# Chemistry Basics

An Introduction to the
Various Areas of Chemistry

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# Course Goal

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The overall goal of this course are to enable you understand the differences between the various areas of chemistry and some basics in each of those areas.

The four areas include:

- Inorganic
- Nuclear
- Organic
- Biochemistry

# Course Contents

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**Section 1** will introduce you to some of the basics of Inorganic Chemistry.

**Section 3** will introduce you to Organiic Chemistry, the chemistry of Carbon.

Section 1 → Section 2 → Section 3 → Section 4

**Section 2** will show you some basics in the area of Nuclear Chemistry.

**Section 4** provides an introduction to Biochemistry with a focus on Carbohydrates, Lipids, and Proteins.


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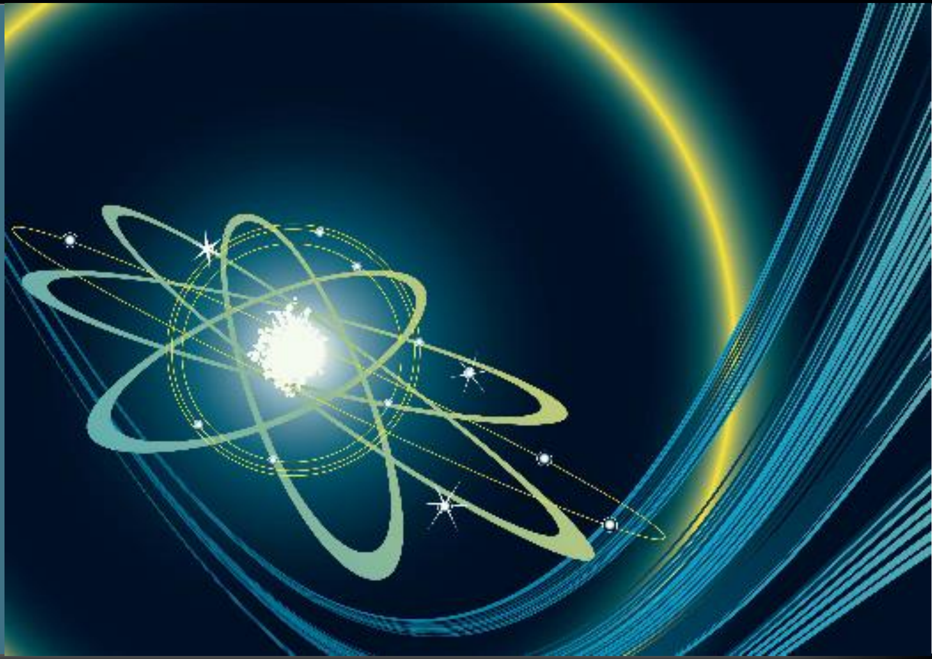
# Section 1

## Inorganic Chemistry



# Section One Objectives



## Section 1

In this section, you will learn about:

- Inorganic Chemistry
- Units of Measurement
- Metric Prefixes
- Scientific Calculations
- Density
- Elements and the Periodic Table
- Parts of the Atom
- Compounds

# What is Inorganic Chemistry?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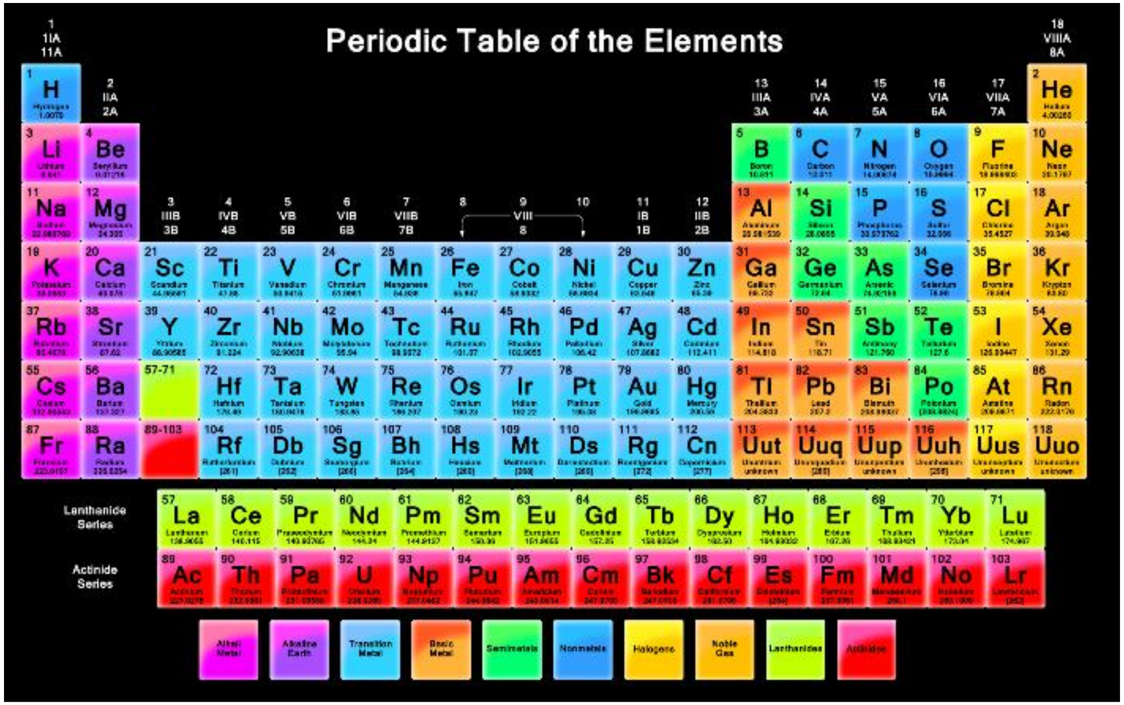
**Inorganic chemistry** is the study of the synthesis and behavior of inorganic and organo-metallic compounds.

This field covers all chemical compounds except the myriad organic compounds (carbon based compounds, usually containing C-H bonds), which are the subjects of organic chemistry.




# Measurements

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**Measurements** are an important part of many of the jobs we do today. Measurements are particularily important in the health sciences.

The **metric system** is the system of measurement that is used by scientists and health professionals throughout the world. Many clinical evaluations are recorded using the metric system.

In 1960, the International System of Units (SI), a modification of the metric system, was adopted to provide additional uniformity.

# Length

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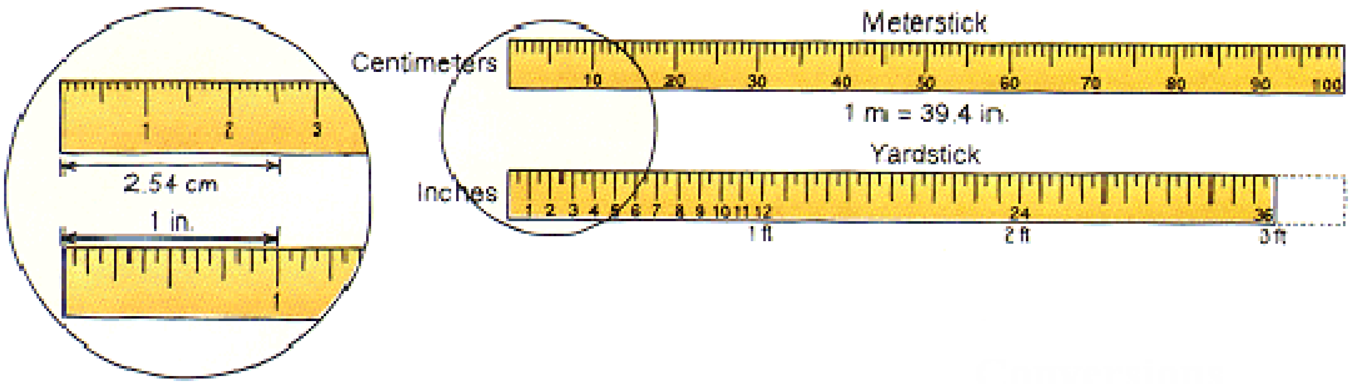
The unit of measure for **length** is the **meter** (m) in both the metric system and the SI.




