Chapter 2 Chemistry in Biology

2.1 Atoms, Elements & Compounds

2.2 Chemical Reactions

2.3 Water and Solutions

2.4 The Building Blocks of Life

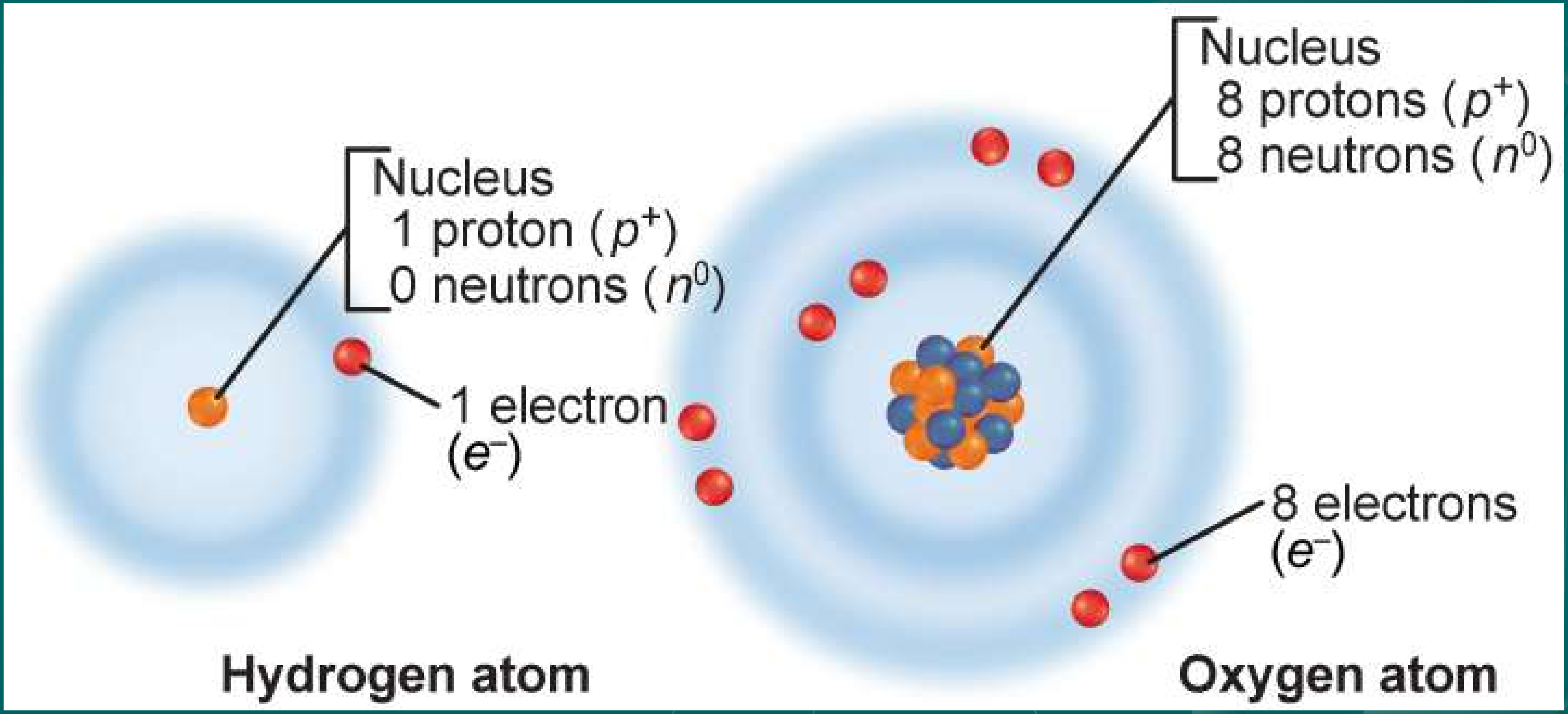
2.1 Atoms, Elements, and Compounds

- Main idea: Matter is composed of tiny particles called atoms
- Objectives:
  - Identify the particles that make up atoms
  - Diagram the particles that make up an atom
  - Compare covalent bonds and ionic bonds

Atoms

- Chemistry is the study of matter.
- Atoms are the building blocks of matter.
- **Neutrons and protons are located at the center of the atom called the nucleus.**
- **Protons are positively charged particles (p^+).**
- **Neutrons are particles that have no charge (n^0).**
- **Electrons are negatively charged particles that are located outside the nucleus (e^-).**

Atoms

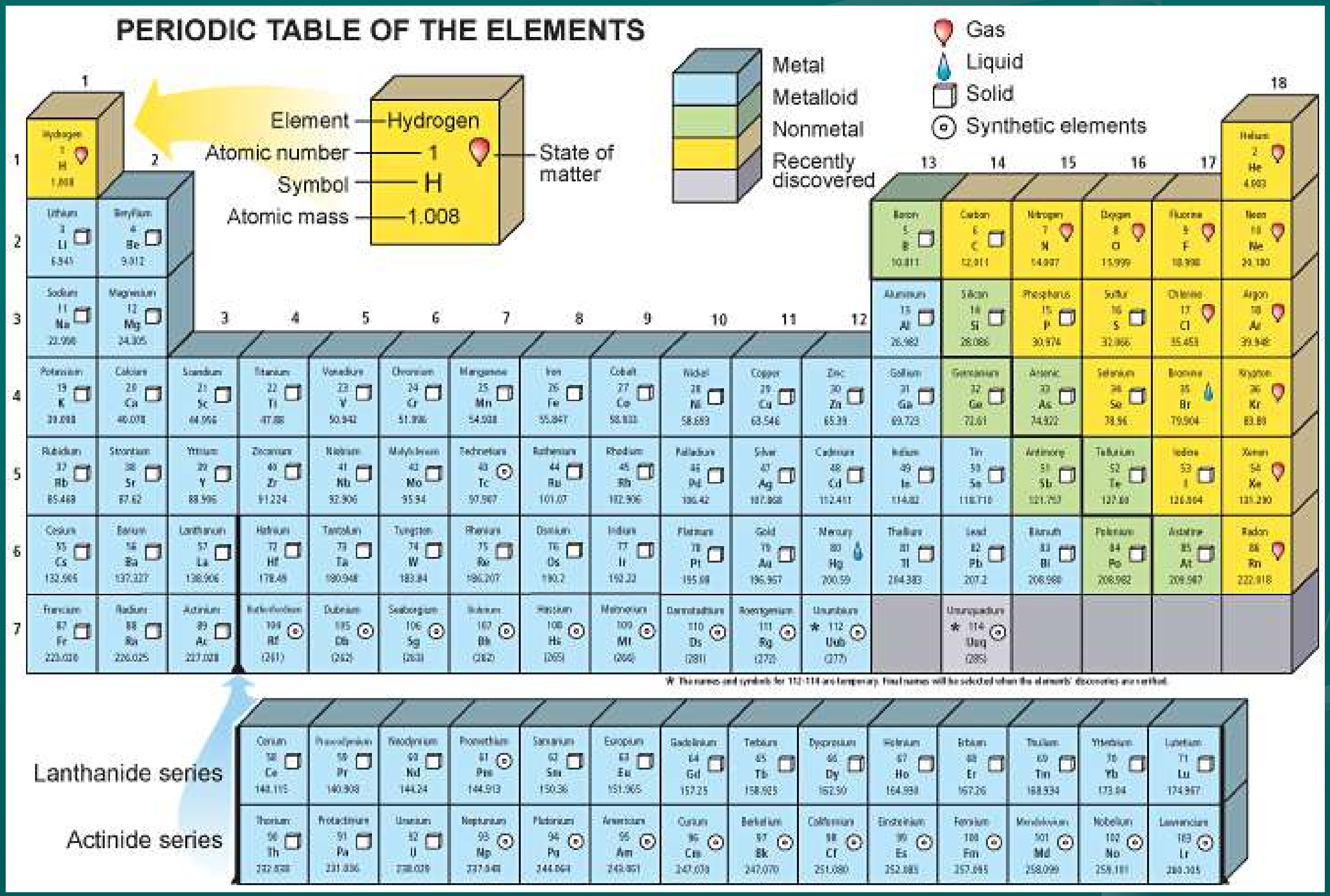

Nucleus
1 proton (p^+)
0 neutrons (n^0)
1 electron
(e^-)
Nucleus
8 protons (p^+)
8 neutrons (n^0)
8 electrons
(e^-)
Hydrogen atom
Oxygen atom

Elements

- **An element is a pure substance that cannot be broken down into other substances by physical or chemical means.**
- **There are over 100 known elements, 92 of which occur naturally. (Carbon, Hydrogen, Oxygen, Nitrogen most abundant in living things).**
- Each element has a unique name and symbol.
- All of this data, and more, are collected in an organized table called the periodic table of elements.

