

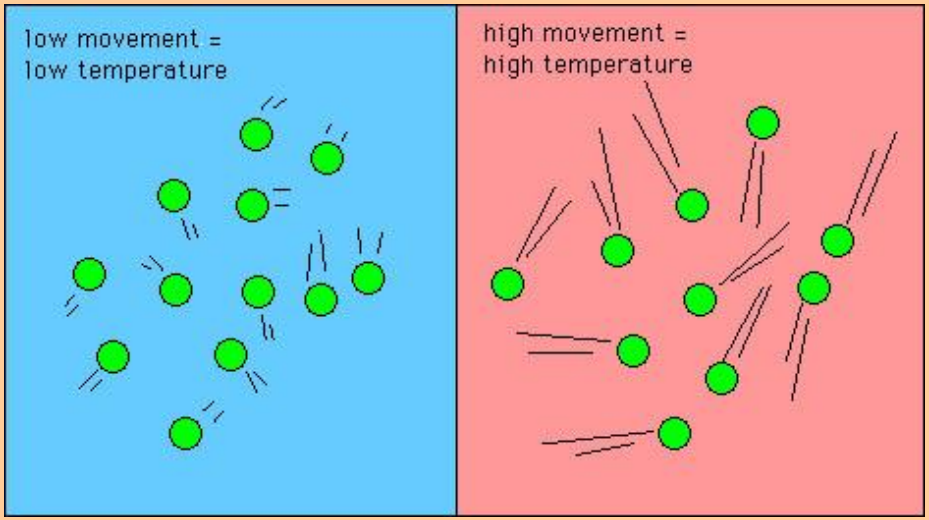


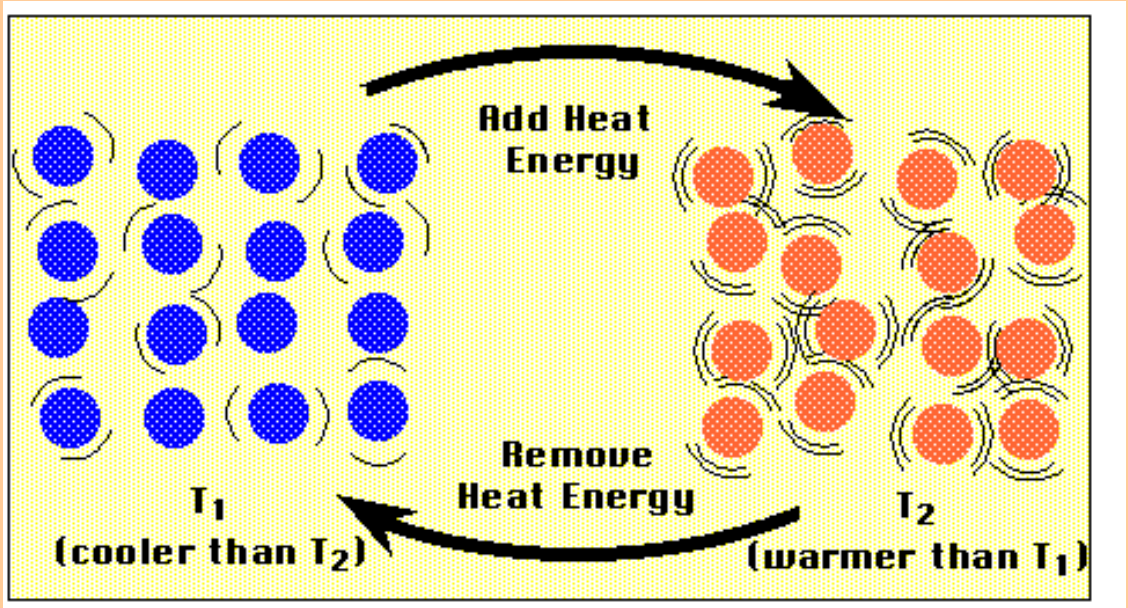
3) Temperature Moderation

- **Heat** → energy in transfer from a **warmer to a cooler** substance.
- **Temperature** measures the **amount of heat energy** — that is, the average **speed of molecules** in a substance.
  - The higher the heat energy the higher the temperature.

