2.1 Atoms, Ions, and Molecules

Living things consist of atoms of different elements.

- An atom is the smallest basic unit of matter.
- An element is one type of atom.
- 6 elements make up 99% of all living things - carbon (C), oxygen (O), hydrogen (H), nitrogen (N), phosphorus (P), and sulfur (S).
- What do the above elements spell? S-P-O-N-C-H !!
2.1 Atoms, Ions, and Molecules

Atomic Structure: an atom is composed of proton, neutron and electron.

<table>
<thead>
<tr>
<th>Type</th>
<th>Symbol</th>
<th>Charge</th>
<th>Mass</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton</td>
<td>p⁺</td>
<td>+1</td>
<td>1 amu</td>
<td>nucleus</td>
</tr>
<tr>
<td>neutron</td>
<td>n⁰</td>
<td>0</td>
<td>1 amu</td>
<td>nucleus</td>
</tr>
<tr>
<td>electron</td>
<td>e⁻</td>
<td>-1</td>
<td>~ 0</td>
<td>energy level</td>
</tr>
</tbody>
</table>

(amu = atomic mass unit)
### 2.1 Atoms, Ions, and Molecules

#### Periodic Table

The Periodic Table of the Elements is a chart that organizes the elements based on their atomic number. Each element is represented by a symbol and its atomic number. The table is divided into periods and groups, with elements in the same group having similar properties. The periodic table is a fundamental tool in chemistry and helps in understanding the behavior of elements and their compounds.
2.1 Atoms, Ions, and Molecules

Periodic Table

- Elements are organized by the number of $p^+$, $n^0$, $e^-$
- Rows = “periods”; represents the number of energy levels
- Columns = “groups”; represents the number of valence $e^-$

Valence electrons = electrons on the outermost energy level

Oxygen has 6 valence electrons.

Oxygen atom (O)
2.1 Atoms, Ions, and Molecules

**Periodic Table**

- Each element is represented by atomic number and atomic mass.

<table>
<thead>
<tr>
<th>Li</th>
<th>3</th>
<th>7</th>
</tr>
</thead>
</table>

  Atomic number = # of proton or electron

  Lithium (Li) = # of p⁺ = 3
  # of e⁻ = 3
  # of n⁰ = 4 (atomic mass – atomic number)
### Periodic Table

Some more practice:

<table>
<thead>
<tr>
<th>Element</th>
<th>Charge</th>
<th>Mass</th>
<th># of $p^+$</th>
<th># of $e^-$</th>
<th># of $n^0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl</td>
<td>17</td>
<td>35</td>
<td>17</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Fe</td>
<td>26</td>
<td>56</td>
<td>26</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>Ag</td>
<td>47</td>
<td>108</td>
<td>47</td>
<td>47</td>
<td>61</td>
</tr>
</tbody>
</table>
How to draw an atom?

- You can draw an atom by showing how electrons are arranged in each energy level.
- Electrons move around the energy levels (aka “electron shells” or “electron orbitals”) outside the nucleus rapidly to form an electron cloud.
- The number of electrons each energy level can hold is:
  - 1st energy level holds 2 electrons
  - 2nd energy level holds 8 electrons
  - 3rd energy level holds up to 18 electrons
2.1 Atoms, Ions, and Molecules

Rules of electron placement when drawing an atom:

- Fill e- starting from the level closest to the nucleus.
- e- like to be in pairs, but fill single e- first before pairing them up.
- Octet rule = an atom in 2\textsuperscript{nd} energy level always likes to have 8 e- on the outermost energy level.
- When bonds form between two atoms, only the unpaired valence e- from the two atoms pair up.
2.1 Atoms, Ions, and Molecules

- A molecule is made of two or more elements bonded together (may be same or different)
  ex: $H_2O$, $CO_2$, $O_2$
- A compound is a large molecule in which elements are chemically bonded in a certain ratio.
  ex: $C_6H_{12}O_6$
2.1 Atoms, Ions, and Molecules

- An ion is a charged atom (+ or -)
- Some atoms are more stable as ions when they gain or lose one or more electrons.

Example 1:
Group 1 elements tend to lose 1e- and form + ions.

Example 2:
Group 7 elements tend to gain 1e- and form - ions.
2.1 Atoms, Ions, and Molecules

Types of Bonds

- Bond = the force that holds two atoms together.

1) Ionic bonds form between oppositely charged ions. Ex: NaCl, MgS
2) A covalent bond forms when atoms share a pair of electrons. (ex: H$_2$O, CO$_2$)
2.3 Carbon-Based Molecules

Carbon-based molecules are the foundation of life.

- Carbon-based molecules are called **organic molecules** or **macromolecules** *(macro- = large)*
- Carbons are bonded together to form the “backbone”.

- Four major groups:
  1. **carbohydrates**
  2. **lipids**
  3. **proteins**
  4. **nucleic acids**

![Diagram of glucose, hemoglobin, and DNA](image-url)
Many macromolecules are made of many small subunits bonded together.