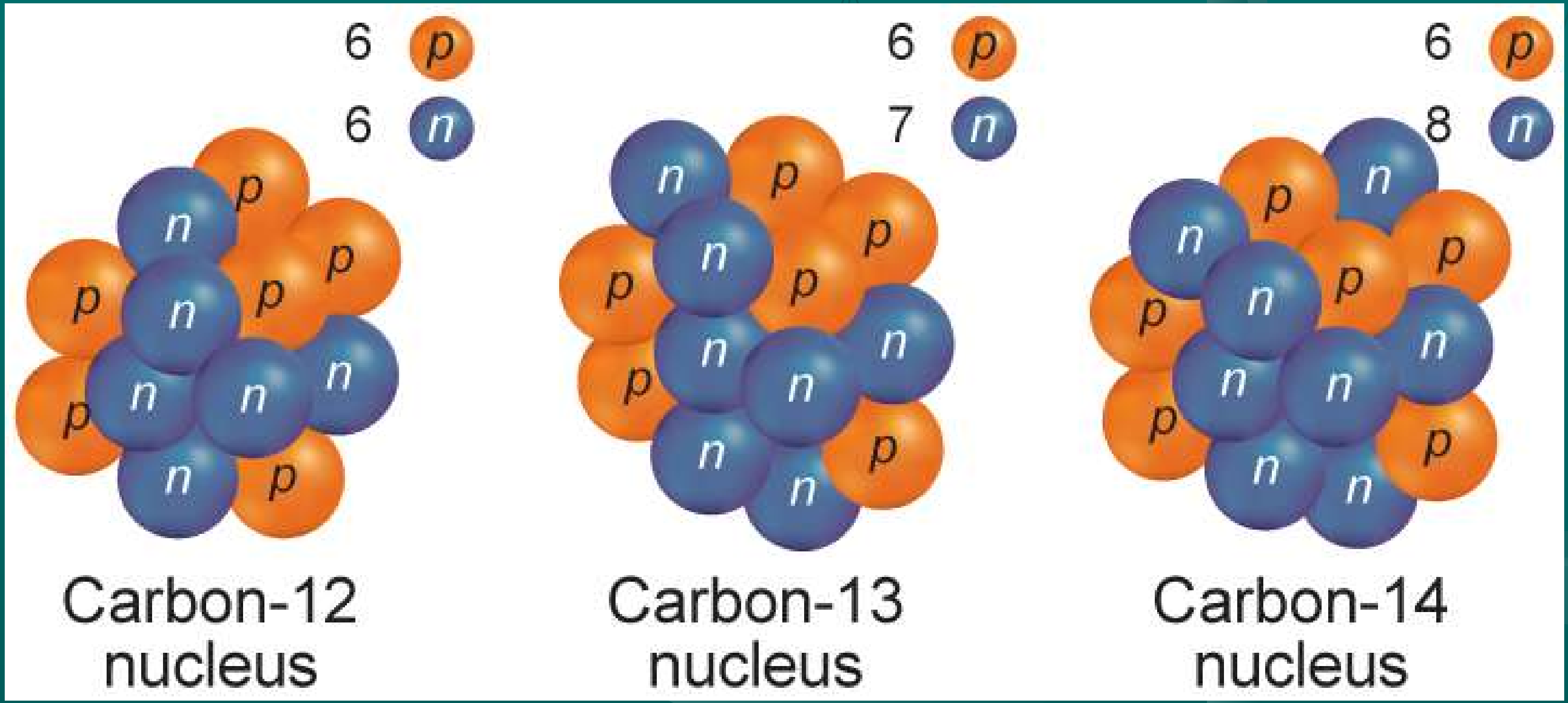
The Periodic Table of Elements

- Horizontal rows are called periods.
- Vertical columns are called groups.



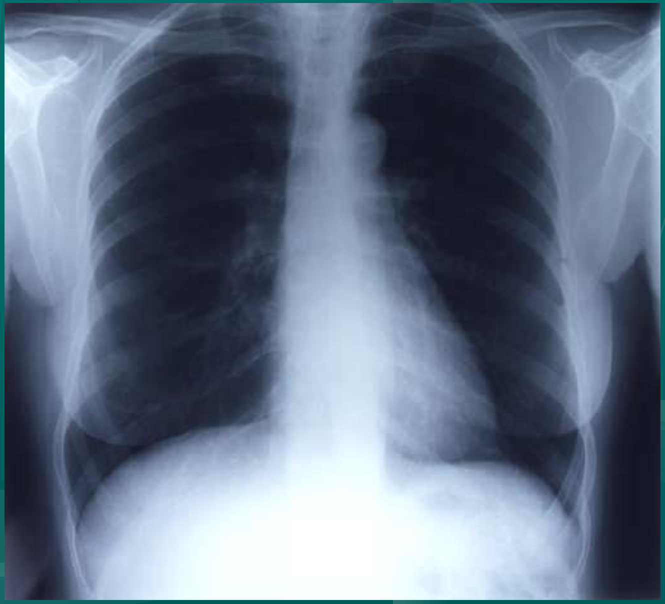
Isotopes

- **Atoms of the same element that have the same number of protons and electrons but have a different number of neutrons**



Radioactive Isotopes

- When a nucleus breaks apart, it gives off radiation that can be detected and used for many applications.
- Examples include Carbon dating and radiation therapy to treat cancer.



Compounds

- **A pure substance formed when two or more different elements combine**
- Each compound has a chemical formula made up of the chemical symbols from the periodic table.
  - Water – H_2O
  - Sodium Chloride – NaCl – Table Salt
  - Hydrocarbons composed of Carbon and Hydrogen: Methane – CH_4
- Compounds cannot be broken down into simpler compounds or elements by physical means but they can be broken down chemically.

Chemical Bonds

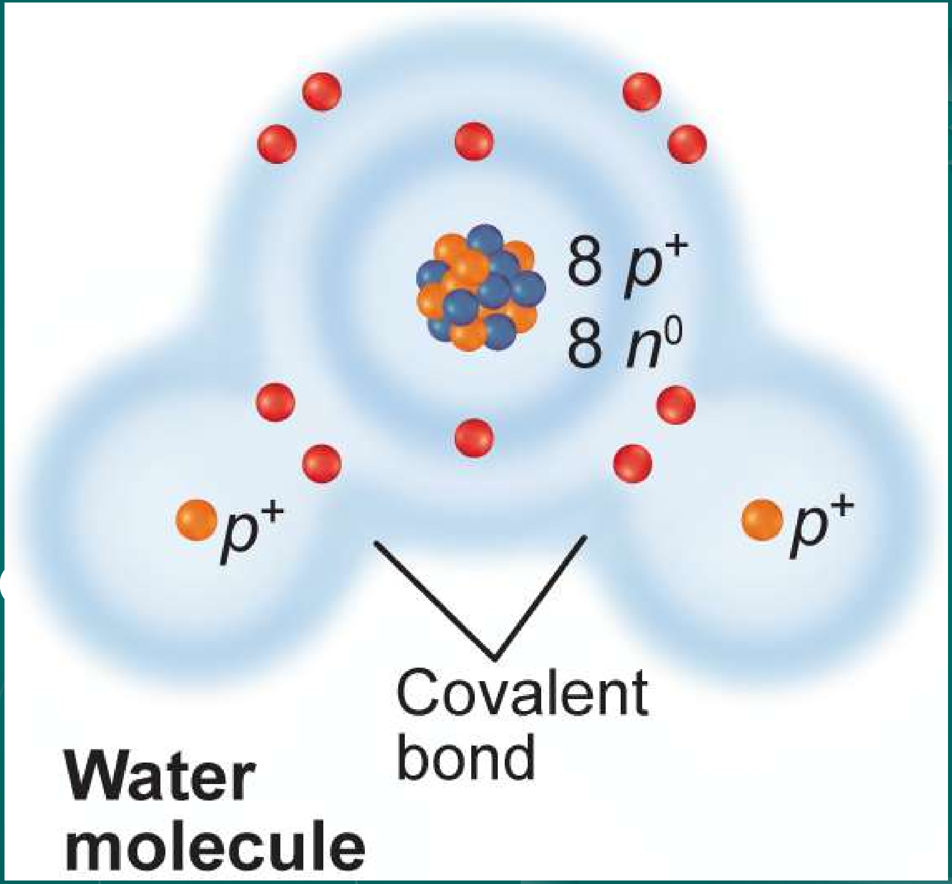
- Compounds such as water, salt, and methane are formed when two or more substances combine.
- **The force that holds the substances together is called a chemical bond.**
- The electrons are involved directly in forming the chemical bonds.