3) Temperature Moderation

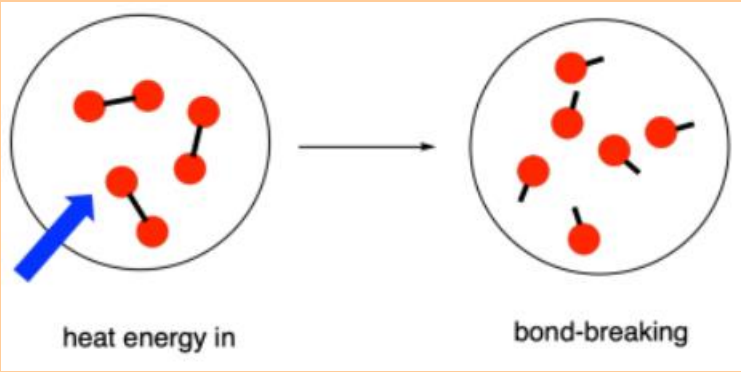


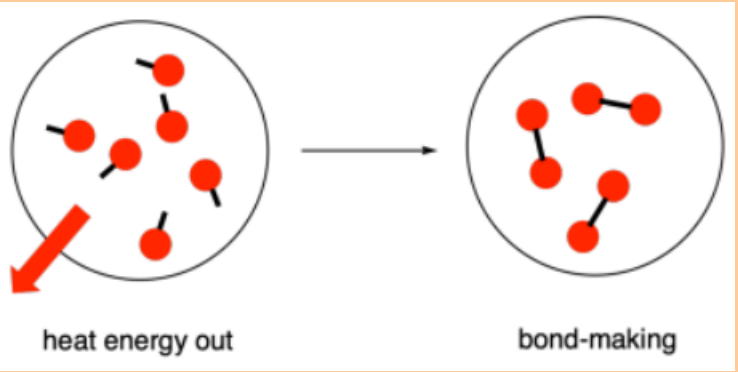




3) Temperature Moderation

- **Heat** must be absorbed to break hydrogen bonds.
- **Heat** is released when hydrogen bonds form.
- To raise the temperature of water, hydrogen bonds between water molecules must be broken before the molecules can move faster.





Specific Heat of Water

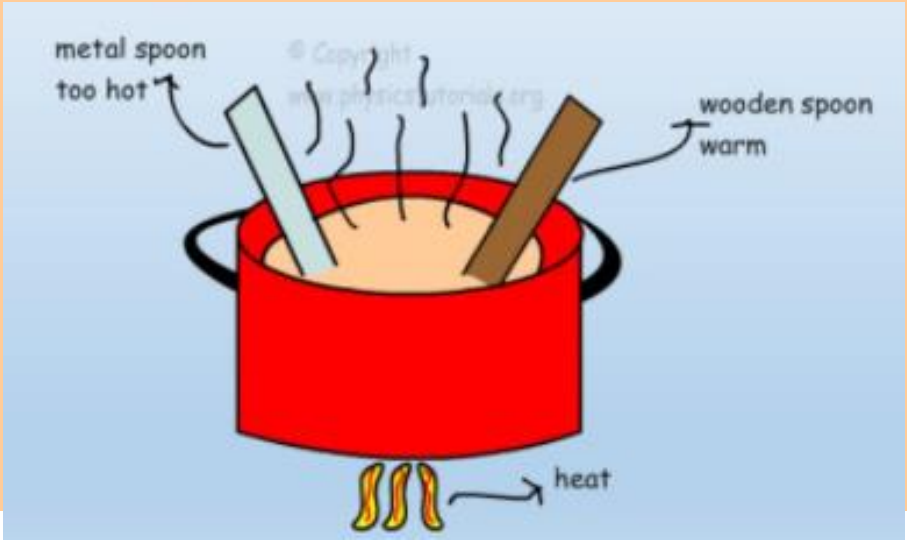
The **specific heat capacity**, or simply the specific heat (C) of a substance, is the amount of heat it takes to raise the temperature of 1 g of the substance 1º C.