**Conversions**

**1 m = 39.4 in.**

**2.54 cm = 1 in.**

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# Volume

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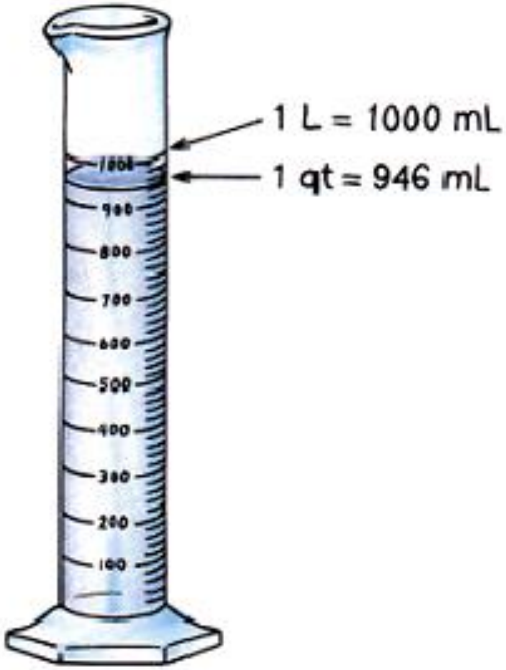
The metric unit **liter** (L) is commonly used to measure volume. The **milliliter** (mL) is a more convenient unit for measuring smaller volumes of fluids in hospitals and laboratories.

The **graduated cylinder** is a device used to measure volumes of liquids.

**Conversions**

1 L = 1.06 qt

946 mL = 1 qt

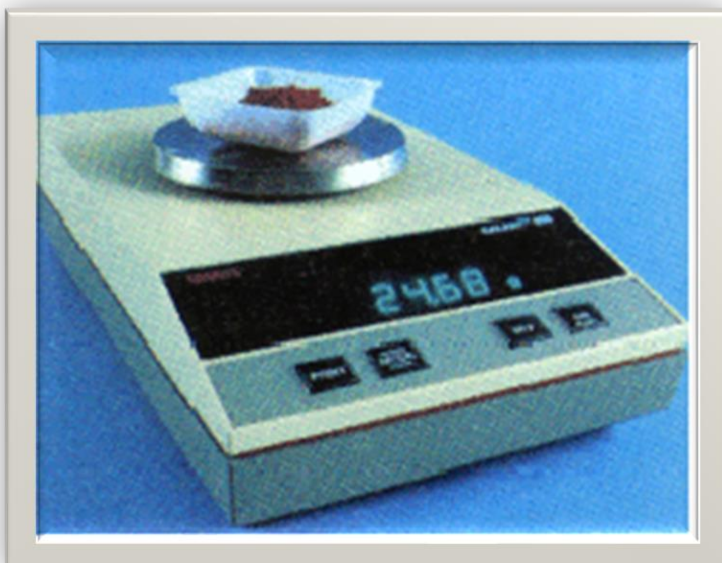




# Mass

**Mass** is a measure of the amount of material a substance contains. The metric unit of measure for mass is grams. The SI unit for mass is the **kilograms** (kg).

The **electronic balance** is used to measure mass of a substance in the chemistry laboratory.



**Conversions**

| |
|---|
| 1 kg = 2.20 lb |
| 454 g = 1 lb |

# Temperature



The temperature of an object tells us how hot or cold an object is. In the U.S., we commonly use the **Fahrenheit** scale.

The **Celsius** (C) scale is used to measure temperature in the metric system.

The **Kelvin** temperature scale is used in the SI system.

| System | Boiling Point of Water | Freezing Point of Water |
|---|---|---|
| U.S. | 212 °F | 32 °F |
| Metric | 100 °C | 0 °C |
| SI | 273 K | 0 K |

# Metric Prefixes



A special feature of the metric system of units is that you can attach a prefix to any physical quantity to increase or decrease its size by some factor of 10. This makes the conversion from one quantity to another a very easy process. Often, all you need to do is move the decimal place. The prefix values may also be expressed in scientific notation using powers of 10.

The relationship of a unit to its base unit can be expressed by replacing the prefix with its numerical value.

1 **kilo**meter (1km) = **1000** meters (1000 m)
1 **kilo**liter (1 kL) = **1000** liters (1000 L)
1 **kilo**gram (1kg) = **1000** grams (1000 g)

# Commonly Used Prefixes

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The table here shows some of the commonly used prefixes and their values.

| Prefixes that Increase the Size of a Unit | | | Prefixes that Decrease the Size of a Unit | | |
|---|---|---|---|---|---|
| Prefix | Symbol | Value | Prefix | Symbol | Value |
| mega | M | one million | deci | d | one-tenth |
| kilo | k | one thousand | centi | c | one-hundredth |
| hecto | h | one hundred | milli | m | one-thousandth |
| deka | da | ten times | micro | µ | one-millionth |

# Measuring Length

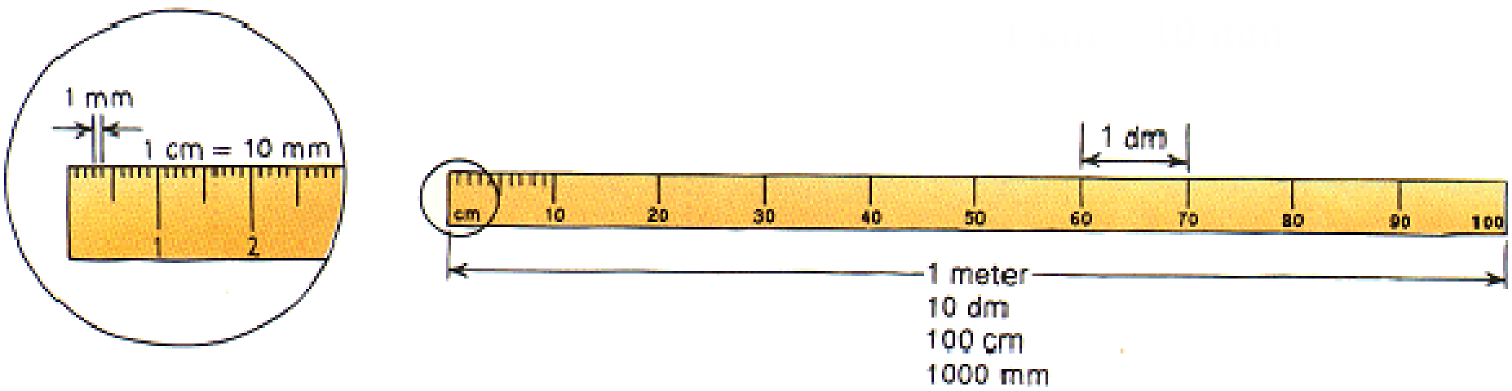


When the prefix **centi** is used with the unit meter, it indicates the unit centimeter. Thus the centimeter is 1/100 of a meter. The equality would be:

1 cm = 1/100 m

Rearranging this equality gives the expression:

100 cm = 1 m

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# Measuring Volume



Volumes of 1 L or smaller are common in health sciences. Laboratory results for blood work are often expressed in dL while the volume of syringes is expressed as cc, a relationship that is similar to the **mL**.

The cubic centimeter (cm3 or cc) is the volume of a cube whose dimensions are 1 cm on each side. A **cc** has the same volume as a **mL**.

A valuable expression:

$$1 \text{ mL} = 1 \text{ cc} = 1 \text{ cm}^3$$

# Measuring Mass



Your body mass is expressed as **kg** whereas the results of laboratory tests are reported in **grams**, **milligrams**, or **micrograms**. Medications (dosages) are often given in milligrams.

**Mass Equalities**

1 kg = 1000 g
1 g = 1000 mg
1 mg = 1000 µg

# Scientific Calculations



There are four basic steps in solving a problem:

1. Identify the given quantity and unit.

2. Write down a unit plan to help you think about changing from the given unit to the answer unit. Be sure you can supply a conversion factor for each change.