Chemical Bonds

- A partially-filled energy level is not as stable as an energy level that is empty or completely filled.
- **Atoms become more stable by losing electrons or attracting electrons from other atoms.**
- **This results in the formation of chemical bonds between atoms.**
- **Two main types of chemical bonds –**
  - **Covalent bonds**
  - **Ionic bonds**

Covalent Bonds

- **Chemical bond that forms when electrons are shared**.
- Most compounds in living organisms have covalent bonds holding them together.
- A molecule is a compound in which the atoms are held together by covalent bonds.

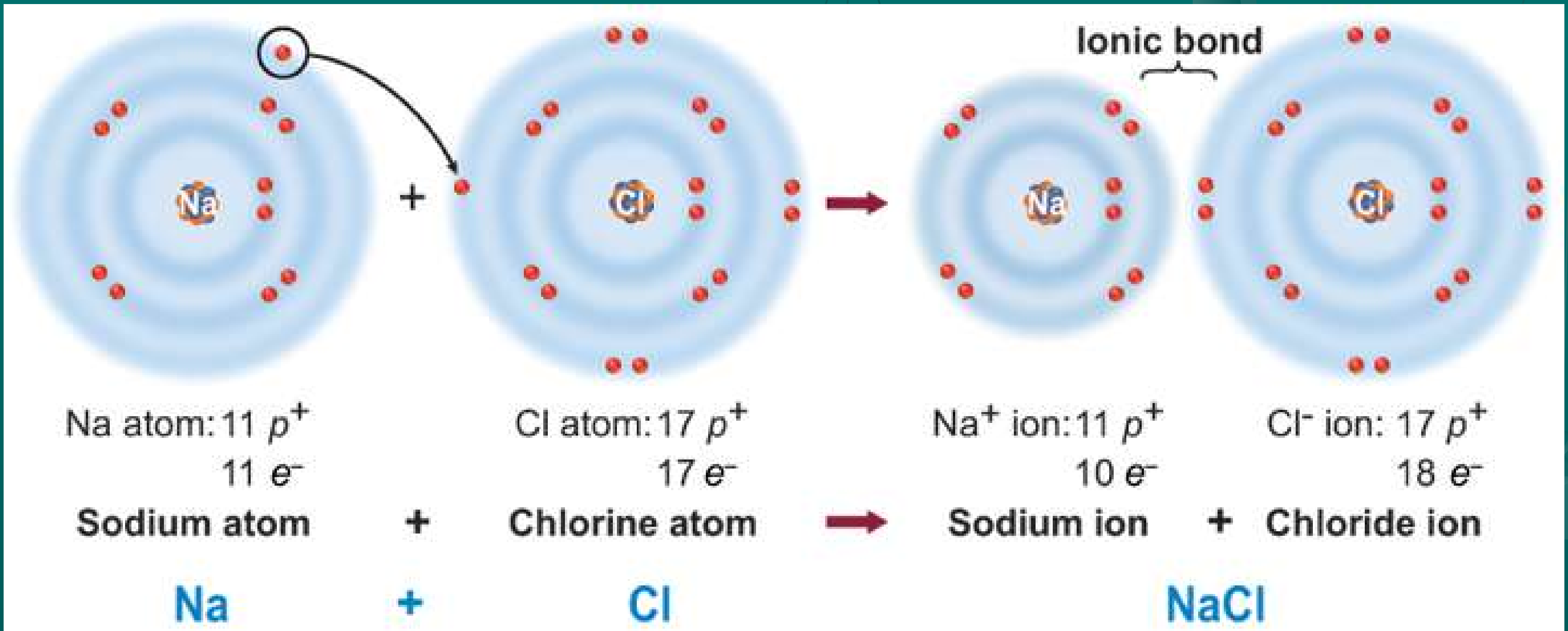


Ionic Bonds

- **An atom that has lost or gained one or more electrons becomes an ion and carries an electric charge.**
- **An ionic bond is an electrical attraction between two oppositely charged atoms or groups of atoms called ions.**

Ionic Bonds

- Ions in living things include sodium, potassium, calcium, chloride, and carbonate ions.
- They help maintain homeostasis as they travel in and out of cells.
- In addition, ions help transmit signals among cells that allow you to see, taste, hear, feel, and smell.



Water and Solutions

- Main idea: The properties of water make it well-suited to help maintain homeostasis in an organism.
- Objectives:
  - Evaluate how the structure of water makes it a good solvent.
  - Describe the difference between acids and bases.

Water's Polarity

- Water molecules are formed by covalent bonds that link two Hydrogen (H) atoms to one oxygen (O) atom.
- **In water, the electrons spend more time near the oxygen nucleus than they do near the hydrogen nuclei.**
- **This results in the oxygen end of the molecule having a slightly negative charge and the hydrogen ends of the molecule a slightly positive charge.**

