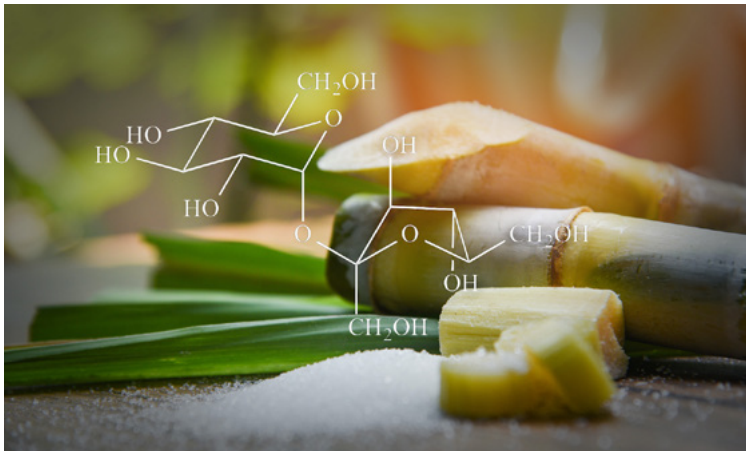
Chapter 2

The Chemistry of Life



Summary of Terms

- **Acid** A chemical that donates hydrogen ions to other chemicals.
- **Atom** An incredibly small fundamental unit of matter consisting of subatomic particles, such as electrons, protons, and neutrons.
- **Atomic nucleus** The dense, positively charged center of an atom.
- **Atomic Number** The number of protons in the nucleus of the atoms of an element.
- **Atomic symbol** An abbreviation for an element or atom.
- **Base** A chemical that accepts hydrogen ions from other chemicals.
- **Carbohydrate** Organic molecules containing only carbon, hydrogen and oxygen including simple sugars and chains of sugars.
- **Catalyst** Any substance that increases the rate of a chemical reaction without itself being consumed by the reaction.
- **Chemical compound** A material in which atoms of different elements are bonded to one another.
- **Chemical formula** A notation that indicates the composition of a compound, consisting of the atomic symbols for the different elements of the compound and numerical subscripts indicating the ratio in which the atoms combine.
- **Chemical reaction** The transformation of one or more chemicals into different chemicals by a rearrangement of atoms.
- **Covalent compound** A substance, such as an element or chemical compound, in which atoms are held together by covalent bonds.
- **Dissolving** The process of mixing a solute in a solvent to produce a homogeneous mixture.

- **Electron** An extremely small, negatively charged subatomic particle found in a cloud outside the atomic nucleus.
- **Element** Any material that is made up of only one type of atom.
- **Elemental formula** The chemical symbol of an element followed by a numeral subscript indicating the number of atoms in each molecule of the element.
- **Endothermic** Description of a chemical reaction in which there is a net absorption of energy.
- **Exothermic** Description of a chemical reaction in which there is a net release of energy.
- **Hydronium ion** A polyatomic ion made by adding a proton (hydrogen ion) to a water molecule.
- **Hydroxide ion** A polyatomic ion made by removing a proton (hydrogen ion) from a water molecule.
- **Ion** An atom having a net electric charge because of either a loss or gain of electrons.
- **Ionic bond** A chemical bond in which there is an electric force of attraction between two oppositely charged ions.
- **Lipid** Hydrophobic organic molecules, many of which include fatty acids as a primary component.
- **Mixture** A combination of two or more substances in which each substance retains its chemical properties.
- **Molecule** A group of atoms held tightly together by chemical bonds.
- **Neutron** A subatomic particle with no electric charge found within the atomic nucleus.
- **Nucleic acid** Organic molecules that are composed of chains of nucleotides and store genetic information.
- **Organic chemistry** The study of carbon-containing compounds.
- **Oxidation** The process whereby a reactant loses one or more electrons.
- **Periodic table** A chart in which all known elements are listed.
- **pH** A measure of the acidity of a solution related to the hydronium-ion concentration.
- **Polar** Description of a chemical bond or molecule that has a dipole. In a polar bond or molecule, electrons are congregated to one side. This makes that side slightly negative, while the opposite side (lacking electrons) becomes slightly positive.
- **Protein** Organic molecules composed of folded chains of amino acids.
- **Proton** A subatomic particle with a +1 electric charge and found in the nucleus of any atom.
- **Pure** The state of a material that consists solely of a single element or compound.

- **Reaction rate** A measure of how quickly the concentration of products in a chemical reaction increases or the concentration of reactants decreases.
- **Reduction** The process whereby a reactant gains one or more electrons.
- **Solute** Any component in a solution that is not the solvent.
- **Solution** A homogeneous mixture in which all components are dissolved in the same phase.
- **Solvent** The component in a solution that is present in the largest amount.
- **Suspension** A homogeneous mixture in which the various components are finely mixed, but not dissolved.