3. Determine the equalities and corresponding conversion factors you will need to change from one unit to another.

4. Set up the problem according to your unit plan. Arrange each conversion factor to cancel the preceding unit. Check that the units cancel to give the unit of the answer. Carry out the calculations and give a final answer with the correct number of significant figures and unit.

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# A Sample Calculation




**SAMPLE PROBLEM** **2.00 in. is equal to how many cm?**

**Step 1**

Write down what is given. In this case it is 2.00 in.

**Step 2**

Decide on a unit plan:

**in.** **to** **cm**
**(given)** **(desired)**

**Step 3**

Use the information given or some known equality to come up with two conversion factors.

$$\frac{2.54\ \text{cm}}{1\ \text{in.}} \quad \text{or} \quad \frac{1\ \text{in.}}{2.54\ \text{cm}}$$

**Step 4**

Set up the problem using this information.

$$2.00\ \cancel{\text{in}} \times \frac{2.54\ \text{cm}}{1\ \cancel{\text{in}}.} = 5.08\ \text{cm}$$

Convert this to a Steps Interaction in Storyline.

# Density



**Density** is the comparison of the mass of a substance to the volume of the substance at a given temperature.

The usual units are:

g/cm3 (grams per cubic centimeter) or g/mL

**Formula for Density**

$$\text{Density} = \frac{\text{mass of substance}}{\text{volume of substance}}$$

# Sink or Float?

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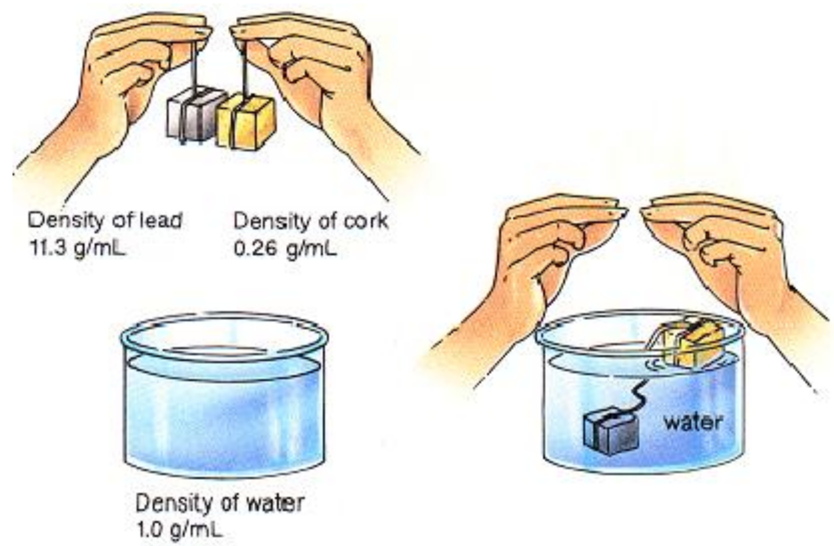
Substances with lesser densities tend to float on top of substances with greater densities. Substances with greater densities tend to sink.

| Substance | Density (g/mL) |
|---|---|
| Water | 1.00 |
| Ethyl alcohol | 0.79 |
| Ice | 0.92 |
| Lead | 11.3 |
| Cork | 0.26 |



# A Sample Density Calculation



**Density** is a comparison of two units and can also be used as a conversion factor. For example, if you know the volume and density, you can calculate the mass. If you know the mass and density, you can calculate the volume.

A substance has a density of 1.8 g/cm 3. What is the mass of this substance if its volume is 12.0 cm 3 ?

$$12.0\ \text{c}\cancel{\text{m}}^3 \quad \times \quad \frac{1.8\ \text{g}}{1\ \text{c}\cancel{\text{m}}^3} \quad = \quad 21.6\ \text{g}$$

# Elements




**Elements** are the primary substances from which all other substances are built.

Elements cannot be broken down into simpler substances.

Many of the elements were named for planets, mythological figures, minerals, colors, geographic locations, and famous people.

# Chemical Symbols



**Chemical symbols** are abbreviations for the names of the elements. Most are formed from one or two letters of the name. The first letter is capitalized; a second letter, if there is one, is lowercase. Some (such as Na for sodium) are derived from the ancient Latin or Greek names.

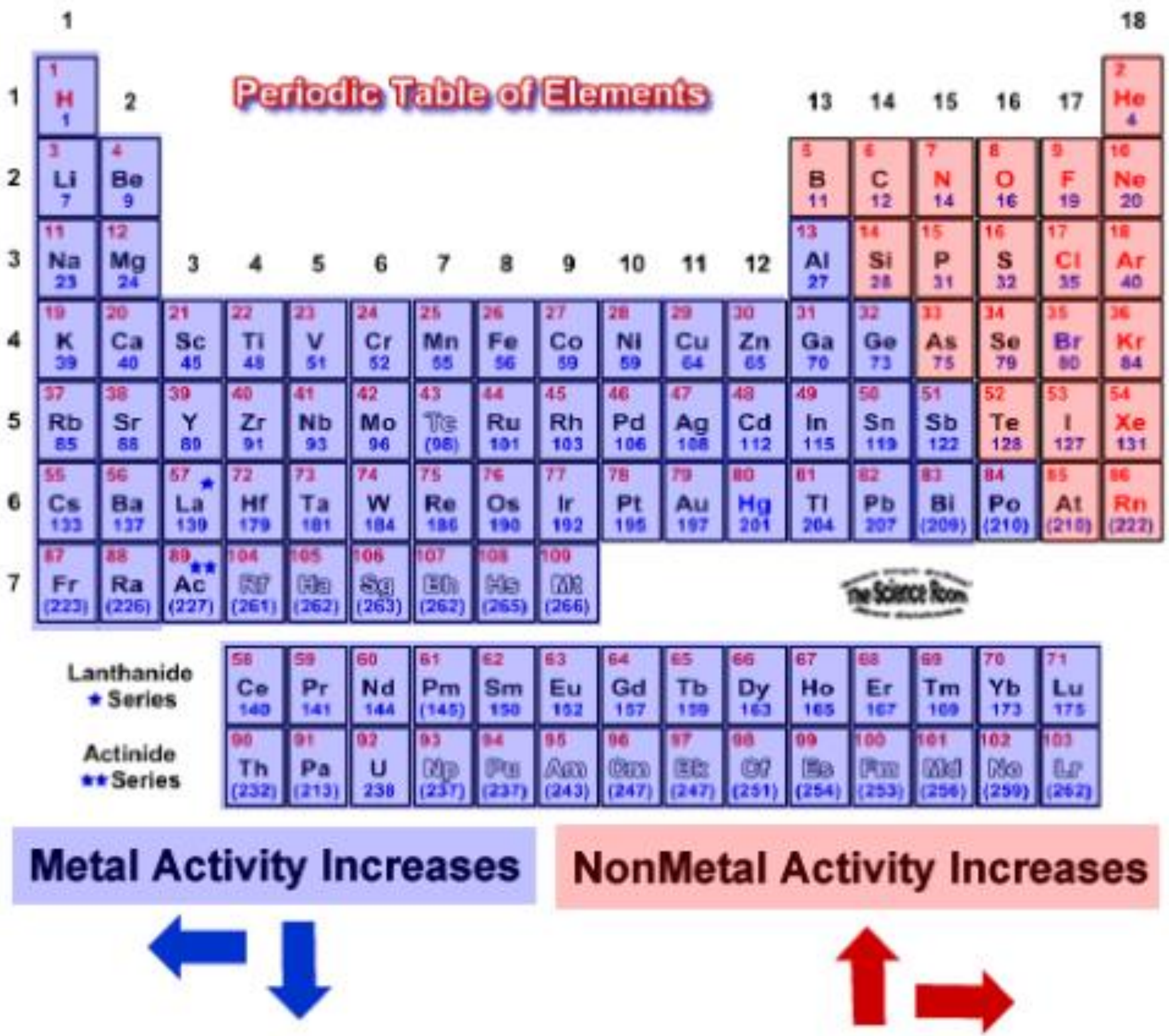
| Element Name | Element Symbol |
|---|---|
| Carbon | C |
| Sulfur | S |
| Nitrogen | N |
| Iodine | I |
| Cobalt | Co |
| Neon | Ne |
| Nickel | Ni |
| Sodium | Na |

# The Periodic Table



Mendeleev proposed that the elements could be arranged in groups that showed similar physical and chemical properties.