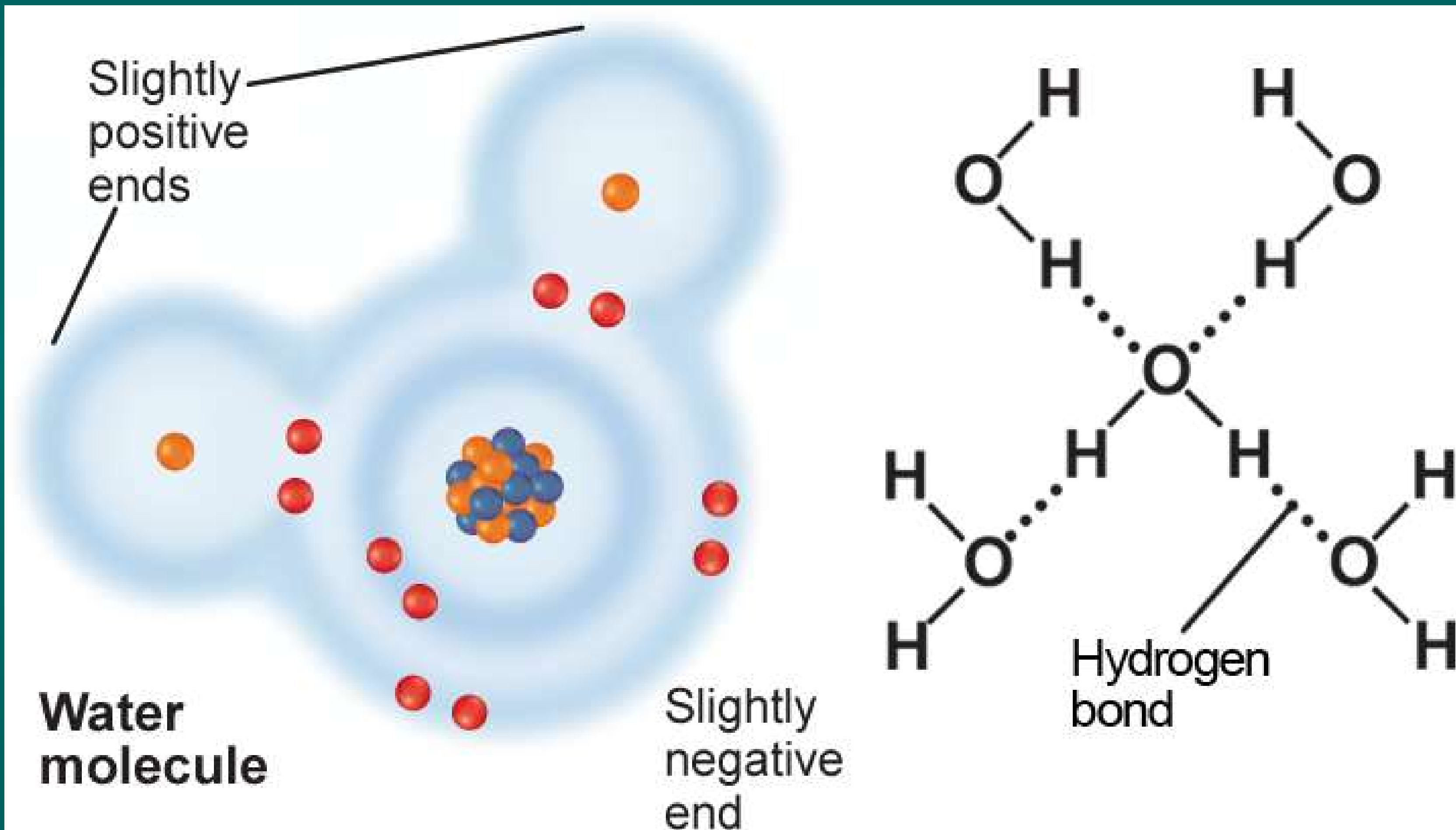
Water’s Polarity

- **Molecules that have an unequal distribution of charges are called polar molecules.**
- Polarity is the property of having two opposite poles.
- A hydrogen bond is a weak electrostatic attraction or interaction involving a hydrogen atom and a fluorine, oxygen, or nitrogen atom.

Hydrogen Bonds

- **The slightly negative oxygen of one water molecule is attracted to the slightly positive hydrogen molecule of another water molecule.**
- **This is a hydrogen bond and leads to all the unique properties of water.**

Water's Polarity



Properties of Water

- Water is vital to life on Earth, its properties allow it to provide environments suitable for life and to help organisms maintain homeostasis.
- Humans can survive many days without food, but can survive only a few days without water.
- Water is called the universal solvent because many substances dissolve in it.

Properties of Water

- High Specific Heat: a lot of energy to change the temp. of water
- Evaporative cooling
- Cohesion
- Adhesion
- Less dense as a solid than a liquid = ice floats.
- Universal solvent

Water is Adhesive & Cohesive

- **Adhesive – water forms hydrogen bonds with molecules on other surfaces.**
- Capillary action is the result of adhesion -water travels up the stem of a plant, and seeds swell and germinate.
- **Cohesive – the water molecules are attracted to each other due to hydrogen bonds.**
- This attraction creates surface tension, which causes water to form droplets and allows insects and leaves to rest on the surface of a body of water.

Water in Solution

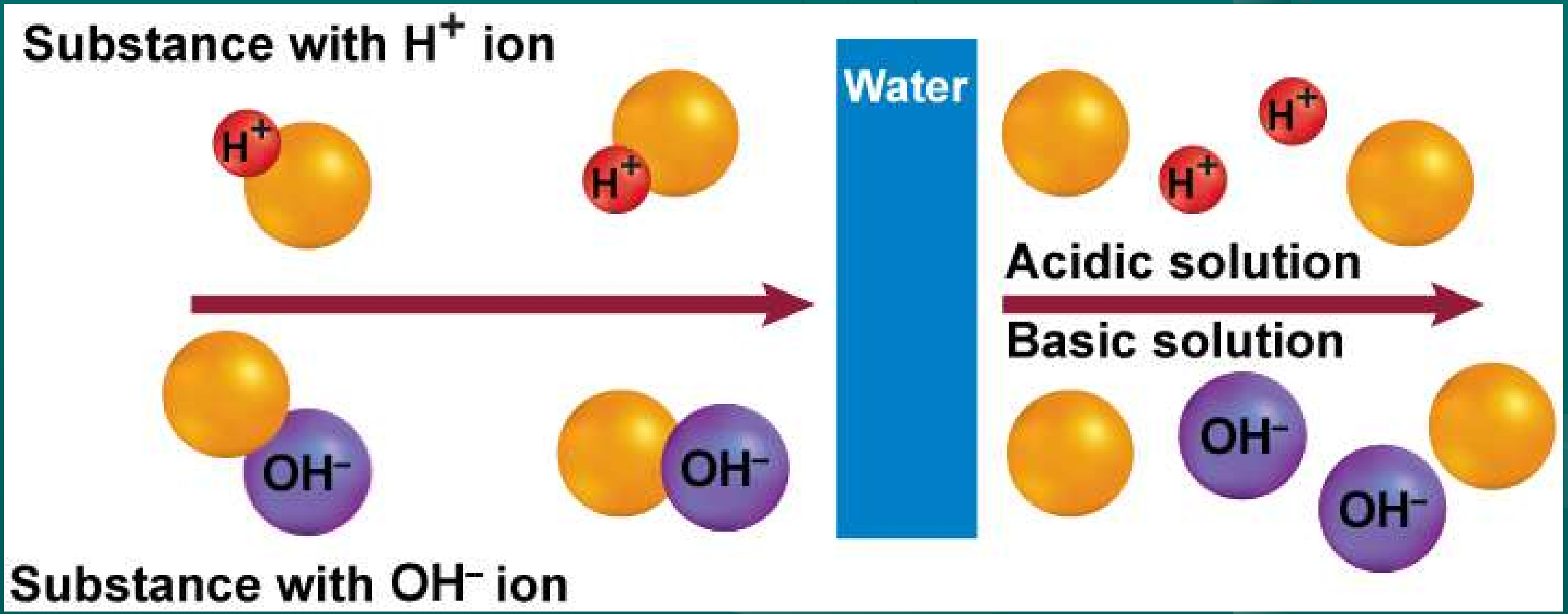
- Learner Outcomes:
  - I can explain the difference between a solution, a solute, and a solvent.
  - I can explain the difference between an acid and a base and describe the importance of buffers.
  - I can analyze the pH scale.