Detailed Chapter Summary

The study of atoms and molecules is **chemistry**. This chapter is a review of the basic chemistry concepts underlying biology, which is the study of life.

Atoms are a fundamental building block of matter. Atoms are incredibly small—smaller than the wavelengths of visible light. Atoms themselves are made of even smaller subatomic particles, which includes the central **atomic nucleus** surrounding by a cloud of tiny **electrons**. While the atomic nucleus is positively charged, electrons are negatively charged. Atoms can bind together to form a **molecule**. Thus, molecules are made of atoms. A material made of only one type of atom is called an **element**. The **periodic table** shows a listing of all known elements. Each element is represented by its **atomic symbol**.

Different types of atoms can join together to form a **chemical compound**, such as sodium chloride, NaCl, or ammonia, NH_3. A chemical compound is represented by its **chemical formula**, which shows the atomic symbols for the elements that combine to make that compound. A chemical compound is uniquely different from the elements used to make that compound.

Atoms can become attached to adjacent atoms by what is known as a **chemical bond**. The **ionic bond** is the attraction between oppositely charged ions. An **ion** is an atom that has either lost or gained electrons. Atoms of elements to the lower left of the periodic table tend to lose electrons while atoms to the upper right tend to gain electrons. Thus, ionic bonds tend to occur between atoms found on opposite sides of the periodic table. An example is sodium chloride, NaCl, which is common table salt. In a **covalent bond**, atoms are held together by the attraction they have for electrons they share. Atoms to the upper right side of the periodic table are the ones that tend to form covalent bonds, and they do so primarily with other atoms of the upper right side of the periodic table. An example is carbon dioxide, CO_2.

Within a covalent bond, the electrons might not be shared evenly because one of the two atoms has a greater affinity for the electrons. This results in a situation where one side of the covalent bond becomes slight negative in charge, while the opposite side becomes slightly positive. Such a covalent bond is described as a **polar** covalent bond. A water molecule has two polar covalent bonds that make the oxygen side of a water molecule slightly negative and the hydrogen sides slightly positive. This makes a water

molecule electrically "sticky". In other words, it's easy for two water molecules to stick to each other and this explains why water has such a high boiling point. It also explains how ionic materials such as salt readily dissolve in water.

A **pure** substance is made of only one material. A **mixture** is a collection of two or more pure substances. A **solution** is an example of a mixture where all the components are in the same phase, such as a liquid, gas, or solid. A **suspension** is when the mixture consists of different phases. A cloud is an example of a suspension (liquid water droplets suspended in the air), as is blood (solid blood cells suspended in the blood plasma). In describing solutions, the component present in the largest amount is the **solvent**, and any other components are **solutes**.

In a **chemical reaction**, atoms change partners to form new materials. A chemical reaction that results in the net release of energy is **exothermic**. One that has a net absorption of energy is **endothermic**. How fast a chemical reaction occurs is described by its **reaction rate**. The faster the rate, the more quickly products are formed. Warmer temperatures tend to favor faster reactions, as do **catalysts**.

Two types of chemical reactions are acid-base reactions and oxidation-reduction reactions. An **acid-base** reaction involves the transfer of a hydrogen ion from one reactant to the other. An **oxidation-reduction** reaction involves the transfer of an electron. The pH of a solution is a measure of its concentration of **hydronium ions**, H_3O^+. The lower the pH, the greater this concentration, and the greater the acidity (H_3O^+ is a very strong acid made from water). The pH of the solution can determine whether an atom, such as nitrogen or oxygen, is ionized. Relative to biomolecules, this can have a major effect on the overall shape of the biomolecule, which profoundly impacts the functioning of that biomolecule.

A well-known behavior of oxygen atoms is that they like to attract electrons. Recall that this is why water is a polar molecule. It also explains how oxygen can cause other atoms or molecules to lose their electrons, a process called **oxidation**. These sorts of reactions tend to be exothermic. We see this in the burning of a campfire and in the breakdown of the food molecules we eat.

Carbon is unique in its ability to form repeated bonds with other carbon atoms as well as bonds to non-carbon atoms, such as hydrogen, nitrogen, and oxygen. The study of carbon-containing compounds is a special field known as **organic chemistry**.

There are four basic large organic molecules used by living things. These are **proteins**, **carbohydrates**, **lipids**, and **nucleic acids**. Proteins are folded chains of smaller units called amino acids. Proteins play a wide range of functions in living things. For example, they provide structure, such as in skin and hair, act as hormones that allow communication between body cells, allow for muscle contraction, transport oxygen to body tissues, break down food during digestion, and protect the body from disease. Carbohydrates store energy in organisms -- sugars such as glucose and fructose are examples. Lipids include fats and oils and are also used to store energy. Some carbohydrates and lipids play structural roles as well. Nucleic acids, such as DNA and RNA, store genetic material. DNA is made up of four different nucleotides -- adenine, cytosine, guanine, and thymine.