The **Periodic Table** arranges the elements by increasing atomic number in such a way that similar properties repeat at periodic intervals.



# Groups and Periods




A **group** is a vertical column of elements that have similar physical and chemical characteristics.

The elements are divided into **representative** elements and **transition** elements.

The groups of representative elements are identified by numbers (1-8) that go across the top of the periodic table. A group is also known as a family.

A single horizontal row in the periodic table is called a **period**. Each row is counted from the top of the table down as Period 1, Period 2, Period 3, and so forth.

# Classification of Groups

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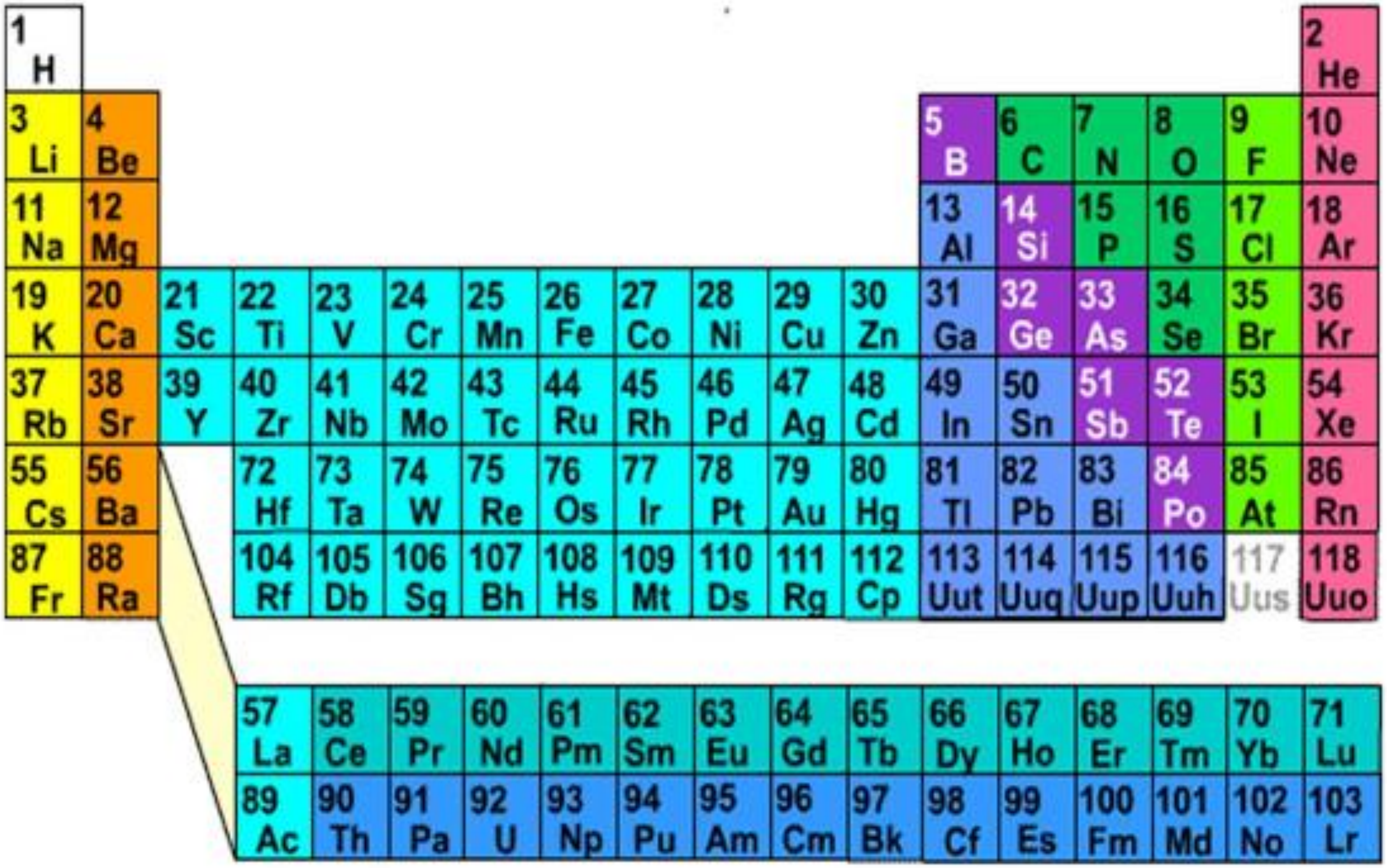
Several groups of elements have special names:

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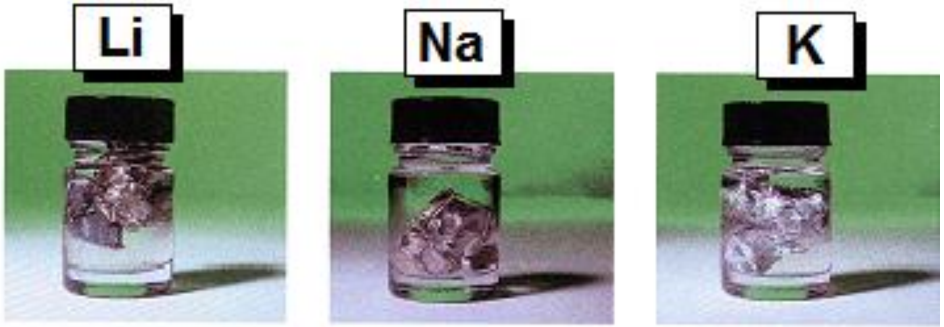
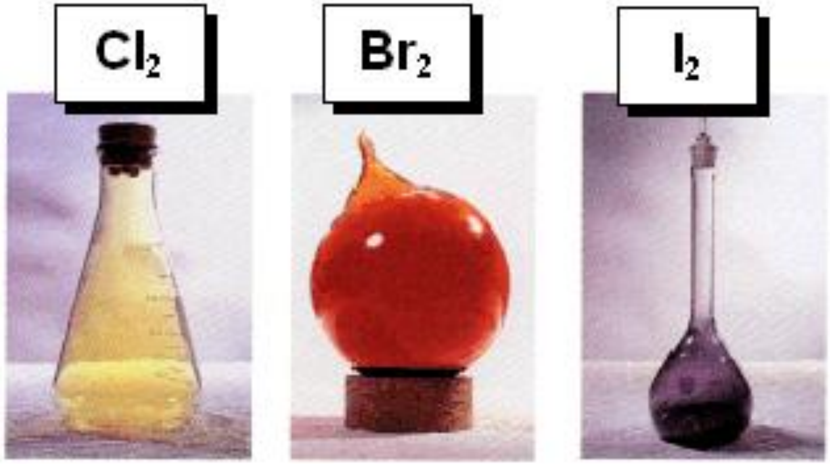
# Samples of Some Elements




Some alkali metals of Group 1.




Some halogens of Group 7 (exist as diatomic molecules).



# Metals vs. Non-Metals




In the periodic table, a heavy zigzag line separates the elements into metals and nonmetals.

The metals are those elements on the left of the line (except for hydrogen). The nonmetals are the elements on the right.

In general, most **metals** are shiny solids. They can be shaped into wires (ductile) or hammered into a flat sheet (malleable). Many metals are good conductors of electricity and heat. All of the metals (except Hg which is a liquid) are solids at room temperature.

**Nonmetals** are not very shiny, malleable, or ductile. They are often poor conductors of electricity. They typically have low melting points and low densities.