Mixtures with Water

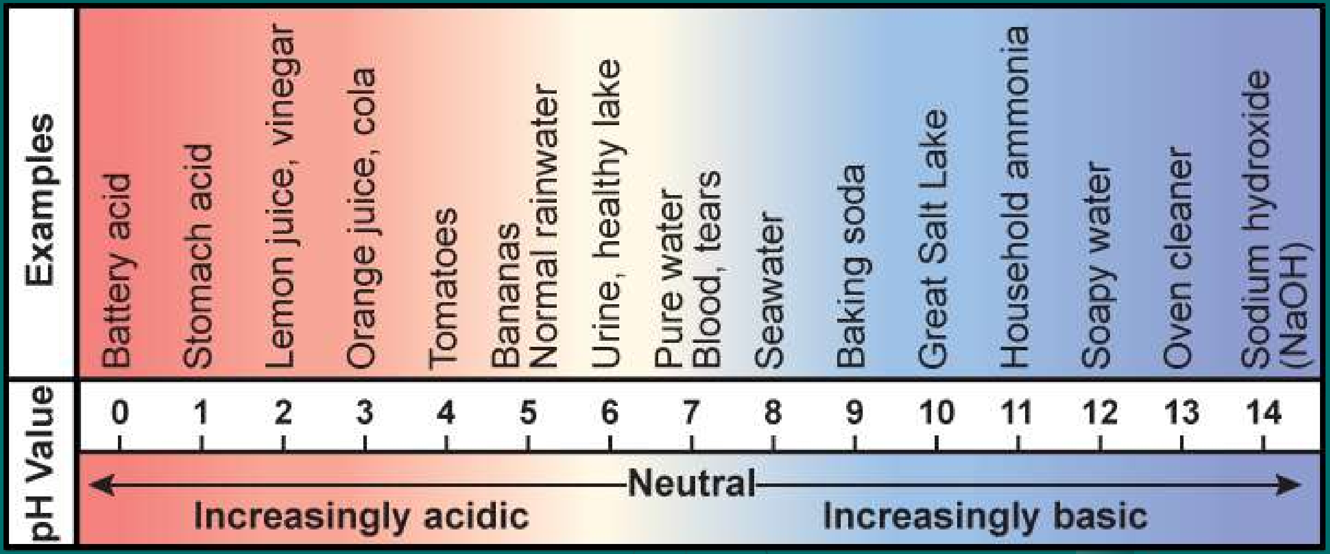
- A mixture is a combination of two or more substances in which each substance retains its individual characteristics and properties.
- A mixture that has a uniform composition throughout is a homogenous mixture and is also known as a solution.
- A solvent is a substance in which another substance is dissolved.
- A solute is the substance that is dissolved in the solvent.

Acids and Bases

- Substances that release hydrogen ions (H+) when dissolved in water are called acids.
- Substances that release hydroxide ions (OH–) when dissolved in water are called bases.



pH and Buffers



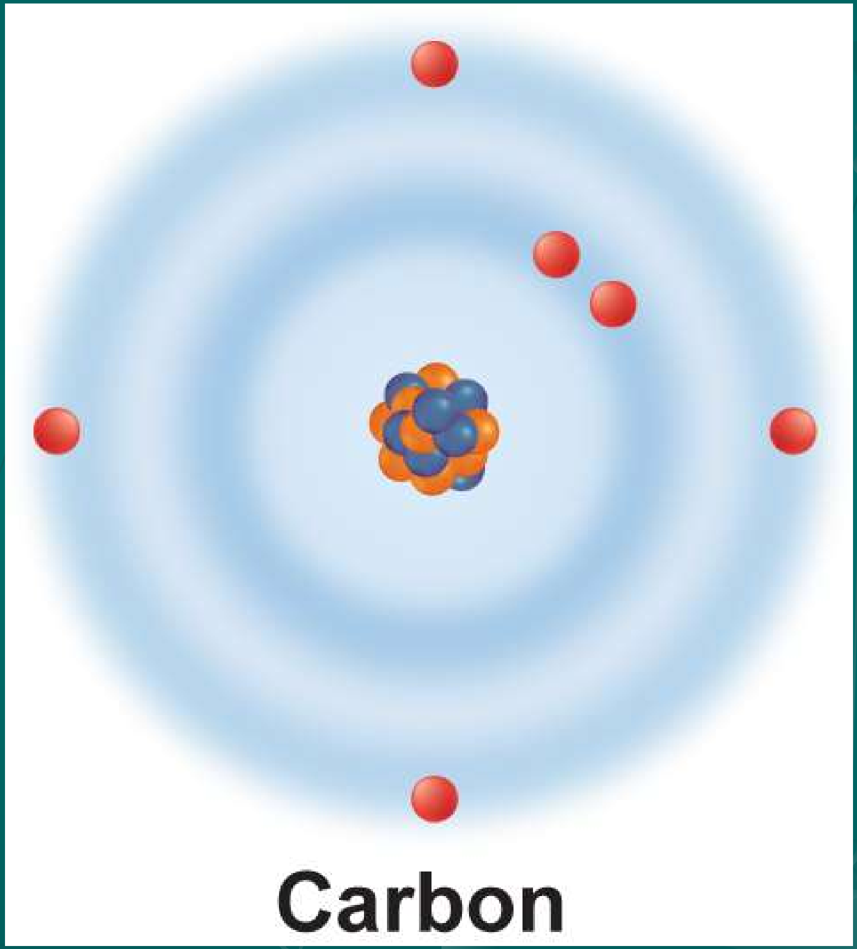
- The measure of concentration of H+ in a solution is called pH.
- Acidic solutions have an abundance of H^+ ions and pH values lower than 7.
- Basic solutions have an abundance of OH^- ions and pH values higher than 7.
- Buffers are mixtures that can react with acids or bases to keep pH within a particular range.

The Building Blocks of Life

- Main idea: Organisms are made up of carbon-based molecules.
- Objectives:
  - Describe the role of carbon in living organisms.
  - Summarize the four major families of biological macromolecules.
  - Compare the functions of each group of biological macromolecules.
- Review Vocabulary:
  - Organic compound: carbon-based substance that is the basis of living matter.

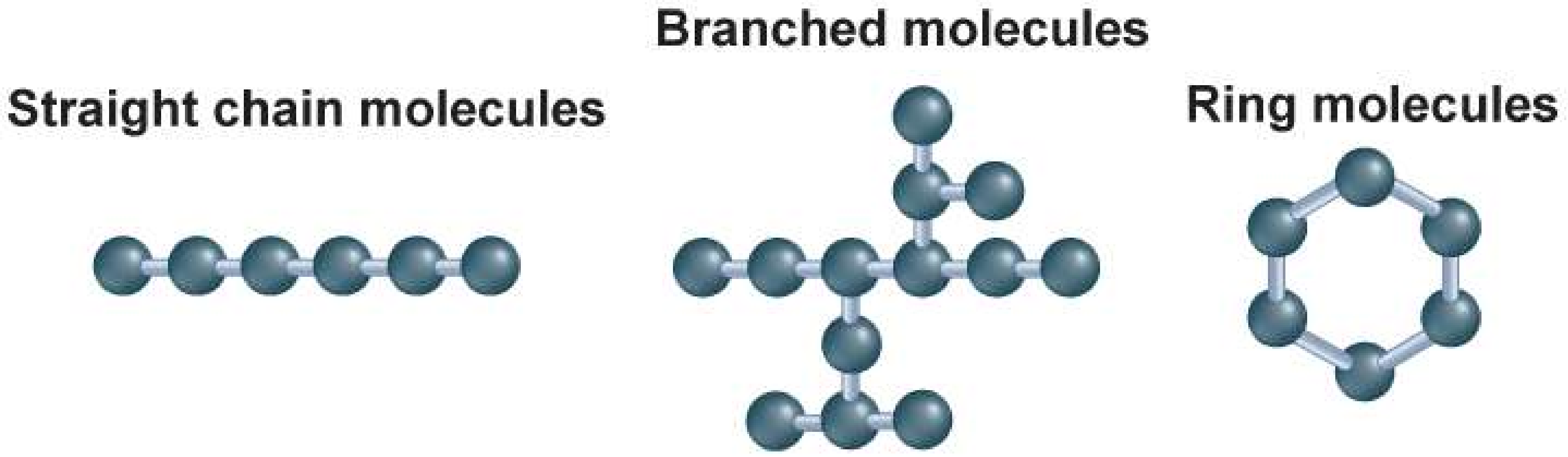
Organic Chemistry

- The element carbon is a component of almost all biological molecules.
- Carbon has four electrons in its outermost energy level.
- One carbon atom can form four covalent bonds with other atoms.



Carbon Compounds

- Carbon compounds can be in the shape of straight chains, branched chains, and rings.
- Together carbon compounds lead to the diversity of life on Earth.



