Atoms, Elements, and Compounds

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.
- **Protons** are positively charged particles.
- **Neutrons** are particles that have no charge.
Electrons are negatively charged particles that are located outside the nucleus.
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.
- Each element has a unique name and symbol.
The Periodic Table of Elements

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

Atoms, Elements, and Compounds
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.
Compounds

- A pure substance formed when two or more different elements combine

- Compounds are always formed from a specific combination of elements in a fixed ratio.

- Compounds cannot be broken down into simpler compounds or elements by physical means.
Chemical Bonds

- **Covalent bonds**
  - Chemical bond that forms when electrons are shared
  - A molecule is a compound in which the atoms are held together by covalent bonds.
Ionic Bonds

- Electrical attraction between two oppositely charged atoms or groups of atoms.

Na atom: 11 protons, 11 electrons
Sodium atom

Cl atom: 17 protons, 17 electrons
Chlorine atom

Na⁺ ion: 11 protons, 10 electrons
Sodium ion

Cl⁻ ion: 17 protons, 18 electrons
Chloride ion

NaCl
Ionic Bonds
Atoms, Elements, and Compounds

- Some atoms tend to donate or accept electrons more easily than other atoms.
- The elements identified as metals tend to donate electrons.
- The elements identified as nonmetals tend to accept electrons.
Most ionic compounds are crystalline at room temperature and have higher melting points than molecular compounds formed by covalent bonds.
van der Waals Forces

- When molecules come close together, the attractive forces between slightly positive and negative regions pull on the molecules and hold them together.

- The strength of the attraction depends on the size of the molecule, its shape, and its ability to attract electrons.
Chemical Reactions

Reactants and Products

- A chemical reaction is the process by which atoms or groups of atoms in substances are reorganized into different substances.

- Clues that a chemical reaction has taken place include the production of heat or light, and formation of a gas, liquid, or solid.
Chemical Reactions

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.

Reactants → Products
Glucose and oxygen react to form carbon dioxide and water.

\[ C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O \]
Chemical Reactions

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.

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \]
The **activation energy** is the minimum amount of energy needed for reactants to form products in a chemical reaction.
This reaction is exothermic and released heat energy.

The energy of the product is lower than the energy of the reactants.
This reaction is endothermic and absorbed heat energy.

The energy of the products is higher than the energy of the reactants.
Chemical Reactions

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.

- **Enzymes** are biological catalysts.
Chemical Reactions

- 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.
Chemical Reactions

- The active site changes shape and forms the enzyme-substrate complex, which helps chemical bonds in the reactants to be broken and new bonds to form.

- Factors such as pH, temperature, and other substances affect enzyme activity.
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 interaction involving a hydrogen atom and a fluorine, oxygen, or nitrogen atom.
Water and Solutions

Enzyme-Controlled Reactions

Virtual Lab  Click here to proceed!

Chemistry in Biology

Section 3
Visualizing Properties of Water
Water and Solutions

Homogenous Mixtures

- A mixture that has a uniform composition throughout

- A solvent is a substance in which another substance is dissolved.

- A solute is the substance that is dissolved in the solvent.
Chemistry in Biology

Section 3

Water and Solutions

Heterogeneous Mixtures

- In a heterogeneous mixture, the components remain distinct.
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**.
The measure of concentration of $H^+$ in a solution is called **pH**.

- Acidic solutions have pH values lower than 7.
- Basic solutions have pH values higher than 7.
Buffers are mixtures that can react with acids or bases to keep the pH within a particular range.
The element carbon is a component of almost all biological molecules.
The Building Blocks of Life

- Carbon has four electrons in its outermost energy level.
- One carbon atom can form four covalent bonds with other atoms.
- Carbon compounds can be in the shape of straight chains, branched chains, and rings.

![Diagram of straight chain, branched, and ring molecules]
The Building Blocks of Life

Macromolecules

- Carbon atoms can be joined to form carbon molecules.

- **Macromolecules** are large molecules formed by joining smaller organic molecules together.

- **Polymers** are molecules made from repeating units of identical or nearly identical compounds linked together by a series of covalent bonds.
<table>
<thead>
<tr>
<th>Group</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>• Stores energy</td>
</tr>
<tr>
<td></td>
<td>• Provides structural support</td>
</tr>
<tr>
<td>Lipids</td>
<td>• Stores energy</td>
</tr>
<tr>
<td></td>
<td>• Provides steroids</td>
</tr>
<tr>
<td></td>
<td>• Waterproofs coatings</td>
</tr>
<tr>
<td>Nucleic acids</td>
<td>• Transports substances</td>
</tr>
<tr>
<td></td>
<td>• Speeds reactions</td>
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<tr>
<td></td>
<td>• Provides structural support</td>
</tr>
<tr>
<td></td>
<td>• Provides hormones</td>
</tr>
<tr>
<td>Proteins</td>
<td>• Stores and communicates genetic information</td>
</tr>
</tbody>
</table>

Drag each group to its corresponding function.
Carbohydrates

- Compounds composed of carbon, hydrogen, and oxygen in a ratio of one oxygen and two hydrogen atoms for each carbon atom—$(\text{CH}_2\text{O})_n$
Values of $n$ ranging from three to seven are called simple sugars, or monosaccharides.

Two monosaccharides joined together form a disaccharide.

Longer carbohydrate molecules are called polysaccharides.
The Building Blocks of Life

Lipids

- Molecules made mostly of carbon and hydrogen
- A triglyceride is a fat if it is solid at room temperature and an oil if it is liquid at room temperature.
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.
The Building Blocks of Life

Proteins

- A compound made of small carbon compounds called amino acids
- Amino acids are small compounds that are made of carbon, nitrogen, oxygen, hydrogen, and sometimes sulfur.
Amino acids have a central carbon atom.

One of the four carbon bonds is with hydrogen.

The other three bonds are with an amino group (–NH₂), a carboxyl group (–COOH), and a variable group (–R).
The number and the order in which the amino acids are joined define the protein’s primary structure.

After an amino acid chain is formed, it folds into a unique three-dimensional shape, which is the protein’s secondary structure, such as a helix or a pleat.
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.