Chapter 2

Life’s chemical basis
Start With Atoms

CHARACTERISTICS OF ATOM

Atom
- Building blocks of all substances
- They consist of 3 subatomic particles- Protons, Electrons, Neutrons
- Protons - positive charge
- Electron - negative charge
- Neutrons - neutral charge
- All atoms have a nucleus
Atoms

a. nucleus
b. electron
c.
Start With Atoms

**Element**

- They are pure substances
- Each element is made up of atoms of the same type
- Example: Element Oxygen is made up of Oxygen atoms
Start With Atoms

Atomic Number

- The number of protons, which is unique to that element
- Example: Element Carbon has six protons in its nucleus, so the atomic number is 6

Mass Number

- Total number of protons and neutrons
Start With Atoms

Isotopes
- All atoms of that element that differ in their number of neutrons
- Example: $^{12}_6C, ^{13}_6C, ^{14}_6C$

Periodic table
- Dmitry Mendeleev arranged the periodic table based on the chemical properties.
- Symbol for each element is an abbreviation of its name (1or 2 letters of the element)
- Elements in the far right column of the table are inert gases.
# Periodic Table of Elements

![Periodic Table Image](image_url)

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Putting Radioisotopes To Use

Radioisotopes

- The atoms of radioisotopes spontaneously emit subatomic particles or energy when their nucleus break.
- This decay can transform one element to another.
- Example: Radioactive carbon decays to form nitrogen.

Uses

- To estimate the age of rocks and fossils.
- Researchers and clinicians use radioactive isotopes in living organisms.
- Radioisotopes have uses in medicine, PET scan.
Why Electrons Matter

Electrons and energy levels

- Electrons occupy in different orbital around the nucleus

Shells and electrons

- Help us to check an atom for vacancies.
- Represent the orbital energy level as successively larger circles or shells
- Used to view an atoms electron structure.
The diagram illustrates electron configurations for elements in their ground state. It separates the elements into three energy levels:

- **First shell**: Lowest energy, showing the elements hydrogen and helium. Hydrogen has 1 proton and 1 electron, while helium has 2 protons and 2 electrons.
- **Second shell**: More energy, showing the elements carbon, oxygen, neon, sodium, and chlorine. Carbon has 6 protons and 6 electrons, oxygen has 8 protons and 8 electrons, and neon has 10 protons and 10 electrons. Sodium and chlorine have configurations of 11 protons and 11 electrons, and 17 protons and 17 electrons, respectively.
- **Third shell**: Greatest energy, showing the elements argon and neon. Argon has 18 protons and 18 electrons, and neon has 10 protons and 10 electrons.

Each shell represents an increase in energy, with elements in higher energy levels having more electrons.
Why Electrons Matter

Atoms and Ions

Atoms

- An atom with equal number of protons and electrons has no net charge.

Ions

- An atom that have gained or lost electrons.
- An ion is an atom that carries a charge, it acquires a negative charge by pulling an electron away from other atom or it acquires a positive charge by losing an electron.
Ion Formation

Sodium atom

11 p⁺
11 e⁻
no net charge

Sodium ion

11 p⁺
10 e⁻
net positive charge

electron loss

Chlorine atom

17 p⁺
17 e⁻
no net charge

Chloride ion

17 p⁺
18 e⁻
net negative charge

electron gain
Why Electrons Matter

Electronegativity
- It is the measure of atom’s ability to pull electrons from other atoms.

From atoms to molecules
- A chemical bond is an attractive force that arises between two atoms when their electrons interact

Molecule - It is formed when two or more atoms of same or different element join in chemical bonds.
Why Electrons Matter

**Compounds** - They are molecules that consist of two or more different elements in proportions that do not vary.

- Example – Water(H2O), It has 1 Oxygen atom bonded to 2 Hydrogen atoms.

**Mixtures** - Two or more substances intermingle, but do not bond with each other.

- Example - Sugar and water.
What Happens When Atoms Interact?