Macromolecules

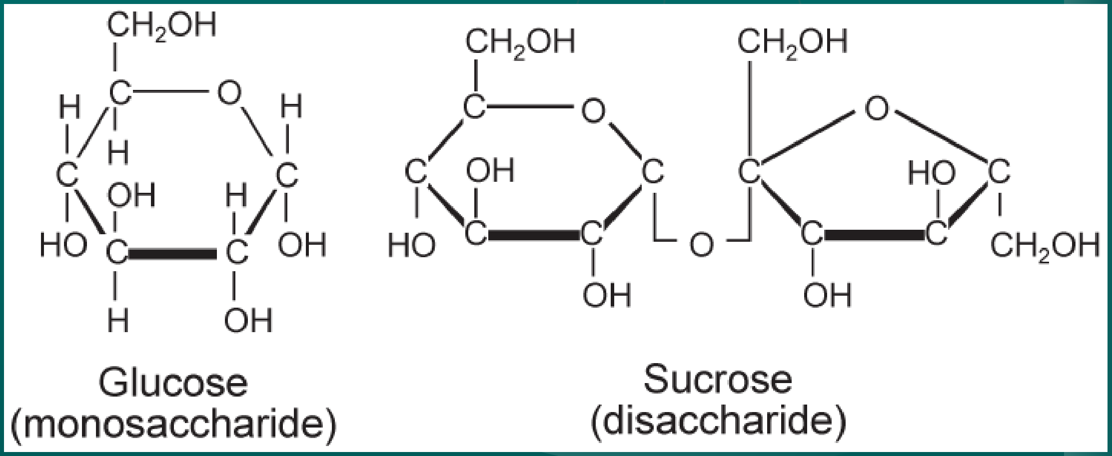
- Carbon atoms can be joined to form carbon molecules.
- Large molecules that are formed by joining smaller organic molecules together are called macromolecules.
- Polymers are molecules made from repeating units of identical or nearly identical compounds linked together by a series of covalent bonds.

Biological Macromolecules

Group	Examples	Function
Carbohydrates	Pasta, breads & grains	■ Stores energy ■ Provides structural support
Lipids	Beeswax, fat & oils	■ Stores energy ■ Provides steroids ■ Waterproofs coatings
Proteins	Hemoglobin and Amylase	■ Transport substances ■ Speeds reactions ■ Provides structural support ■ Provides hormones
Nucleic Acids	DNA stores genetic info in the cell's nucleus	■ Stores and communicates genetic information

Carbohydrates

- Compounds composed of carbon, hydrogen, and oxygen.
- Simple sugars are called monosaccharides (glucose).
- Two monosaccharides joined together form a dissaccharide (sucrose – table sugar & lactose – component of milk).
- Longer carbohydrate molecules are called polysaccharides (glycogen).
- Energy sources, cellulose-structural support in cell walls of plants, and chitin-outer shells of shrimp, lobster & small insects, as well as the cell wall of some fungi.



Lipids

- Molecules made mostly of carbon and hydrogen that make up the fats, oils and waxes.
- Lipids are composed of fatty acids, glycerol, and other components.
- The primary function is to store energy.
- A triglyceride is a fat if it is solid at room temperature and an oil if it is liquid at room temperature (stored in fat cells of the body).
- Plant leaves are coated with lipids called waxes to prevent water loss, and the honeycomb in a beehive is made of beeswax.

Saturated and Unsaturated Fats

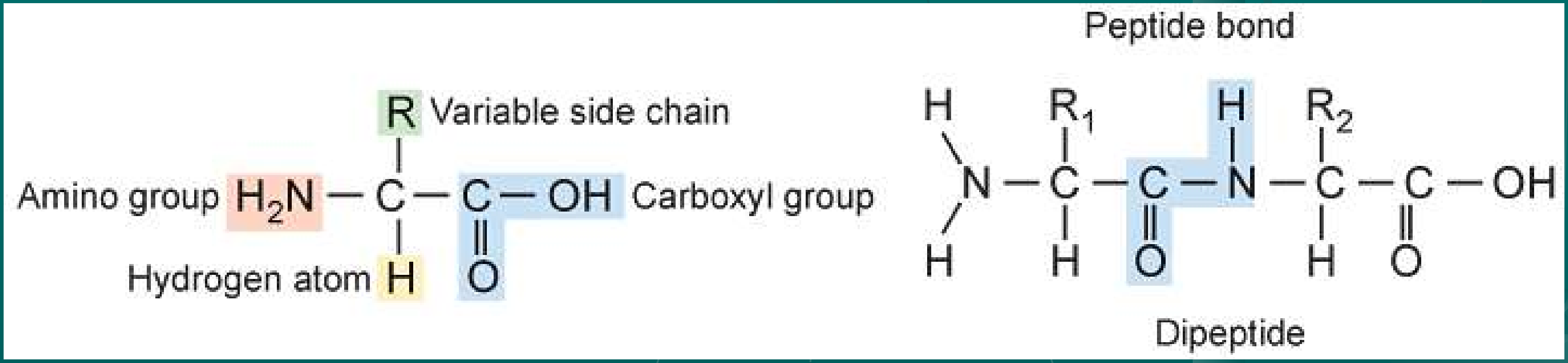
- Lipids that have tail chains with only single bonds between the carbon atoms are called saturated fats.
- Lipids that have at least one double bond between carbon atoms in the tail chain are called unsaturated fats.
- Fats with more than one double bond in the tail are called polyunsaturated fats.

Phospholipids & Steroids

- The structure and function of the cell membrane is due to phospholipids.
- Steroids include substances such as cholesterol and hormones.

Proteins

- A compound made of small carbon compounds called amino acids
- There are 20 different amino acids, and proteins are made of different combinations of all 20 different amino acids.