- **Monomers** are the individual subunits.
- **Polymers** are made of many monomers.
2.3 Carbon-Based Molecules

Carbohydrates

• Made of C, H, O; ratio is 1:2:1 (ex: $\text{C}_6\text{H}_{12}\text{O}_6$)
• Function = provide short-term energy
2.3 Carbon-Based Molecules

Carbohydrates

- Monomers (simple sugar) = monosaccharides (ex: glucose)
- Polymers (complex sugar) =
  - Disaccharides are two monosaccharides linked together (ex: sucrose).
  - Polysaccharides are made of many monosaccharides (ex: starches, cellulose, and glycogen).

Glucose ($C_6H_{12}O_6$) can be ring shaped and is often shown as a simplified hexagon.
2.3 Carbon-Based Molecules

Carbohydrates

- **Starch** is where plants store food.
  
  Polymer (starch)

  ![Starch structure]

  Starch is a polymer of glucose monomers that often has a branched structure.

- **Cellulose** is what makes up plant cell wall.
  
  Polymer (cellulose)

  ![Cellulose structure]

  Cellulose is a polymer of glucose monomers that has a straight, rigid structure.
2.3 Carbon-Based Molecules

**Lipids**
- Made of **C, H, O**
- Function = provide long-term energy; make up cell membrane; used to make hormones
- Monomers = carbon chains of **fatty acids**
- Polymers = fats, oil, phospholipids, cholesterol
2.3 Carbon-Based Molecules

**Lipids**

- Fats and oils contain **fatty acids** bonded to **glycerol**. (ex: triglyceride)
2.3 Carbon-Based Molecules

**Lipids**

- Fats and oils have different types of fatty acids.
  - **saturated** fatty acids (bad!)
  - **unsaturated** fatty acids (good!)

![Saturated fatty acid](image)

Saturated fats contain fatty acids in which all carbon–carbon bonds are single bonds.

![Unsaturated fatty acid](image)

Unsaturated fats have fatty acids with at least one carbon–carbon double bond.
Lipids

- **Phospholipids** make up the cell membrane.
- They are made of a phosphate head and two fatty acid tails.

The cell membrane is made of two phospholipid layers embedded with other molecules, such as proteins, carbohydrates, and cholesterol.
2.3 Carbon-Based Molecules

Nucleic Acids

- Made of **C, H, O, N, P**
- Function = carry and transmit genetic information
- Monomers = **nucleotides**
- Polymers = **DNA** and **RNA**
- Nucleotides are linked together in a specific order to transmit heredity information
2.3 Carbon-Based Molecules

Nucleic Acids

- Nucleotides are made of a **sugar**, **phosphate group**, and a **nitrogen base**.

- **DNA** (Deoxyribonucleic acid) stores genetic information.

- **RNA** (Ribonucleic acid) builds proteins.
2.3 Carbon-Based Molecules

Proteins

- Made of C, H, O, N, S
- Function = structure, regulation, immunity, contraction, transport, catalysis
- Monomers = amino acids
- Polymers = proteins (ex: enzyme, transport protein)
2.3 Carbon-Based Molecules

Proteins

– **Twenty** different amino acids are used to build proteins in organisms.
– Amino acids differ in side groups, or **R groups**.
– Amino acids are linked by **peptide bonds**.

![Peptide bond diagram](image)
2.3 Carbon-Based Molecules

Proteins are made of specific sequences of amino acids

• Order of the amino acids is determined by the order of the nucleotides in the DNA molecule.
• Properties of amino acids cause protein to fold up into a specific shape to do its specific function.
• SHAPE = FUNCTION!!
All chemical reactions in living organisms require enzymes to work.

• Building molecules (synthesis/anabolic):

• Breaking down molecules (digestion/catabolic):
Enzymes are proteins that act as catalysts for chemical reactions in living things.

- Catalysts are substances that speed up chemical reactions by decreasing activation energy.

- Catalysts are not used up in the reaction. (recyclable)
- Ex: digestive enzymes speed up digestion of food
2.5 Enzymes

- Enzymes are very specific.
- An enzyme’s structure allows only certain reactants to bind to the enzyme.
  - substrates = what enzyme acts on
  - active site = where substrate and enzyme bind

enzyme – substrate pairs
- amylase breaks down starch
- lactase breaks down lactose
- lipase breaks down lipid
- protease breaks down protein
- DNA polymerase builds DNA
2.5 Enzymes

- Lock-and-key model = illustrate how enzymes function

![Enzyme diagram](image)
2.5 Enzymes

- **Lock-and-key model**
  1) Substrates (key) exactly fit the active sites of enzymes (lock).
  2) Substrates are brought together (or broken down) and bonds are weakened.
  3) A new product is formed and released.

Substrates bind to an enzyme at certain places called active sites.

The enzyme brings substrates together and weakens their bonds.

The catalyzed reaction forms a product that is released from the enzyme.
2.5 Enzymes

- Enzymes function best in a small range of conditions.
  - Factors that can affect enzyme activities: temperature, pH, enzyme/substrate concentration
  - Enzymes can denature in extreme temperature and pH (shape and function are irreversibly destroyed!!)
  - SHAPE = FUNCTION!!

In protein, it's not the size, it's the SHAPE that matters!