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# Metals vs. Non-Metals

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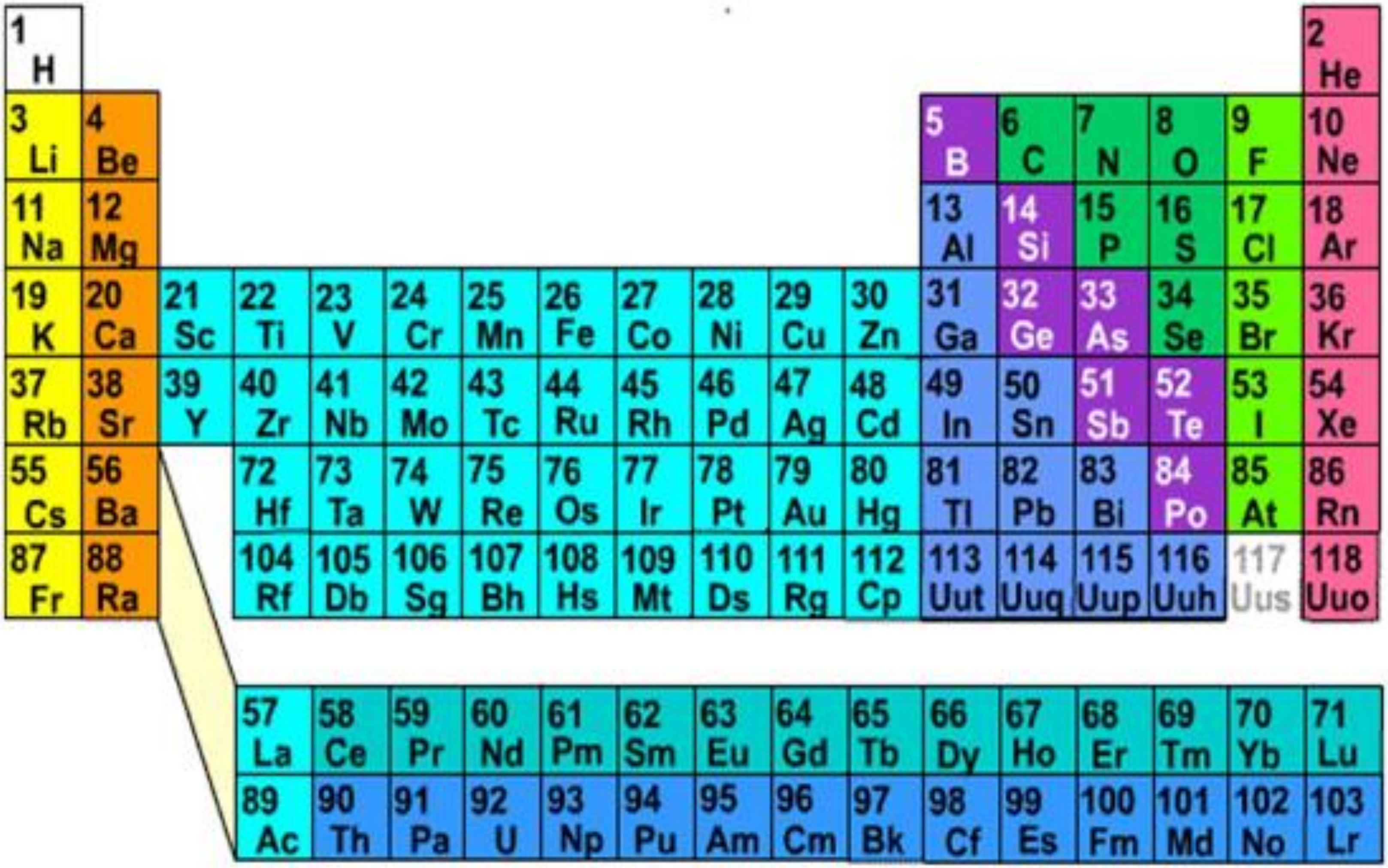

# The Atom




An **atom** is the smallest part of an element that still retains the characteristics of that element. The atomic theory of John Dalton helps us understand the atom.

**DALTON'S LAW OF ATOMIC THEORY**

1. Matter is made up of tiny particles called atoms.
2. Atoms of a given element are similar to one another and different from atoms of other elements.
3. Atoms of two or more different elements combine to form compounds. A particular compound is always made up of the same kinds of atoms and always has the same number of each kind of atom.
4. A chemical reaction involves the rearrangement, separation, or combination of atoms. Atoms are never created or destroyed during a chemical reaction.

# Parts of the Atom

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An atom is composed of small bits of matter called subatomic particles.

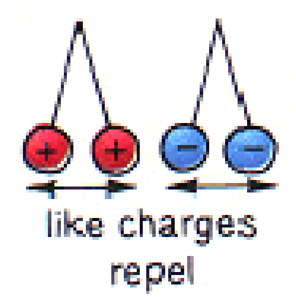
There are three subatomic particles of interest to us. Two of the subatomic particles carry electrical charges.

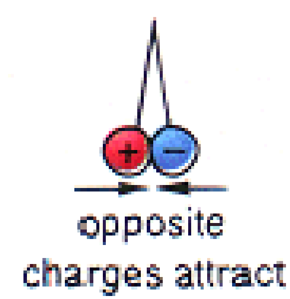
There are three subatomic particles of interest to us. Two of the subatomic particles carry electrical charges.

**Proton** -- carries a positive charge (+).

**Electron** -- carries a negative charge (-).

**Neutron** -- has no charge.



# Structure of the Atom

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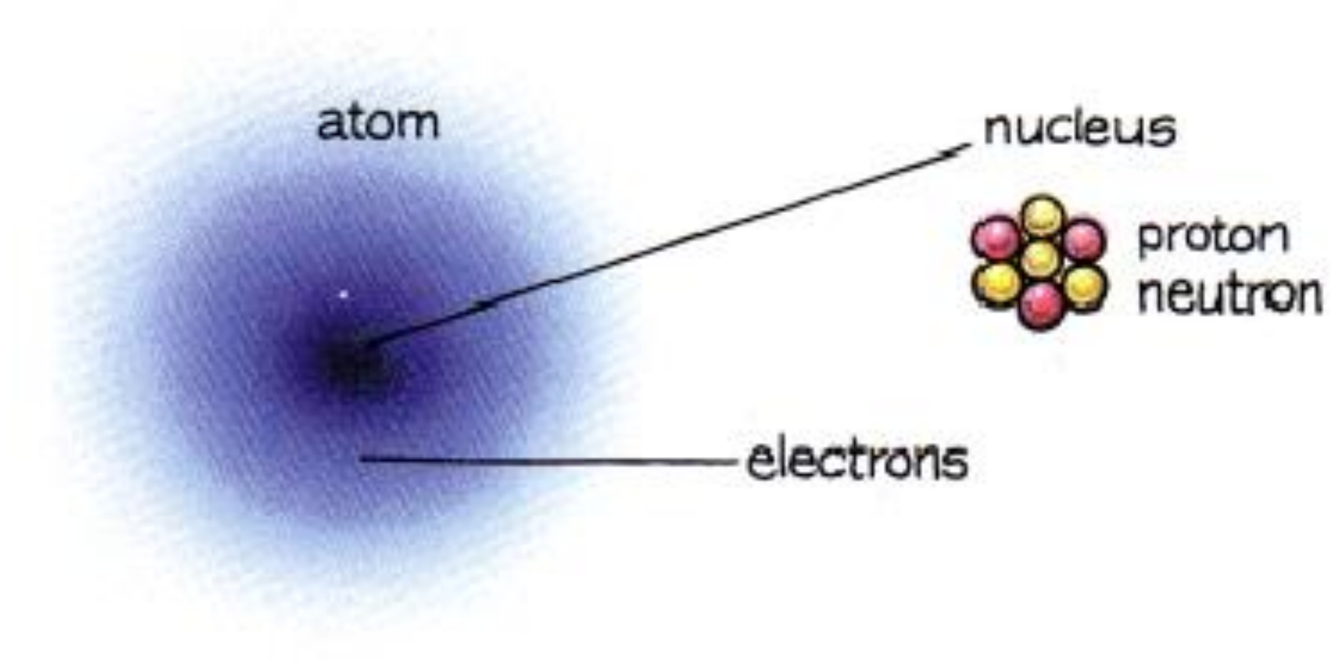
Rutherford discovered that most of the mass of the atom was contained in a small region at the center of the atom, the nucleus which contains protons and neutrons. The electrons are outside the nucleus.



