Welcome to Chem Up!
An Introduction to Basic Chemistry Concepts
Please sign in.

Water
- The compound, water makes up a majority of most organisms and is a critical component making the processes of life possible.
- Water is known by other names including
  - Oxidane
  - Hydrogen oxide
  - Dihydrogen monoxide
  - Hydric acid, etc
- Water consists of two hydrogen atoms covalently bonded to one oxygen atom.

Properties of Water
- Polar molecule
- Universal Solvent
- Adhesion/Cohesion
- Surface Tension
- Capillarity
- High Specific Heat
- High Heat of Vaporization
- Density
- Participates in chemical reactions

Water: Polarity
- Oxygen has a greater attraction for electrons than does hydrogen due to electronegativity.
- The oxygen atom gains a slight excess of negative charge (partial negative charge), and the hydrogen atoms become slightly positive (partial positive charge).
- An individual water molecule has a bent shape because the dipoles do not cancel.
- Water is polar thus having positive & negative partial charges on its ends.
Solvency

- Solvency - ability to dissolve other chemicals
  - Solvent - the part of a solution present in the largest amount.
  - Solute - the substance that is present in a solution in a smaller amount and is dissolved by the solvent.
  - Hydrophilic (charged, ionic or polar substances) dissolve easily in water - salt.
  - Hydrophobic (neutral or non-polar substances) do not easily dissolve in water - oil.

- Water = universal solvent

Water as a Solvent

- Water is a versatile solvent due to its polarity.
- It can form aqueous solutions.
- The different regions of the polar water molecule can interact with ionic compounds called solutes and dissolve them.

Water - Hydrogen Bonds

- The slightly negative oxygen atom of one water molecule is attracted to the slightly positive hydrogen atoms of nearby water molecules, forming hydrogen bonds.
  - Each water molecule can form hydrogen bonds with up to four neighbors.
  - Hydrogen bonds hold water molecules together.
  - They form, break, and reform with great frequency.

- Extraordinary Properties that are a result of hydrogen bonds:
  - Cohesive and adhesive behavior
  - Resists changes in temperature
  - High heat of vaporization
  - Expands when it freezes
  - Versatile solvent

Cohesion/Adhesion of Water

- Cohesion
  - The attraction of like molecules to each other, i.e. water molecules cling to other water molecules.

- Adhesion
  - The attraction of water molecules to other substances.
  - Water is adhesive to any substance with which it can form hydrogen bonds.
Surface Tension

- Surface tension, a measure of the force necessary to stretch or break the surface of a liquid due to cohesion.
- Water has a greater surface tension than most other liquids because hydrogen bonds among surface water molecules resist stretching or breaking the surface.
- Water behaves as if covered by an invisible film.
- Some animals can stand, walk, or run on water without breaking the surface.

Capillarity

- Capillarity is the ability of water to be drawn up a narrow tube.
- Is a combination of surface tension, cohesion, and adhesion.
- This action helps pull water up through the microscopic vessels of plants.
- It is also responsible for transporting fluids and nutrients in and out of cells.

Temperature

Water can absorb or release relatively large amounts of heat with only a slight change in its own temperature.

Water serves as a large heat sink responsible for:
1. Prevention of temperature fluctuations that are outside the range suitable for life.
2. Coastal areas having a mild climate.
3. A stable marine environment.

<table>
<thead>
<tr>
<th>Celsius Scale at Sea Level</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>100°C</td>
<td>Water boils</td>
</tr>
<tr>
<td>37°C</td>
<td>Human body temperature</td>
</tr>
<tr>
<td>23°C</td>
<td>Room temperature</td>
</tr>
<tr>
<td>0°C</td>
<td>Water freezes</td>
</tr>
</tbody>
</table>

Specific Heat

- The specific heat of a substance is the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1°C.
- Water has a high specific heat, absorbs and releases heat very slowly, which minimizes temperature fluctuations to within limits that permit life.
- Heat is absorbed when hydrogen bonds break.
- Heat is released when hydrogen bonds form.
- The specific heat of water is 1 cal/g/°C.
- Water resists changing its temperature because of its high specific heat.
Evaporative Cooling

- Evaporation is the transformation of a substance from liquid to gas.
- Heat of vaporization is the quantity of heat a liquid must absorb for 1 gram of it to be converted from a liquid to a gas.
- Water requires a great amount of heat to change to a gas.
  - Evaporative cooling - Allows water to cool a surface due to water’s high heat of vaporization.
  - The cooling of a surface occurs when the liquid evaporates.
- This is responsible for:
  - moderating earth’s climate
  - stabilizing temperature in aquatic ecosystems
  - preventing organisms from overheating