<table>
<thead>
<tr>
<th>Common name</th>
<th>Water</th>
<th>Familiar term.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical name</td>
<td>Hydrogen oxide</td>
<td>Systematically describes elemental composition.</td>
</tr>
<tr>
<td>Chemical formula</td>
<td>H₂O</td>
<td>Indicates unvarying proportions of elements. Subscripts show number of atoms of an element per molecule. The absence of a subscript means one atom.</td>
</tr>
<tr>
<td>Structural formula</td>
<td>H—O—H</td>
<td>Represents each covalent bond as a single line between atoms. The bond angles also may be represented.</td>
</tr>
<tr>
<td>Structural model</td>
<td><img src="image" alt="Structural model" /></td>
<td>Shows the positions and relative sizes of atoms.</td>
</tr>
<tr>
<td>Shell model</td>
<td><img src="image" alt="Shell model" /></td>
<td>Shows how pairs of electrons are shared in covalent bonds.</td>
</tr>
</tbody>
</table>
What Happens When Atoms Interact?

Types of Bond

- Ionic bond
- Covalent bond
- Hydrogen bond
Ionic Bonds

- Strong association between a positive ion and a negative ion (attraction of opposite charges)

![Ionic Bonds Diagram](image)

- A crystal of table salt is a cubic lattice of many sodium ions and chloride ions.
- The mutual attraction of opposite charges holds the two kinds of ions together closely in the lattice.
What Happens When Atoms Interact?

**Covalent bond** – two atoms share a pair of electrons

**Polar covalent bond** – two atoms do not share electrons equally (oxygen is partial negative and hydrogen is partial positive)

Example - Water molecule

**Non-polar covalent bond** – atoms share electrons equally

Example - molecular Hydrogen, Oxygen
Molecular hydrogen (H—H)

Two hydrogen atoms, each with one proton, share two electrons in a single nonpolar covalent bond.

Molecular oxygen (O—O)

Two oxygen atoms, each with eight protons, share four electrons in a nonpolar double covalent bond.

Water molecule (H—O—H)

Two hydrogen atoms each share an electron with an oxygen atom in two polar covalent bonds. The oxygen exerts a greater pull on the shared electrons, so it has a slight negative charge. Each hydrogen has a slight positive charge.
What Happens When Atoms Interact?

Hydrogen Bond

- Formed between a Hydrogen atom and an electronegative atom
- Example - Bond between two water molecules, and between water and ammonia
Hydrogen Bonds

![Diagram of hydrogen bonds between a water molecule and an ammonia molecule.](image)

**a** Two molecules interacting in one hydrogen (H) bond.

![Diagram of DNA structure with hydrogen bonds highlighted.](image)

**b** Numerous H bonds (white dots) hold the two coiled-up strands of a DNA molecule together. Each H bond is weak, but collectively these bonds stabilize DNA’s large structure.
Water’s Life Giving Properties

Polarity of water molecule
- polarity of each molecule attracts other water molecules

**Hydrophilic substance** (water-loving)
- any substance that has an affinity for water
  - Example - Water forms hydrogen bonds with sugar and other water molecules

**Hydrophobic substance** (water-dreading)
- substances that do not have an affinity for water
  - Example - Salad oil
Polarity of water molecule

slight negative charge on the oxygen atom

The positive and negative charges balance each other; overall, the molecule carries no charge.

slight positive charge on the hydrogen atoms
Water’s Life Giving Properties

Water’s temperature-stabilizing effects

- Temperature – It is a way to measure of energy of molecular motion
- Evaporation – heat energy converts liquid water to a gas

Water’s solvent property

- Solvent – substances that dissolve other substances
- Solute – the substance that is dissolved
Water’s Life Giving Properties

**Sphere of hydration** – clustering of water molecules around a solute
- Example - Pour table salt into a cup of water

**Water’s cohesion** – molecules resist separating from one another
- Example - Tossing a pebble into a pond
Water’s Solvent Properties

- **Solvents** dissolve **solutes** (spheres of hydration)
Water’s Cohesion
Acids and bases