- Water has the second highest specific heat of all liquids.
- Metals generally have low specific heats.

Specific Heats of Some Common Substances		
Substance	Specific heat (c_p)	
	J/(g·ºC)	cal/(g·ºC)
Liquid water	4.18	1.00
Ethanol	2.4	0.58
Ice	2.1	0.50
Steam	1.9	0.45
Chloroform	0.96	0.23
Aluminum	0.90	0.21
Iron	0.46	0.11
Silver	0.24	0.057

3) Temperature Moderation

- **Water has a high specific heat**
  - when warming up, water absorbs a large amount of heat.
  - when water cools, water molecules slow down, more hydrogen bonds form, and a considerable amount of heat is released.



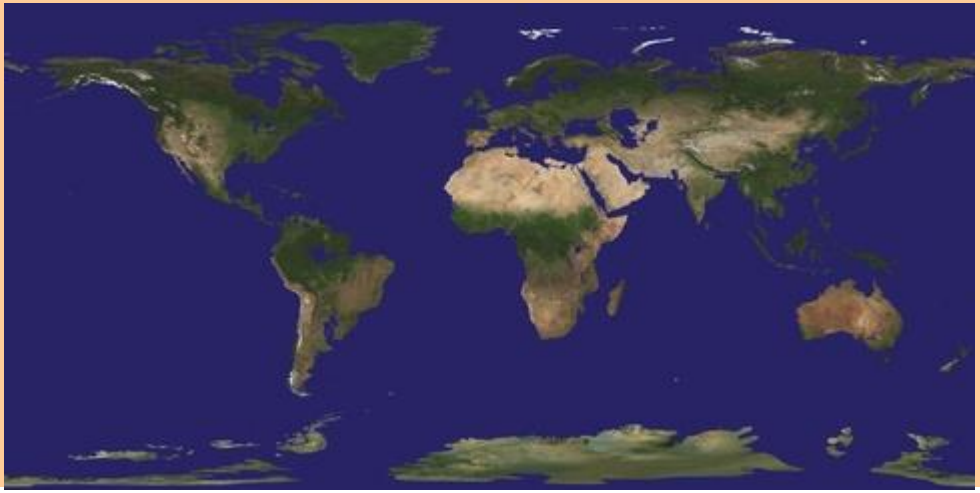
Specific Heat (C)

Some things heat up or cool down faster than others.

e.g. Michigan stays warmer in the winter due to the heat from the lakes (*e.g. hot vegetables stay hot a long time because of their high water content*)