Density of Water

- Ice is about 10% less dense than water at 4°C.
  - Most dense at 4°C
  - Contracts until 4°C
  - Expands from 4°C to 0°C

- The density of water:
  - Prevents water from freezing from the bottom up.
  - Ice forms on the surface first—the freezing of the water releases heat to the water below creating insulation.
  - If ice sank, all bodies of water would eventually freeze solid, making life impossible on Earth.
  - Makes transition between season less abrupt

Carbon

- Carbon is a central element to life because most biological molecules are built on a carbon framework.
- The complexity of living things is facilitated by carbon’s linkage capacity.
- Carbon has great bonding capacity due to its tetrahedral structure.
- Carbon’s outer shell has only four of the eight electrons necessary for maximum stability in most elements.
- Carbon atoms are thus able to form stable, covalent bonds with a wide variety of atoms, including other carbon atoms.

Organic vs Inorganic Compounds

- Compounds which contain carbon - carbon bonds are called organic molecules.
  - Contain carbon and hydrogen.
  - Contains single, double, or triple covalent bonds.
  - Examples - methane, ethane, sugar, lipids
- Compounds which do not contain carbon - carbon bonds are called inorganic.
  - Examples - water, oxygen, ammonia, salt
Organic Compounds

- Organic compounds:
  - always contain carbon and hydrogen, and sometimes oxygen, sulfur, nitrogen, phosphorus, or a halogen
  - occur in nature and are also found in fuel, shampoos, cosmetics, perfumes, and foods
  - are the foundation for understanding biochemistry
  - have low melting and boiling points
  - are not soluble in water and are less dense than water
  - undergo combustion, burning vigorously in air

Formulas for organic compounds are written with carbon first, followed by hydrogen and then other elements.

Hydrocarbons

Hydrocarbons are organic compounds that contain only carbon and hydrogen.

Saturated hydrocarbons contain only single carbon-carbon bonds.

Organic vs Inorganic Compounds

<table>
<thead>
<tr>
<th>Property</th>
<th>Organic</th>
<th>Example: C₂H₅</th>
<th>Inorganic</th>
<th>Example: NaCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements</td>
<td>C and H</td>
<td>C and H</td>
<td>Most metals and nonmetals</td>
<td>Na and Cl</td>
</tr>
<tr>
<td>Bonding</td>
<td>Mostly covalent</td>
<td>Covalent (4 bonds to each C)</td>
<td>Mostly ionic</td>
<td>Ionic</td>
</tr>
<tr>
<td>Type of Compound</td>
<td>Molecular</td>
<td>Molecular</td>
<td>Mostly ionic</td>
<td>Ionic</td>
</tr>
<tr>
<td>Melting Point</td>
<td>Usually low</td>
<td>~188 °C</td>
<td>Usually high</td>
<td>801 °C</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>Usually low</td>
<td>~42 °C</td>
<td>Usually high</td>
<td>1413 °C</td>
</tr>
<tr>
<td>Flammability</td>
<td>High</td>
<td>Burns in air</td>
<td>Low</td>
<td>Does not burn</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>Not usually soluble</td>
<td>No</td>
<td>Most are soluble</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Molecules of Life

<table>
<thead>
<tr>
<th>Type of Molecule</th>
<th>Subgroups</th>
<th>Examples and Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>Monosaccharides</td>
<td>Glucose: Energy source</td>
</tr>
<tr>
<td></td>
<td>Disaccharides</td>
<td>Sucrose: Energy source</td>
</tr>
<tr>
<td></td>
<td>Polysaccharides</td>
<td>Glycogen: Storage form of glucose</td>
</tr>
<tr>
<td></td>
<td>Starch: Carbohydrate storage in plants; used by animals in nutrition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cellulose: Plant cell walls, structure, fiber in animal digestion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chitin: External skeleton of arthropods</td>
<td></td>
</tr>
<tr>
<td>Lipids</td>
<td>Triglycerides</td>
<td>Fats, Oils (butter, corn oil): Food, energy, storage, insulation</td>
</tr>
<tr>
<td></td>
<td>Fatty acids</td>
<td>Stearic Acid: Food, energy sources</td>
</tr>
<tr>
<td></td>
<td>Components of Triglycerides</td>
<td>Cholesterol: Fat digestion, hormone precursor, cell membrane component</td>
</tr>
<tr>
<td></td>
<td>Steroids</td>
<td>Cell membrane structure</td>
</tr>
<tr>
<td></td>
<td>Phospholipids</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polypeptide tail</td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td>Enzymes</td>
<td>Sucrase: Breaks down sugar</td>
</tr>
<tr>
<td></td>
<td>Chemically active</td>
<td>Keratin: Hair</td>
</tr>
<tr>
<td></td>
<td>Structural</td>
<td>HDLs, LDLs: Transport of lipids</td>
</tr>
<tr>
<td></td>
<td>Lipoproteins</td>
<td>Cell surface receptors</td>
</tr>
<tr>
<td></td>
<td>Protein-lipid molecule</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glycoproteins</td>
<td>DNA contains information for the production of proteins</td>
</tr>
<tr>
<td></td>
<td>Protein-sugar molecule</td>
<td>One variety of RNA carries DNA’s information to the site of protein production, the ribosomes; another variety of RNA helps make up ribosomes</td>
</tr>
</tbody>
</table>
Monomers and Polymers