The pH scale – measures Hydrogen ion concentration in a solution

- greater the H+ concentration less is the pH, and vice versa
- At pH 7 (neutral) H+ and OH− concentrations are equal

The difference between acids and bases –
Acids – donate Hydrogen ions
- Example - Lemon juice, coffee
Bases – accept Hydrogen ion as they dissolve in water
- Example - Seawater, egg white
Red Dots-Hydrogen (H$^+$)

Blue Dots-Hydroxyl (OH-)
Acids and bases

Salt and water

**Salt** – any compound that dissolves easily in water and releases ions other than $\text{H}^+$ and $\text{OH}^-$.

- *Example*: $\text{NaCl}$

\[
\text{HCl} + \text{NaOH} \leftrightarrow \text{NaCl} + \text{H}_2\text{O}
\]

- It is formed when acid interacts with base
Acids and bases

Buffers – substances that minimize changes in concentrations of H$^+$ and OH$^-$ in a solution

Buffering system – set of chemicals that keeps the pH of a solution stable
Functions of Buffer Systems

- Buffers help maintain homeostasis

- Most biological processes proceed only within a narrow $p^H$ range, usually near neutrality
  - Acidosis
  - Alkalosis
Table 2.2  Summary of Players in the Chemistry of Life

<table>
<thead>
<tr>
<th><strong>Atom</strong></th>
<th>Particles that are basic building blocks of all matter; the smallest unit that retains an element’s properties.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element</strong></td>
<td>One of ninety-two naturally occurring pure substances. Each consists entirely of atoms that have the same, characteristic number of protons.</td>
</tr>
<tr>
<td><strong>Proton (p⁺)</strong></td>
<td>Positively charged particle of an atom’s nucleus</td>
</tr>
<tr>
<td><strong>Electron (e⁻)</strong></td>
<td>Negatively charged particle that can occupy a volume of space (orbital) around an atom’s nucleus</td>
</tr>
<tr>
<td><strong>Neutron</strong></td>
<td>Uncharged particle of an atom’s nucleus</td>
</tr>
<tr>
<td><strong>Isotope</strong></td>
<td>One of two or more forms of an element’s atoms that differ in the number of neutrons</td>
</tr>
<tr>
<td><strong>Radioisotope</strong></td>
<td>Unstable isotope that emits particles and energy when its nucleus disintegrates.</td>
</tr>
<tr>
<td><strong>Tracer</strong></td>
<td>Molecule that has a detectable substance (such as a radioisotope) attached. Used with tracking devices to identify the movement or destination of the molecule in a metabolic pathway, the body, or some other system</td>
</tr>
<tr>
<td><strong>Ion</strong></td>
<td>Atom that carries a charge after it has gained or lost one or more electrons. A single proton without an electron is a hydrogen ion (H⁺)</td>
</tr>
<tr>
<td><strong>Molecule</strong></td>
<td>Two or more atoms joined in a chemical bond</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td><strong>Compound</strong></td>
<td>Molecule of two or more different elements in unvarying proportions (for example, water)</td>
</tr>
<tr>
<td><strong>Mixture</strong></td>
<td>Intermingling of two or more elements or compounds in proportions that can vary</td>
</tr>
<tr>
<td><strong>Solute</strong></td>
<td>Molecule or ion dissolved in some solvent</td>
</tr>
<tr>
<td><strong>Hydrophilic substance</strong></td>
<td>Polar substance (or molecular region) that readily dissolves in water</td>
</tr>
<tr>
<td><strong>Hydrophobic substance</strong></td>
<td>Nonpolar substance (or molecular region) that resists dissolving in water</td>
</tr>
<tr>
<td><strong>Acid</strong></td>
<td>Substance that releases $\text{H}^+$ when dissolved in water</td>
</tr>
<tr>
<td><strong>Base</strong></td>
<td>Substance that accepts $\text{H}^+$ when dissolved in water</td>
</tr>
<tr>
<td><strong>Salt</strong></td>
<td>Compound that releases ions other than $\text{H}^+$ or $\text{OH}^-$ when dissolved in water</td>
</tr>
</tbody>
</table>