CHEMISTRY
Matter

• Anything that **occupies space** and has **mass**.

• **Examples:**
  1. rock
  2. wood
  3. metal
  4. air
Chemical Element

- **Matter** is composed of *chemical elements*.
- **Examples:** gold, copper, carbon, oxygen
- 92 elements occur in nature.
- **O, C, H** and **N** make up **96% - human body**.
- **trace elements** (minute quantities).
Compound

• Substance containing **two or more elements**.

• **Example:** \( \text{C}_6\text{H}_{12}\text{O}_6 \) (glucose - sugar)
  - 6 - carbons
  - 12 - hydrogen
  - 6 - oxygen
Question:

• Answer the following questions about $C_6H_{12}O_6$

1. How many elements are involved?
2. How many atoms are involved?
Answer:

1. **Elements** - 3 (C, H, O)
2. **Atoms** - 24
Atom

• The **smallest unit of matter** that still retains the properties of an **element**.
Components of an Atom

<table>
<thead>
<tr>
<th>Component</th>
<th>Charge</th>
<th>Mass</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Proton</td>
<td>positive</td>
<td>1</td>
<td>nucleus</td>
</tr>
<tr>
<td>2. Neutron</td>
<td>neutral</td>
<td>1</td>
<td>nucleus</td>
</tr>
<tr>
<td>3. Electron</td>
<td>negative</td>
<td>~0</td>
<td>around the nucleus</td>
</tr>
</tbody>
</table>
Carbon - Atom

Protons - 6
Neutrons - 6
Electrons - 6
Atomic Number

- **Equals** the number of protons within the nucleus of an element.

- **Examples:**
  - Hydrogen (H) - 1
  - Sodium (Na) - 11
  - Carbon (C) - 6
  - Oxygen (O) - 8
  - Gold (Au) - 79
Atomic Mass

• **Equals** the number of protons + neutrons.

• **Examples:**

  - Hydrogen (H) - 1.0079
  - Sodium (Na) - 23
  - Carbon (C) - 12
  - Oxygen (O) - 16
  - Gold (Au) - 197
Charge of an Element

- **Question:** protons = electrons
- **Answer:** charge is neutral

- **Question:** protons ≠ electrons
- **Answer:** the charge is either negative or positive
Isotope

• **Atoms** of elements with different number of neutrons.

• **Examples:**
  - carbon - 12
  - carbon - 13
  - carbon - 14
## Isotopes of Carbon

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>$^{12}\text{C}$</th>
<th>$^{13}\text{C}$</th>
<th>$^{14}\text{C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>protons</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>neutrons</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>electrons</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
Radioactive Isotopes

• **Unstable isotopes.**

• Spontaneously emit **small beta particles** from the nucleus.

• **Examples:** Carbon-14, Hydrogen-3, Potassium-40
Electrons

• orbit around the **nucleus**
• first bonding orbital - **2 electrons**
• all other bonding orbitals - **maximum 8 electrons**
• orbitals have certain **energy levels**
• orbitals farther from the nucleus have the highest energy level.
Sodium and Chlorine – Electrons Bonding Orbitals

Na  Cl
Gases

- **Elements** with **8 electrons** in outer shell are called: **noble gases** or **inert gases**

- **Examples:**
  - Helium (He) – only 2 electrons
  - Neon (Ne)
  - Argon (Ar)
Chemical Bonding

- Three types of bonds with different strengths:
  
  covalent > ionic > hydrogen
Covalent Bonds

- **strongest bond**
- two elements *share one or more pairs* of outer electrons
- **single** and **double bonds**
- **Examples:**
  1. $\text{H}_2\text{O}$ (water - polar molecule)
  2. $\text{CH}_4$ (methane)
  3. $\text{O}_2$ (dioxygen)
Ion

• atom or molecule with an electric charge.
• resulting from a gain or loss of one or more electrons.
• Examples:
  Sodium ion (Na$^+$)
  Chloride ion (Cl$^-$)
Ionic Bonds

- **second strongest bond**
- **two ions with opposite charges attract each other.**
- **Examples:**
  - salts (NaCl)
  - acids
  - bases
Ionic Bond

- **Example:** salt (NaCl)
Electronegativity

• The tendency for an **atom** to pull **electrons** toward itself.