Biological molecules are made by monomers bonding to form polymers

- **Monomers**
  - Molecules that are building blocks for larger molecules
  - Simple sugars, amino acids, nucleotides

- **Polymers**
  - Molecules that consist of multiple monomers
  - Carbohydrates, proteins, nucleic acids
  - Polymers are made by dehydration synthesis (removal of water)
  - Polymers are broken apart by hydrolysis (addition of water).

Carbohydrates

- Carbohydrates are formed from the building blocks or monomers of simple sugars, such as glucose.

- Some simple sugars have the same chemical formula but are arranged differently, such as glucose and fructose. These are called isomers.

- These monomers can be linked to form larger polymers, which are known as disaccharides or polysaccharides (complex carbohydrates).

Carbohydrates - Disaccharides

Disaccharides are two simple sugars bonded together. Some examples include:

- **Sucrose** = glucose + fructose
  - Table sugar

- **Lactose** = glucose + galactose
  - Milk sugar

- **Maltose** = glucose + glucose
  - Found in germinating grains, malt products
Carbohydrates - Polysaccharides

Polysaccharides are made up of many monomers joined together.

Four polysaccharides are critical in the living world:
- **Starch**
  - nutrient storage form of carbohydrates in plants
- **Glycogen**
  - nutrient storage form of carbohydrates in animals
- **Cellulose**
  - rigid, structural carbohydrate found in the cell walls of many organisms
- **Chitin**
  - tough carbohydrate that forms external skeleton of arthropods.

Lipids

- The defining characteristic of all lipids is that they do not readily dissolve in water.
- Lipids do not possess the monomers-to-polymers structure seen in other biological molecules; no one structural element is common to all lipids.

- **Lipids**
  - Triglycerides
  - Steroids
  - Phospholipids
  - Waxes

- **Lipids are used for**
  - Storing energy
  - Insulating and cushioning
  - Hormones - steroids
  - Waterproofing
  - Cell membranes

Lipids - triglycerides

- Among the most important lipids are the triglycerides, composed of a glyceride and three fatty acids.
- Most of the fats that human beings consume are triglycerides.
- Saturated fats are triglyceride molecules that have only single bonds.
- Unsaturated fats are triglyceride molecules that have at least one double bond. The two types of unsaturated fats are:
  - Cis fat - naturally occurring configuration of double bond
  - Trans fat - artificially created configuration of double bond
- Hydrogenated fats are artificially created saturated fats made from cis fats.
Lipids - steroids

- Another important variety of lipids is the steroids, all of which have a core of four carbon rings with various functional groups attached.
- Examples include cholesterol and such hormones as testosterone and estrogen.

Lipids - phospholipids

- A third class of lipids is the phospholipids, each of which is composed of two fatty acids, glycerol, and a phosphate group.
- The phosphate end is polar and attracts water. The fatty acid end is nonpolar and repels water.
- The material forming the outer membrane of cells is largely composed of phospholipids.

Lipids - waxes

- A fourth class of lipids is the waxes, each of which is composed of a single fatty acid linked to a long-chain alcohol.
- Waxes have an important “sealing” function in the living world.
- Almost all plant surfaces exposed to air, for example, have a protective covering made largely of wax.