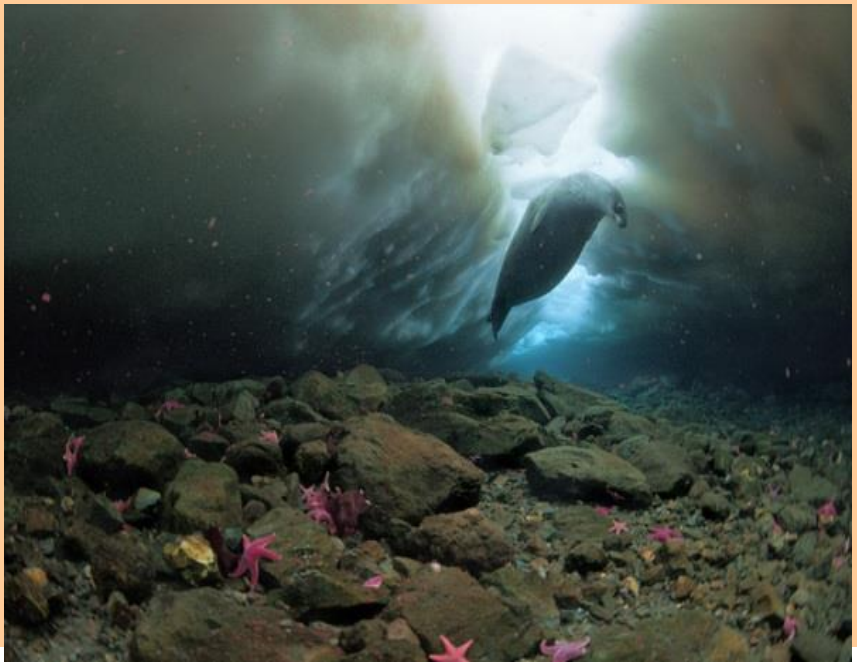
3) Temperature Moderation

- Earth's giant water supply, with its **high resistance to temperature change**, moderates temperatures, helping to keep temperatures within limits that permit life.
- Water's resistance to temperature change also stabilizes ocean temperatures, creating a favorable environment for marine life.



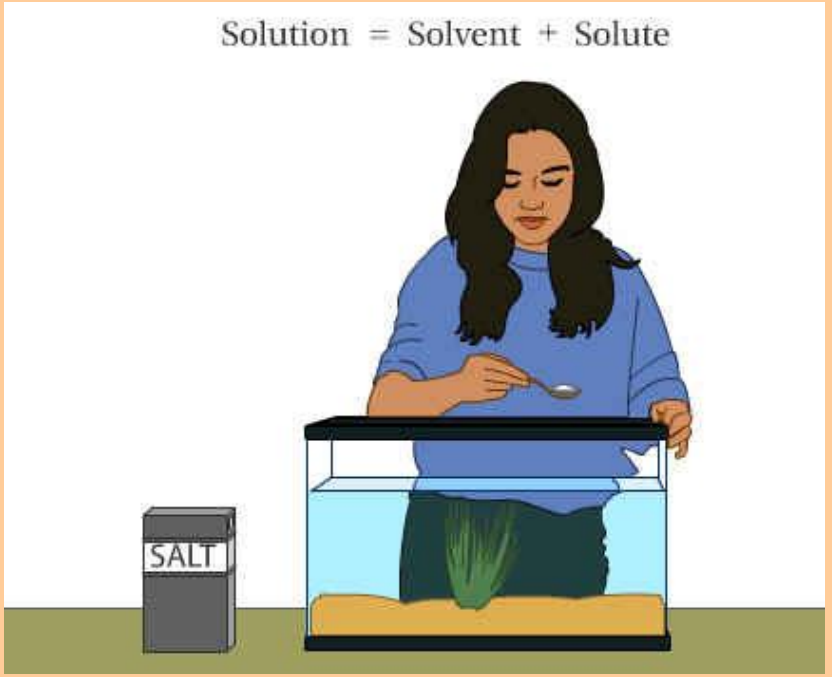
4) Water is Less Dense as a Solid

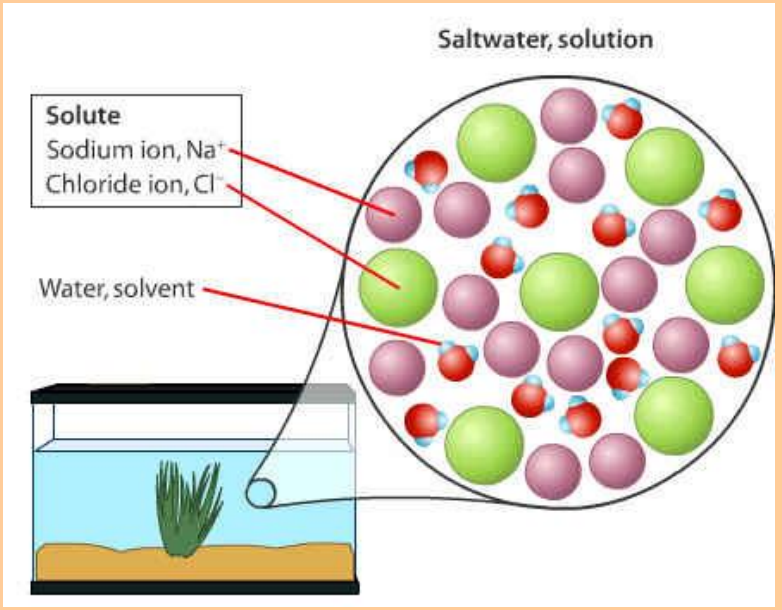
- **Ice floats** because is less dense than liquid water.
- This accounts for lakes and other bodies of water freezing on the top first (insulating the water and organisms below from harsh temperature changes).