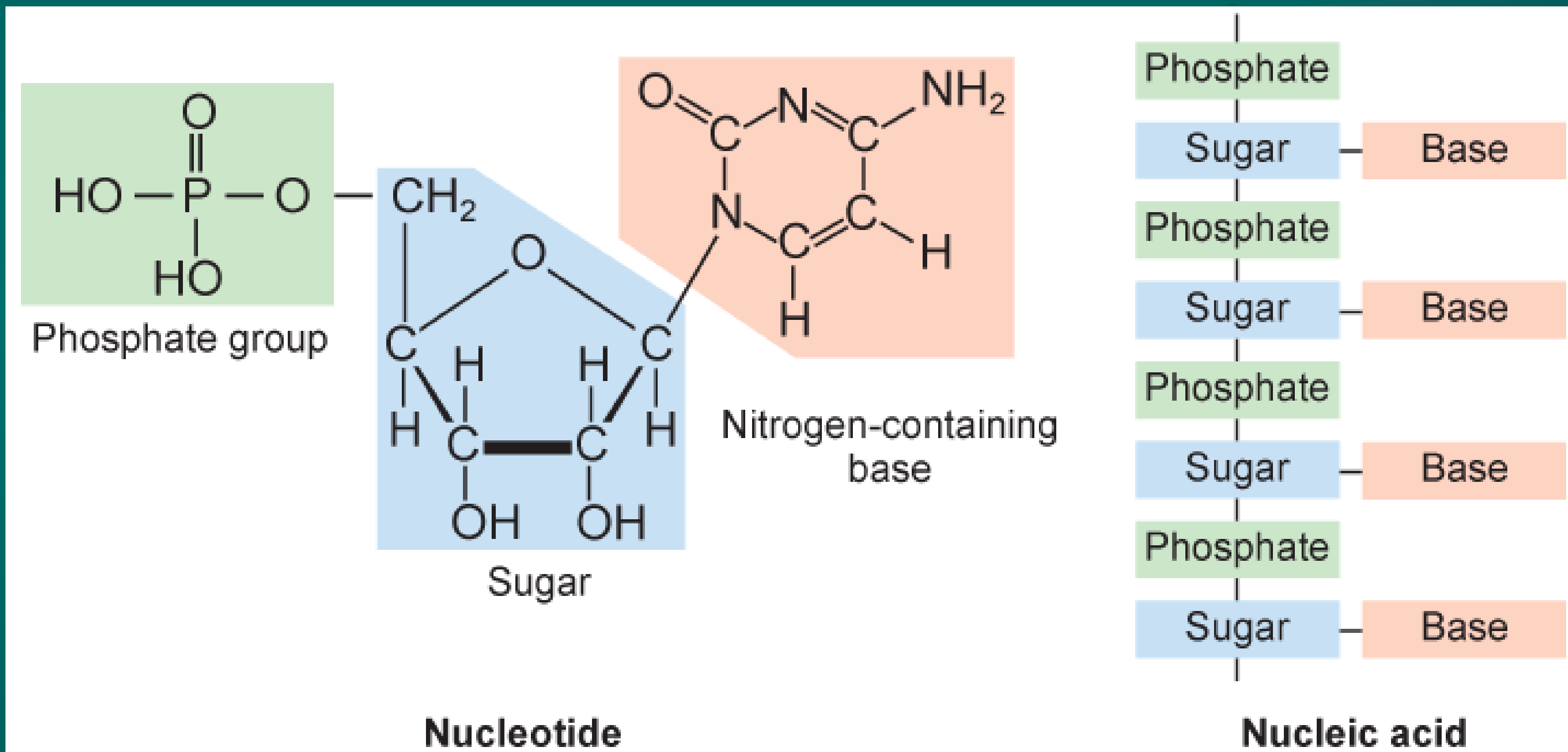
Protein Function

- Proteins make up about 15% of your total body mass and are involved in nearly every function of your body.
- Muscle, skin and hair all are made of protein.
- Your cells contain about 10,000 different proteins that provide structural support, transport substances inside the cell and between cells, speed up chemical reactions, and control cell growth.

Nucleic Acids

- Nucleic acids are complex macromolecules that store and transmit genetic information.
- Nucleic acids are made of smaller repeating subunits called nucleotides, composed of carbon, nitrogen, oxygen, phosphorus, and hydrogen atoms.
- Six major nucleotides, all of which have three units – a phosphate, a nitrogenous base and a sugar.

Nucleic Acids



6.2 Chemical Reactions

- Main idea: Chemical reactions allow living things to grow, develop, reproduce, and adapt.
- Objectives:
  - Identify the parts of a chemical reaction
  - Relate energy changes to chemical reactions
  - Summarize the importance of enzymes in living organisms
- Review Vocabulary
  - Process: a series of steps or actions that produce an end product

Reactants and Products

- A chemical reaction is the process by which atoms or groups of atoms in substances are reorganized into different substances.
- Chemical bonds are broken and/or formed during chemical reactions.
- Clues that a chemical reaction has taken place include the production of heat or light, and formation of a gas, liquid, or solid.

Chemical Equations

- Chemical formulas describe the substances in the reaction and arrows indicate the process of change.
- Reactants are the starting substances, on the left side of the arrow.
- Products are the substances formed during the reaction, on the right side of the arrow.
- The arrow can be read as "yields" or "react to form".

Reactants $\longrightarrow$ Products

Chemical Equations

- Glucose and oxygen react to form carbon dioxide and water.

$$C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$$

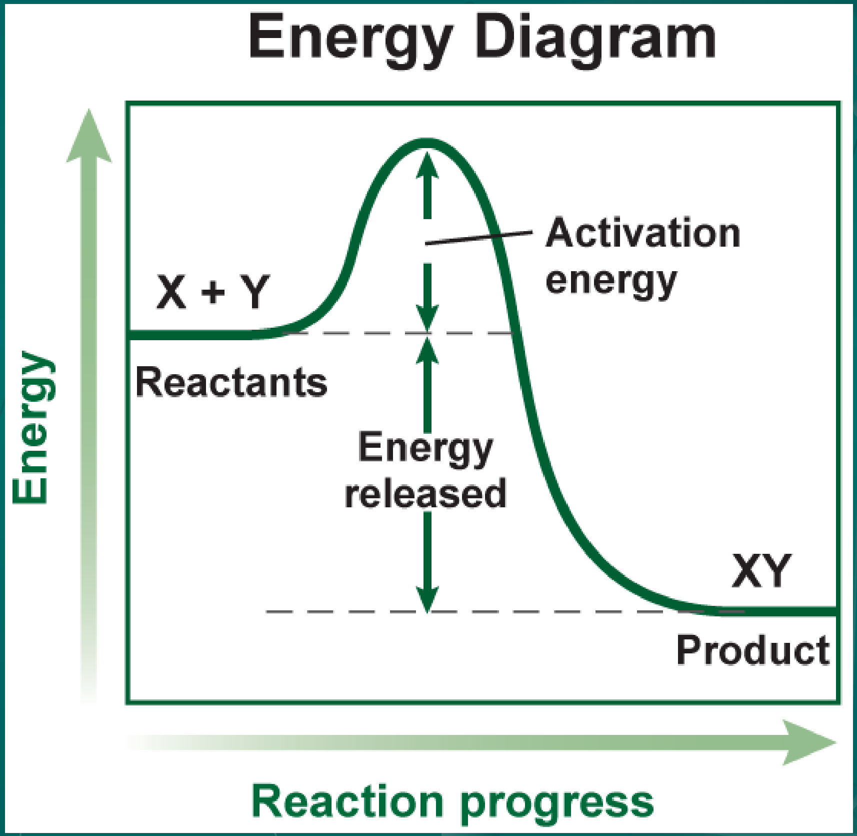
Balanced Equations

- The law of conservation of mass states matter cannot be created or destroyed.
- The number of atoms of each element on the reactant side must equal the number of atoms of the same element on the product side.
- Multiply the coefficient by the subscript for each element. You can see in this example that there are six carbon atoms, twelve hydrogen atoms, and eighteen oxygen atoms on each side of the arrow.
- The equation confirms that the number of atoms on each side is equal, and therefore the equation is balanced.

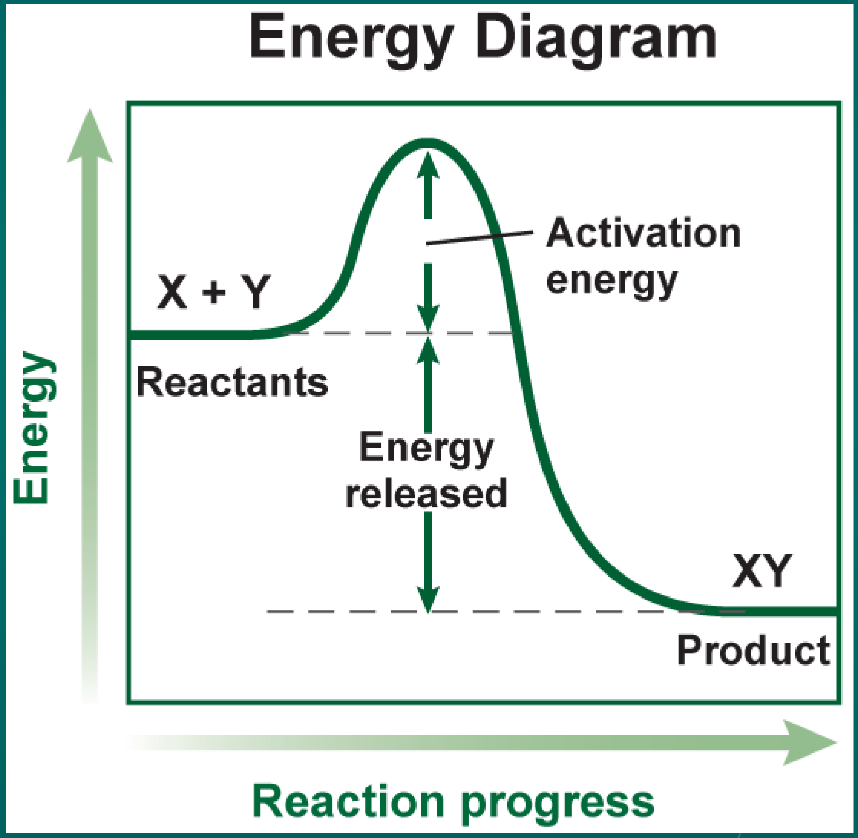
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Energy of Reactions

- Most compounds in living things cannot undergo chemical reactions without energy.
- The activation energy is the minimum amount of energy needed for reactants to form products in a chemical reaction.