Proteins

- Proteins are an extremely diverse group of biological molecules composed of the monomers called amino acids.
- Sequences of amino acids are strung together to produce polypeptide chains, which then fold up into working proteins.
- Important groups of proteins include enzymes, which hasten chemical reactions, and structural proteins, which make up such structures as hair.
Types of Proteins

<table>
<thead>
<tr>
<th>Type</th>
<th>Role</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enzymes</td>
<td>Quicken chemical reactions</td>
<td>Sucrase: Positions sucrose (table sugar) in such a way that it can be broken down into component parts of glucose and fructose</td>
</tr>
<tr>
<td>Hormones</td>
<td>Chemical messengers</td>
<td>Growth hormone: Stimulates growth of bones</td>
</tr>
<tr>
<td>Transport</td>
<td>Move other molecules</td>
<td>Hemoglobin: Transports oxygen through blood</td>
</tr>
<tr>
<td>Contractile</td>
<td>Movement</td>
<td>Myosin and actin: Allow muscles to contract</td>
</tr>
<tr>
<td>Protective</td>
<td>Healing; defense against invaders</td>
<td>Fibrinogen: Stops bleeding Antibodies: Kill bacterial invaders</td>
</tr>
<tr>
<td>Structural</td>
<td>Mechanical support</td>
<td>Keratin: Hair; Collagen: Cartilage</td>
</tr>
<tr>
<td>Storage</td>
<td>Stores nutrients</td>
<td>Ovalbumin: Egg white, used as nutrient for embryos</td>
</tr>
<tr>
<td>Toxins</td>
<td>Defense, predation</td>
<td>Bacterial diphtheria toxin</td>
</tr>
<tr>
<td>Communication</td>
<td>Cell signaling</td>
<td>Glycoprotein: Receptors on cell surface</td>
</tr>
</tbody>
</table>

Proteins - Amino Acids

Amino acids:
- are the building blocks of proteins.
- contain a carboxylic acid group and an amino group on the alpha (α) carbon.
- contain a side chain of atoms (R)
- are ionized in solution

The 20 amino acids are classified into four categories based on their side chains (R-groups).

<table>
<thead>
<tr>
<th>Type of Amino Acid</th>
<th>Type of R Groups</th>
<th>Polarity</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonpolar</td>
<td>Nonpolar</td>
<td>Nonpolar</td>
<td>Hydrophobic</td>
</tr>
<tr>
<td>Polar, neutral</td>
<td>Contain O and S atoms, but no charge</td>
<td>Polar</td>
<td>Hydrophilic</td>
</tr>
<tr>
<td>Polar, acidic</td>
<td>Contain carboxyl groups, negative charge</td>
<td>Polar</td>
<td>Hydrophilic</td>
</tr>
<tr>
<td>Polar, basic</td>
<td>Contain amino groups, positive charge</td>
<td>Polar</td>
<td>Hydrophilic</td>
</tr>
</tbody>
</table>

Proteins - The 20 Amino acids

- Glycine (Gly)
- Alanine (Ala)
- Valine (Val)
- Leucine (Leu)
- Isoleucine (Ile)
- Methionine (Met)
- Tyrosine (Tyr)
- Phenylalanine (Phe)
- Proline (Pro)
- Serine (Ser)
- Threonine (Thr)
- Cysteine (Cys)
- Tryptophan (Trp)
- Asparagine (Asn)
- Aspartic Acid (Asp)
- Glutamic Acid (Glu)
- Lysine (Lys)
- Arginine (Arg)
- Histidine (His)
Proteins - The Beginning of a Protein

The linkage of several amino acids...

- Ala
- Leu
- Ser
- Glu
- His
- Ala
- Glu
- Asp
- Ser
- Tyr
- Ala
- Ser
- Glu
- Glu

... produces a polypeptide chain like this:

Lipoproteins & Glycoproteins

Lipoproteins
- Lipoproteins are biological molecules that are combinations of lipids and proteins.
- High-density and low-density lipoproteins (HDLs and LDLs, respectively), which transport cholesterol in human beings, are important determinants of human heart disease.

Glycoproteins
- Glycoproteins are combinations of carbohydrates and proteins.
- The signal-receiving receptors found on cell surfaces often are glycoproteins.

Nucleic Acids

Nucleic acids are polymers composed of nucleotides.

Nucleic acids are composed of nucleotides that contain a sugar, a phosphate group, and one of five nitrogen-containing bases.

There are two types of nucleic acids:
- DNA, deoxyribonucleic acid
  - DNA is the repository of genetic information
  - The sequences of bases in DNA encodes the information necessary for production of proteins in living things.
- RNA, ribonucleic acid
  - RNA transports the information encoded in DNA to the sites of protein synthesis.
Nucleic Acids - Nucleotides

Nucleotides consist of:

- A pentose sugar
  - Deoxyribose for DNA
  - Ribose for RNA
- A phosphate group
- A nitrogenous base, either a pyrimidine or a purine

The pyrimidines include:
- Cytosine (C) and Thymine (T) for DNA
- Cytosine (C) and Uracil (U) for RNA

The purines include:
- Adenine (A) and Guanine (G)

When Nucleic Acids hydrogen bond to each other they always pair up C to G, and A to T in DNA. For RNA, they pair up C to G and A to U.