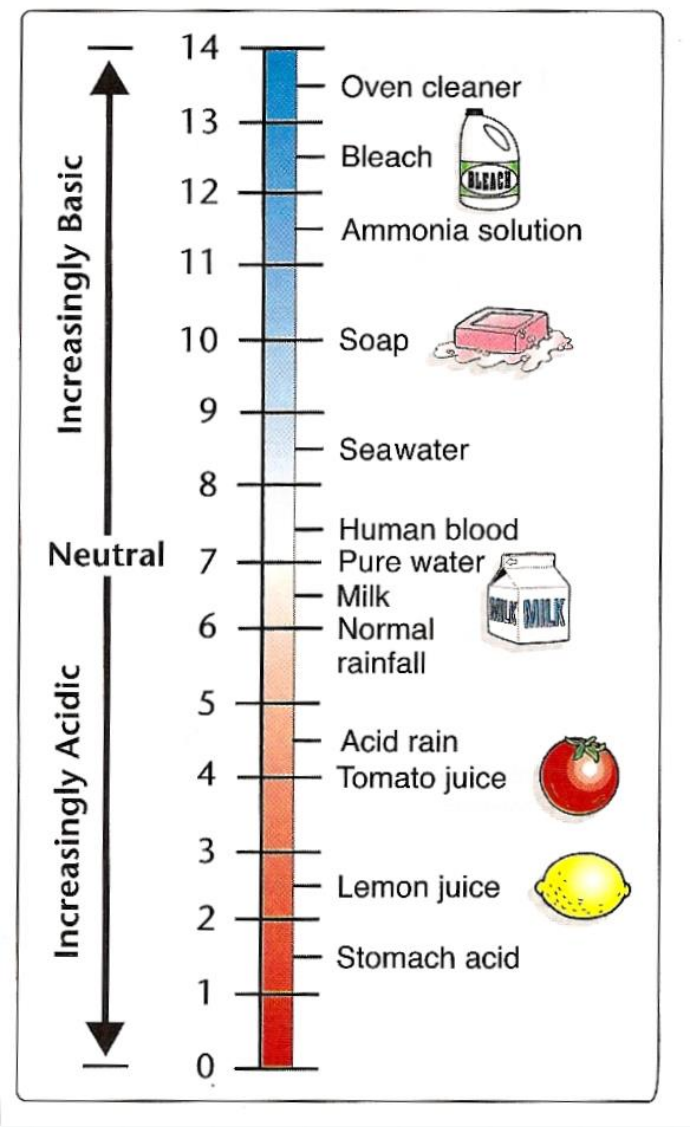
5) Water is the Solvent of Life

- A **SOLUTION** is a liquid consisting of a uniform mixture of two or more substances.
- **Solute** is the substance that is dissolved (lower quantity).
- **Solvent** is the dissolving agent (higher quantity).
- **Aqueous solution** → Water is the solvent.
- **All metabolic processes of life occur in aqueous solution environments.**





Acids, Bases and pH



The pH Scale

- The **pH scale** describes how acidic or basic a solution is.

The pH scales ranges from 0 to 14 .

- Each pH unit represents a 10-fold change in the concentration of H+ in a solution
- A **pH of 7** is a **neutral** solution. This is neither acidic nor basic. **Pure water has a pH of 7.**
- Solutions with a **pH below 7** are considered **acidic** .
- Solutions with a **pH above 7** are considered **basic** .

Acid, Bases and pH

- The chemistry of life is sensitive to acidic and basic conditions.
- **ACID** → substance that donates Hydrogen ions (H+) to solutions.
- **BASE** → substance that reduces the Hydrogen ions (H+) concentration of a solution.