# Atomic Number




The **atomic number**, which is equal to the number of protons in the nucleus of the atom, is used to identify each element.

Atoms of the same element have the same number of protons. This feature makes atoms of one element different from all other elements.

The atomic number is the number above the symbol of the element in the periodic table.

| 6 |
|---|
| C |

**Atomic number = number of protons in an atom**

# Atoms are Neutral

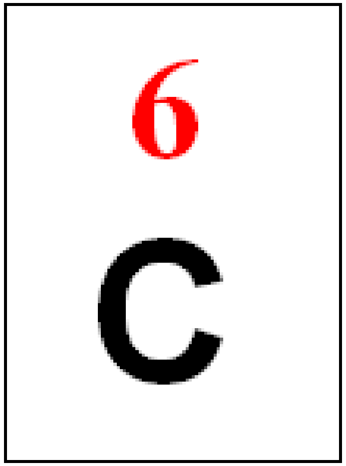


An atom is electrically neutral which means that the number of protons in the nucleus of an atom is equal to the number of electrons outside the nucleus.

This electrical balance gives the atom an overall charge of zero.

**Example**: A neutral atom of carbon has six protons and six electrons.

The atomic number is also equal to the number of electrons for a neutral atom.



# Mass Number

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The protons and neutrons in an atom compose most of the mass of an atom.

The **mass number** of an atom is equal to the number of protons plus the number of neutrons in the nucleus of the atom.

The mass number is always a whole number for an individual atom.

**Mass number = number of protons + number of neutrons**

# Some Common Elements



Here you see the composition of some common elements showing the number of protons, neutrons, and electrons of each.

| Symbol | Atomic Number | Mass Number | Protons | Electrons | Neutrons |
|---|---|---|---|---|---|
| H | 1 | 1 | 1 | 1 | 0 |
| He | 2 | 4 | 2 | 2 | 2 |
| S | 16 | 32 | 16 | 16 | 16 |
| Na | 11 | 23 | 11 | 11 | 12 |

# Isotopes



All atoms of the same element have the same number of protons.

Atoms of the same element are not completely identical because they can have different numbers of neutrons.

Isotopes are atoms of the same element that have different numbers of neutrons.

This means that some atoms of an element are heavier than other atoms of the same element.

In the diagrams of the two isotopes of Carbon, the top number is the **Atomic Mass** and the bottom number is the **Atomic Number**.

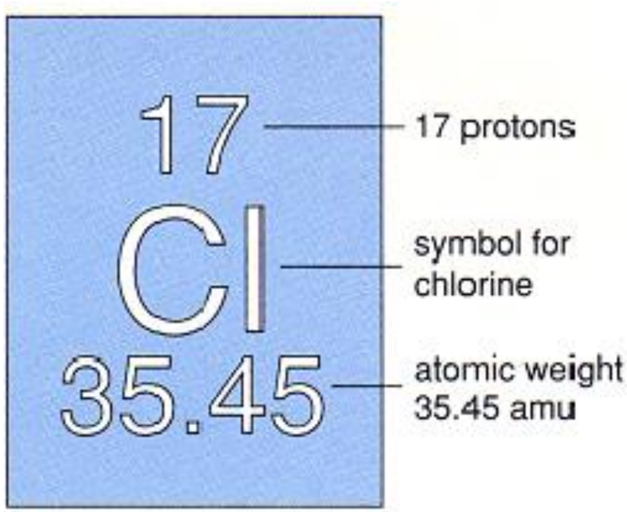
$$^{12}_{6}C \qquad ^{13}_{6}C$$

# Average Atomic Mass



To obtain a convenient mass to work with, chemists use the mass of an "average atom" of each element.

This average atom has an atomic mass, which is the weighted average mass of all of the naturally occurring isotopes of that element.




We obtain the average mass of the different isotopes of an atom to obtain the mass (atomic weight) value that we see in the periodic table. Thus values there seldom are whole numbers. These numbers are obtained by multiplying the percent abundance of each isotope by its weight. Chlorine has a value of 35.45 amu. This is the value below the symbol of each element in the periodic table.

# Models of Some Atoms

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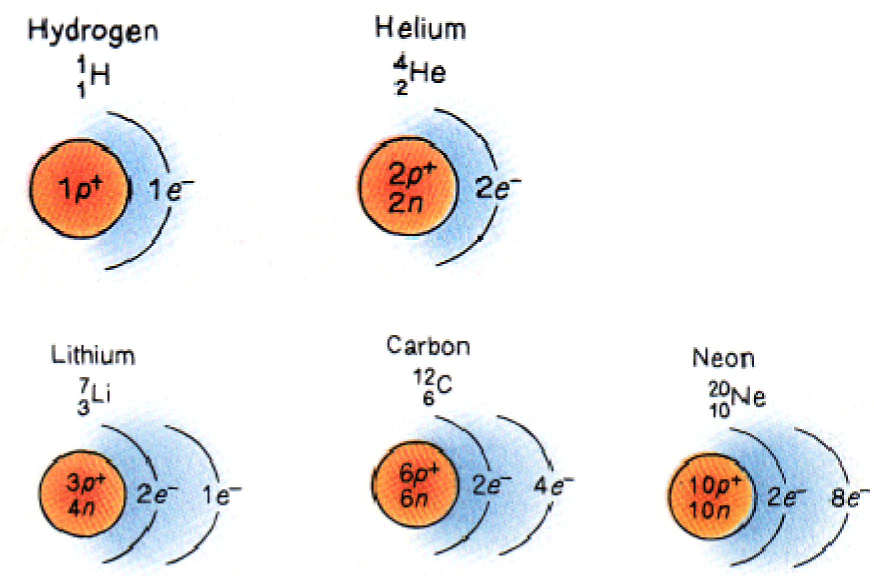
Click each button to view the model (structure of each atom).




Hydrogen contains 1 electron in the first shell.

Helium contains 2 electrons in the first shell.

Lithium contains 2 electrons in the first shell and 1 in the second shell.

Carbon contains 2 electrons in the first shell and 4 in the second shell.

Neon contains 2 electrons in the first shell and 8 in the second shell.

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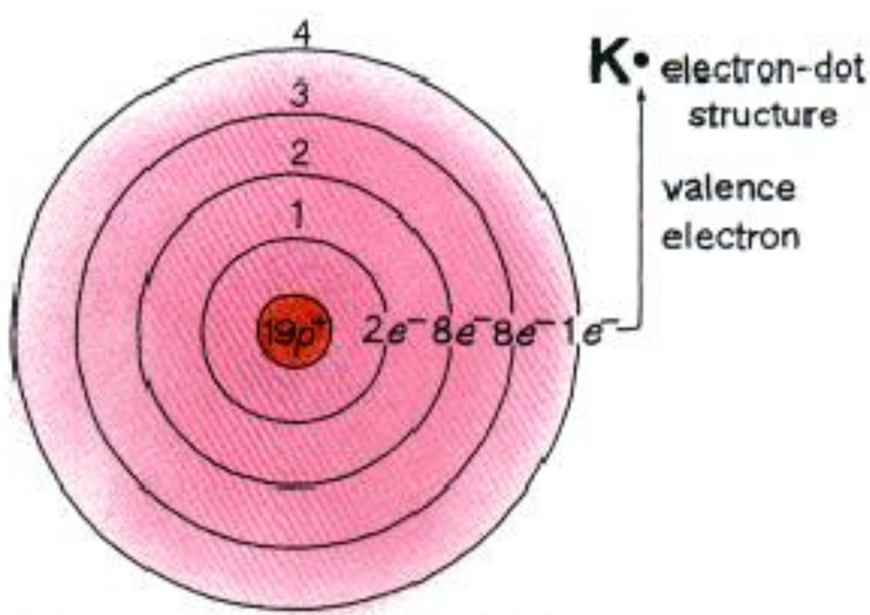
# Valence Electrons



The electron configuration for potassium is 2, 8, 8, 1. This means that the outermost energy level has 1 electron (the valence electron).