**Electronegativity values for atoms of selected elements:**

H(2.1)  
Li(1.0)  Be(1.5)  B(2.0)  C(2.5)  N(3.0)  O(3.5)  F(4.0)  
Na(0.9)  Mg(1.2)  Al(1.5)  Si(1.8)  P(2.1)  S(2.5)  Cl(3.0)  
K(0.8)  Ca(1.0)  Ga(1.6)  Ge(1.8)  As(2.0)  Se(2.4)  Br(2.8)
## Electronegativity

### Electronegativity Difference and Bond Type:

<table>
<thead>
<tr>
<th>Difference</th>
<th>Bond</th>
<th>Example</th>
<th>Example Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-0.4</td>
<td>Covalent (nonpolar)</td>
<td>H-H</td>
<td>0.0</td>
</tr>
<tr>
<td>0.4-1.0</td>
<td>Covalent (polar)</td>
<td>H-Cl</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H$_2$O</td>
<td>0.7</td>
</tr>
<tr>
<td>1.0-2.0</td>
<td>Covalent (very polar)</td>
<td>H-F</td>
<td>1.9</td>
</tr>
<tr>
<td>≥ 2.0</td>
<td>Ionic</td>
<td>NaCl</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Hydrogen Bonding

• **weakest of the three bonds.**

• **Most important and common of all bonds.**

• **Partially positive hydrogen** atom of one molecule is attracted to the **partially negative atom** of another molecule (O or N).

• **Example:** $\text{H}_2\text{O}$

![Diagram of hydrogen bonds in water molecules](image-url)
There are several properties of water that make it unique.

1. States of water.
2. Cohesion and surface tension
3. High heat of vaporization
4. Evaporative cooling
5. Ice is less dense than liquid
6. Versatile solvent
Question:

• What are the three states of water?

• Answer:  
  1. ice  
  2. liquid  
  3. water vapor (gas)
Water (H$_2$O)

2. **Cohesion**
   1. **Hydrogen bonds (H-bonds)** cause water molecules to stick together.
   2. Aides in the transport of water from **roots** to the **leaves**.

• **Surface tension**
  1. Related to **cohesion** (H-bonds)
  2. Allow water striders (insects) to walk on water.
3. **High heat of vaporization**

1. Water absorbs more heat than most substances.

2. It takes a lot of heat to raise the temp of water, thus must lose a lot of heat to lower the temperature.

3. Stabilize and protects organisms from rapid change in temp.

**Example:** ocean
Water ($\text{H}_2\text{O}$)

4. Evaporative cooling
   1. Related to "high heat of vaporization".

   2. Water can absorb a great deal of heat before evaporation.

Example:

Heat absorbed by water $\rightarrow$ evaporation $\rightarrow$ cools organism
Water ($\text{H}_2\text{O}$)

5. **Ice is less dense than liquid**

   1. **H-bonding** produces an open structure when frozen.

**Question:** Why is this significant to living systems like lake or ponds?

**Answer:** Lakes or ponds do not freeze solid, thus insulating the underlying water and its organisms.
Water (H₂O)

6. Versatile solvent

Water dissolves an enormous variety of solutes.

solvent (water) + solute (salt) → solution
Water (H$_2$O)

• **Remember:**

1. **Water** is a **good solvent** and is **hydrophilic** ([water loving](#)) for other **polar** molecules and **ions**.

2. **Hydrophobic** ([water hating](#)) interactions occur between **water** and **non-polar** molecules like **fat (lipids)**.
Acids

- Proton donor
- High number of H\(^+\) - protons and low # of OH\(^-\)
- Examples: HCl (hydrochloric acid)
  H\(_2\)SO\(_4\) (sulfuric acid) - ACID RAIN
Base

- **Proton acceptor**
- **Low number of** $H^+$ **and high # of** $OH^-$
- **Examples:** NaOH (sodium hydroxide)
  NH$_3$ (ammonia)
pH Scale

• Scientist use the **pH scale** to describe the **acidity** of a solution.

• **pH** stands for **potential hydrogen**.

• The **scale** ranges from **0 (most acidic)** to **14 (most basic)**.

• Each **pH** unit represents a tenfold change in the concentration of **H⁺**, - thus pH 2 has **10x as many H⁺ (protons)** as pH 3.
Neutral Solution

- pH of 7 is neither *acidic* or *basic*.
- It is said to be *neutral*.
- This means that there are as many $H^+$ as $OH^-$.
- *Pure water* and *blood* are *neutral*.
pH Scale

1. ___ H+ equals OH-
2. ___ pH values of basic (alkaline solution)
3. ___ pH values of acidic solution
4. ___ Progressing from weak to strong acid
5. ___ Progressing from weak to strong base
6. ___ Result of adding H+ to a solution

<table>
<thead>
<tr>
<th>0</th>
<th>acid</th>
<th>7</th>
<th>base</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>d</td>
<td>e</td>
<td>c</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>f →</td>
<td></td>
<td>→</td>
<td>→</td>
</tr>
</tbody>
</table>

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Buffers

- Substances that resist change in pH.
- Accepts H+ when pH is to low (acidic).
- Donates H+ when pH is to high (basic).