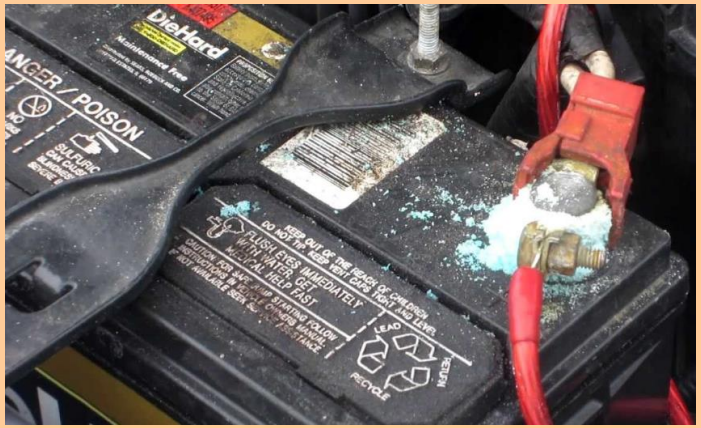
Acidic Solutions

A substance that increases the concentration of H^+ (H_3O^+) ions in solution.

H^+: hydrogen ion … H_3O^+: hydronium ion

In acidic solutions, the hydrogen-ion concentration is greater than the hydroxide-ion concentration.

$[H^+] > [(OH)^-]$



Basic Solutions

A substance that increases the concentration of $(OH)^-$ ions in solution.

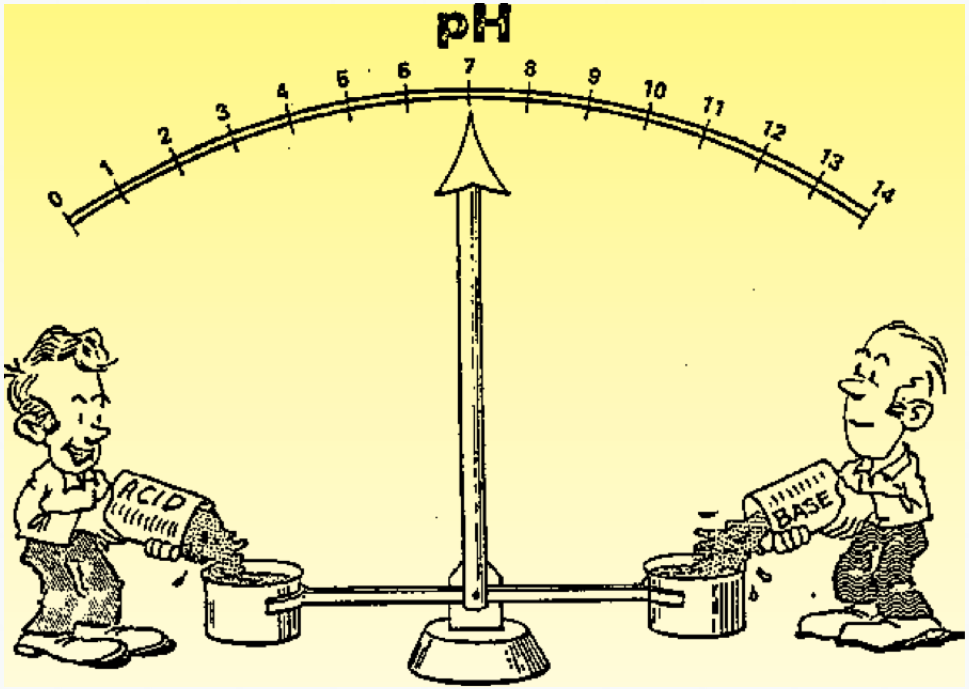
In basic solutions, the hydroxide-ion concentration is greater than the hydrogen-ion concentration.

$[(OH)^-] > [H^+]$

Basic solutions are also known as **alkaline** solutions.