When writing an electron-dot structure, one dot representing the valence electron is placed next to the symbol for the element.




electron arrangement for potassium

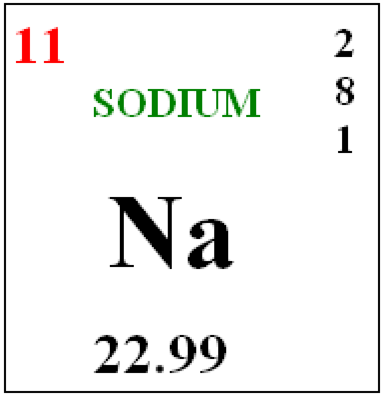


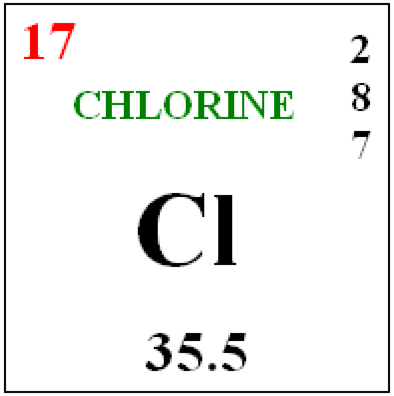

A **compound** is a combination of two or more elements. In the case of ionic compounds are neutral but the various parts are either positively charged or negatively charged.

Usually metals will lose electrons to form positive ions and non-metals gain electrons to form negative ions.

Here you see Na which has one valence electron and Cl which has 7.

**Na** will lose that one electron and **Cl** will gain it to form the compound that we know as **NaCl**, salt.



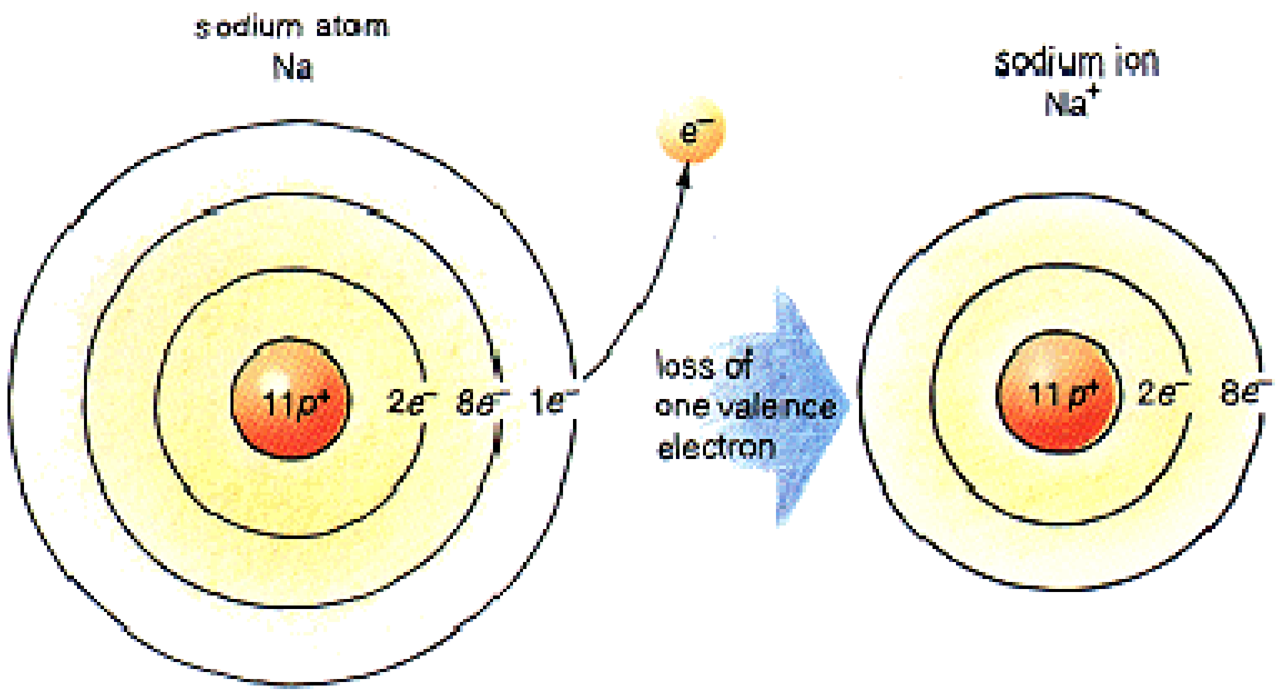



# Forming a Positive Ion



A neutral sodium atom has 11 protons and 11 electrons with one electron in its outermost energy level. In forming an ion, sodium loses the valence electron to attain a noble gas configuration. With 10 electrons (and 11 protons), the sodium ion has a 1+ charge.

$Na^+$



# Forming a Negative Ion

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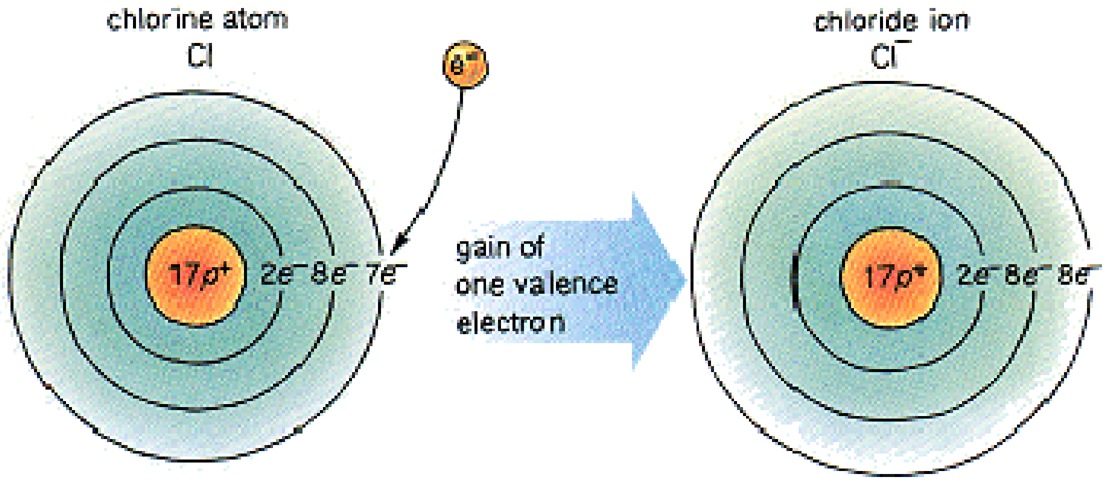
A neutral chlorine atom has 17 protons and 17 electrons with seven electrons in its outermost energy level. In forming an ion, chlorine gains one electron to attain a noble gas configuration. With 18 electrons (and 17 protons), the chloride ion has a 1- charge.