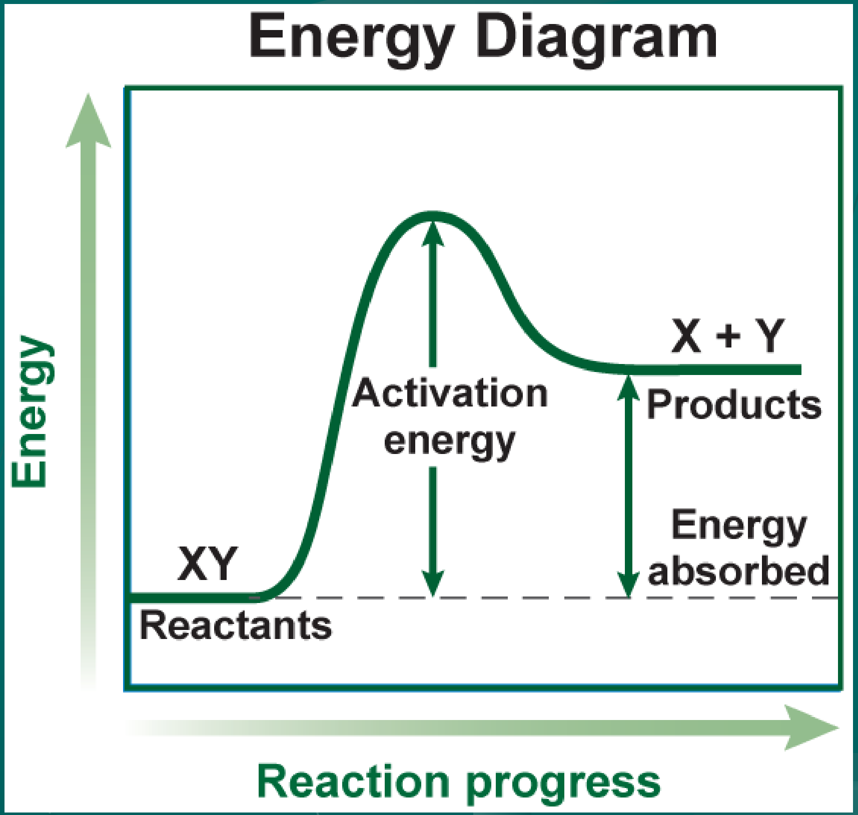
Exothermic



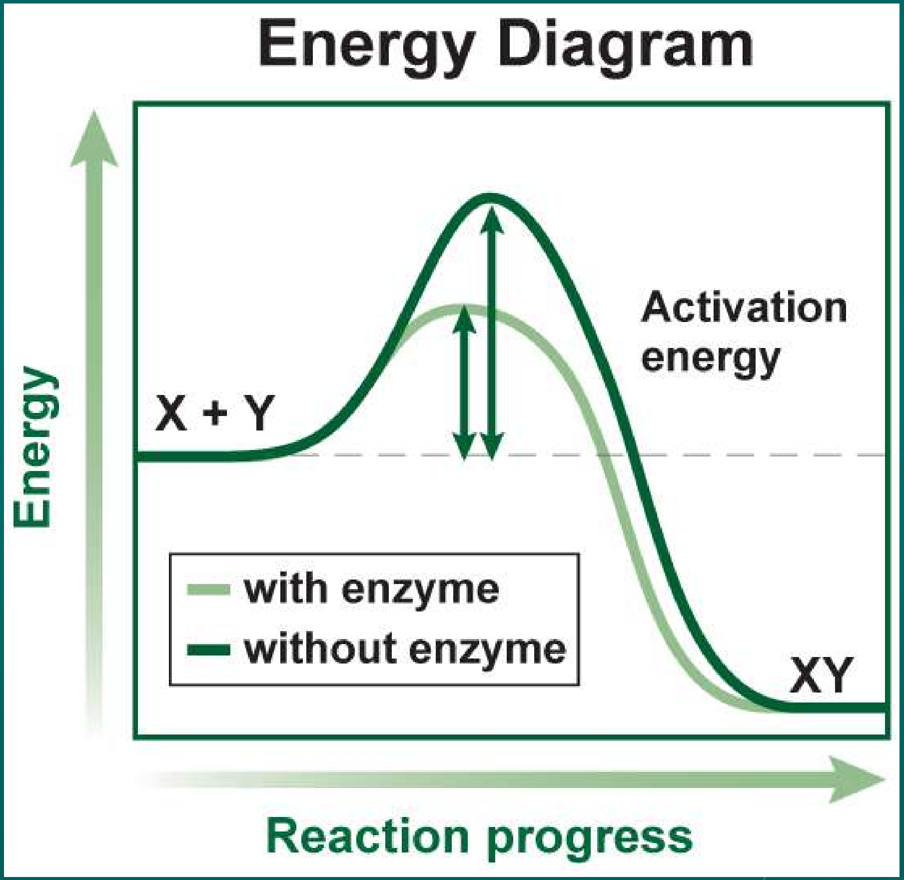
- This reaction is exothermic and released heat energy.
- The energy of the product is lower than the energy of the reactants.

Endothermic

- This reaction is endothermic and absorbed heat energy.
- The energy of the products is higher than the energy of the reactants.

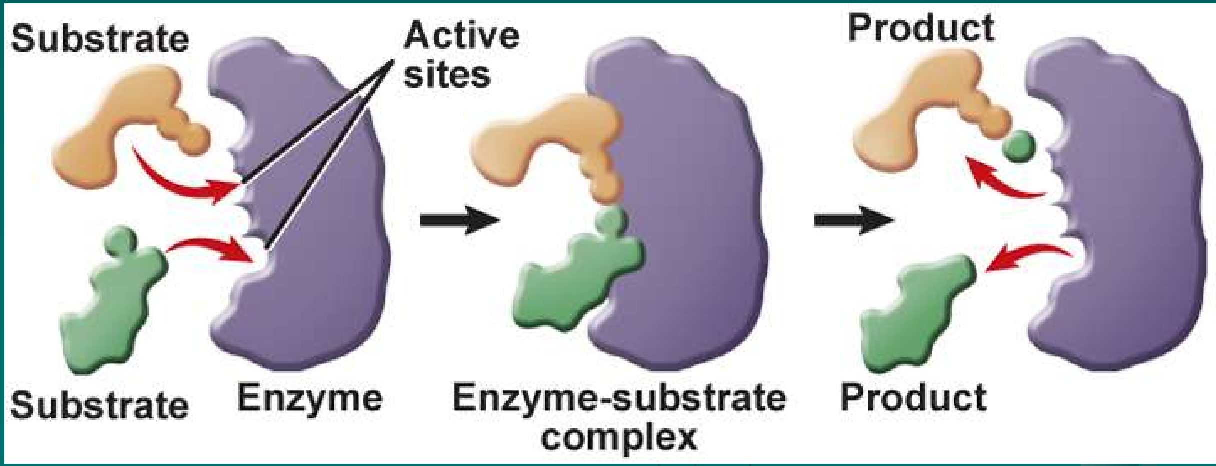


Enzymes



- A catalyst is a substance that lowers the activation energy needed to start a chemical reaction.
- It does not increase how much product is made and it does not get used up in the reaction.
- Special proteins called enzymes are biological catalysts that speed up the rate of chemical reactions in biological processes.
- Enzymes usually end in "ase" and are specific to one reaction.
- Example: Amylase is found in saliva and aids in the digestion of food in the mouth.

How Enzymes Work



- The reactants that bind to the enzyme are called substrates.
- The specific location where a substrate binds on an enzyme is called the active site.
- Once the substrates bind to the active site, the active site changes shape and forms the enzyme-substrate complex.
- The enzyme-substrate complex helps chemical bonds in the reactants to be broken and new bonds to form – the substrates react to form products.
- The enzyme then releases the products.

Enzyme Activity

- Factors that affect enzyme activity:
  - pH
  - Temperature
  - Other substances
- Enzymes affect many biological processes and are the chemical workers in a cell.