Buffers

Example of where they work:



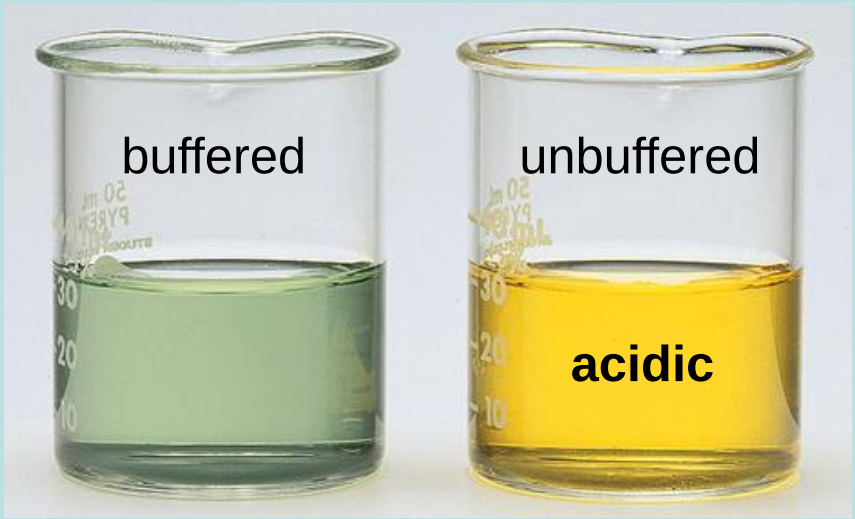
- The pH of most human cells should generally be between 7 and 7.5.
- If the pH gets too high or too low, it affects the chemical reactions that take place within cells.
  - Cells must be able to control their pH.
- **Buffers** are substances produced by cells that prevent sharp, sudden changes in pH.

Buffers

Observe what happens when 1.0 mL of 0.10*M* HCl solution is added to buffered and unbuffered solutions.

PRIOR to adding acid, the indicator shows that both solutions are basic (pH of about 8).

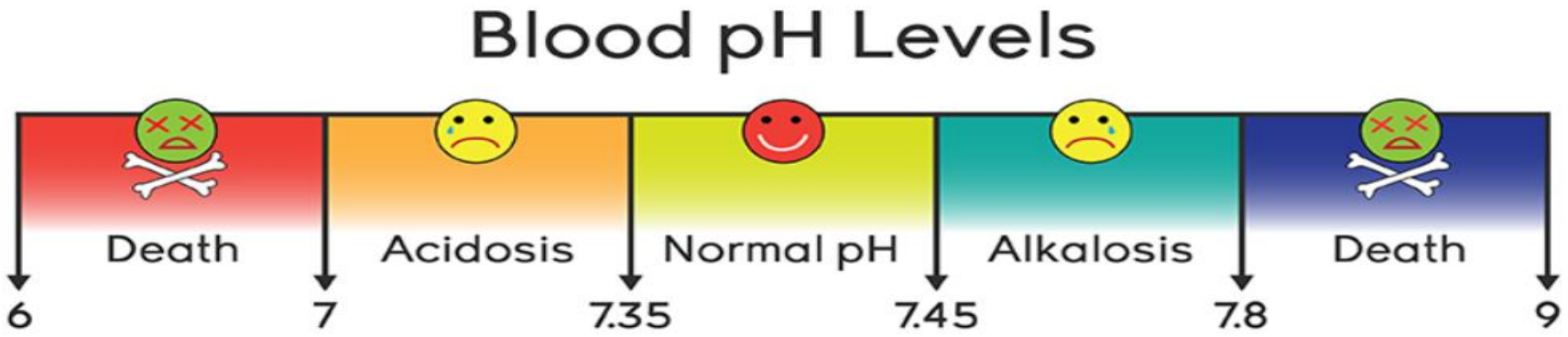
HCl is added to each solution.



The indicator shows no visible pH change in the buffered solution.

The color change in the unbuffered solution indicates a change in pH from 8 to about 3.

Buffers



Buffers cause neutralization reactions that will not have much effect on the overall pH of the buffer solution.

- When hydrogen ions are added to a buffer, they will be neutralized by the base in the buffer.
- Hydroxide ions will be neutralized by the acid.