$Cl^{-}$

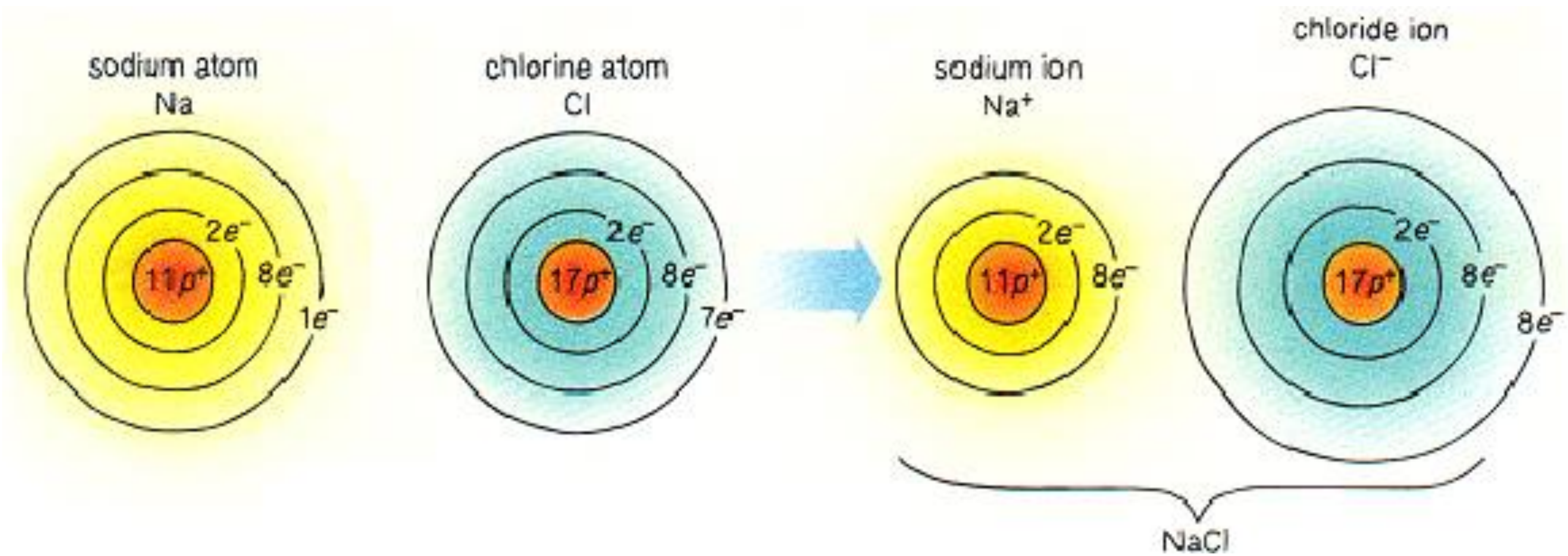


# NaCl



In the formation of sodium chloride, NaCl, one electron is transferred from the Na atom to the Cl atom.

This produces a Na ion and a Cl ion. Since these two ions have opposite charges, there are strong attractive forces between them. This results in the formation of the ionic compound, NaCl.



# Charge Balance in Ionic Compounds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In writing the formula for an ionic compound, the sum of the positive and negative charges must equal zero (known as the net charge).

| | | | | |
|---|---|---|---|---|
| $Na^{+}$ | + | $Cl^{-}$ | = | NaCl |
| 1+ | + | 1- | = | 0 |
| 1+ is the total positive charge | | 1- is the total negative charge | | Overall charge of zero |

# Summary




## Section 1

In this section, you learned about:

- Inorganic Chemistry
- Units of Measurement
- Scientific Calculations
- Density
- Parts of the Atom
- Elements and the Periodic Table
- Compounds

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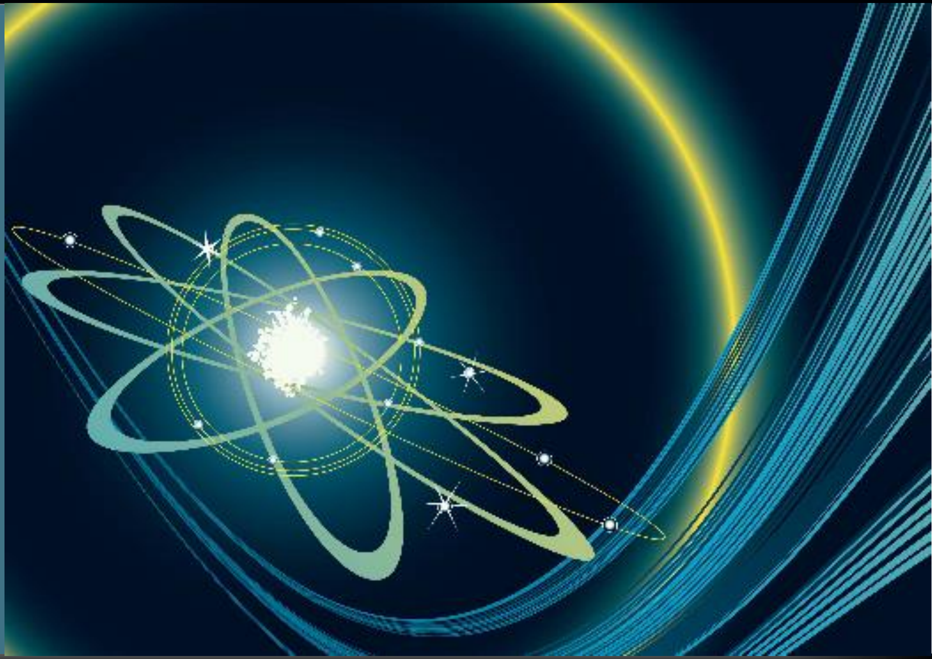
# Section 2

## Nuclear Chemistry



# Section Two Objectives



## Section 2

In this section, you will learn about:

- Nuclear Chemistry
- Natural Radioactivity
- The Alpha Particle, Beta Particle, and Gamma Ray
- Radiation Protection
- Alpha, Beta, and Gamma Emitters
- Radiation Measurement and Protection
- Medical Applications
- Half-lives
- Nuclear Fission and Fusion

# What is Nuclear Chemistry?




Nuclear Chemistry is the chemistry of radioactive elements such as the actinides, radium and radon together with the chemistry associated with equipment (such as nuclear reactors) which are designed to perform nuclear processes.

# Natural Radioactivity



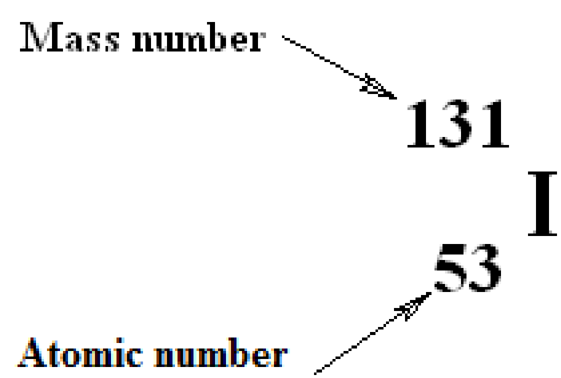
Radioactive isotopes or **radioisotopes** are isotopes of an element that have unstable nuclei. This means that they are likely to go through a change to become stable.  Most of the time energy is given off in this process. This energy is called radiation.

**Radiation** may take the form of particles such as alpha particles or beta particles or pure energy such as gamma rays.

In elements 84 and above, the presence of so many protons and neutrons in the nucleus makes the nuclei unstable.

The example here shows how to write the nuclear symbol for an isotope. This isotope is called

I-131 or iodine-131.



# The Alpha Particle



Different forms of radiation are emitted from an unstable nucleus when a change takes place among its protons and neutrons. These include the alpha particle, the beta particle, and the gamma ray.

The **alpha particle** contains 2 protons and 2 neutrons and has a charge of 2+.

This makes it identical to the helium nucleus.

Its symbol is written as:

$$^{4}_{2}\mathrm{He} \quad \text{or} \quad \alpha$$

# The Beta Particle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The **beta particle** is a high energy electron.

The beta particle has a charge of 1- and a mass number of 0.

Its symbol is written as:

$$^{0}_{-1}e \quad \text{or} \quad \beta$$

# The Gamma Ray




The **gamma ray** is high-energy radiation similar to X rays.

A gamma ray is released as an unstable nucleus undergoes a rearrangement to become more stable.

Its symbol is written as:

$$\gamma$$

# Summary of Types of Radiation

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| Type of Radiation | Symbol | Mass Number | Atomic Number | Charge |
|---|---|---|---|---|
| Alpha particle | $\alpha$ ${}^{4}_{2}He$ | 4 | 2 | 2+ |
| Beta particle | $\beta$ ${}^{0}_{-1}e$ | 0 | 1- | 1- |
| gamma ray, X-ray | $\gamma$ | 0 | 0 | 0 |
| Proton | ${}^{1}_{1}H$ ${}^{1}_{1}p$ | 1 | 1 | 1+ |
| Neutron | ${}^{1}_{0}n$ | 1 | 0 | 0 |

# Radiation Protection



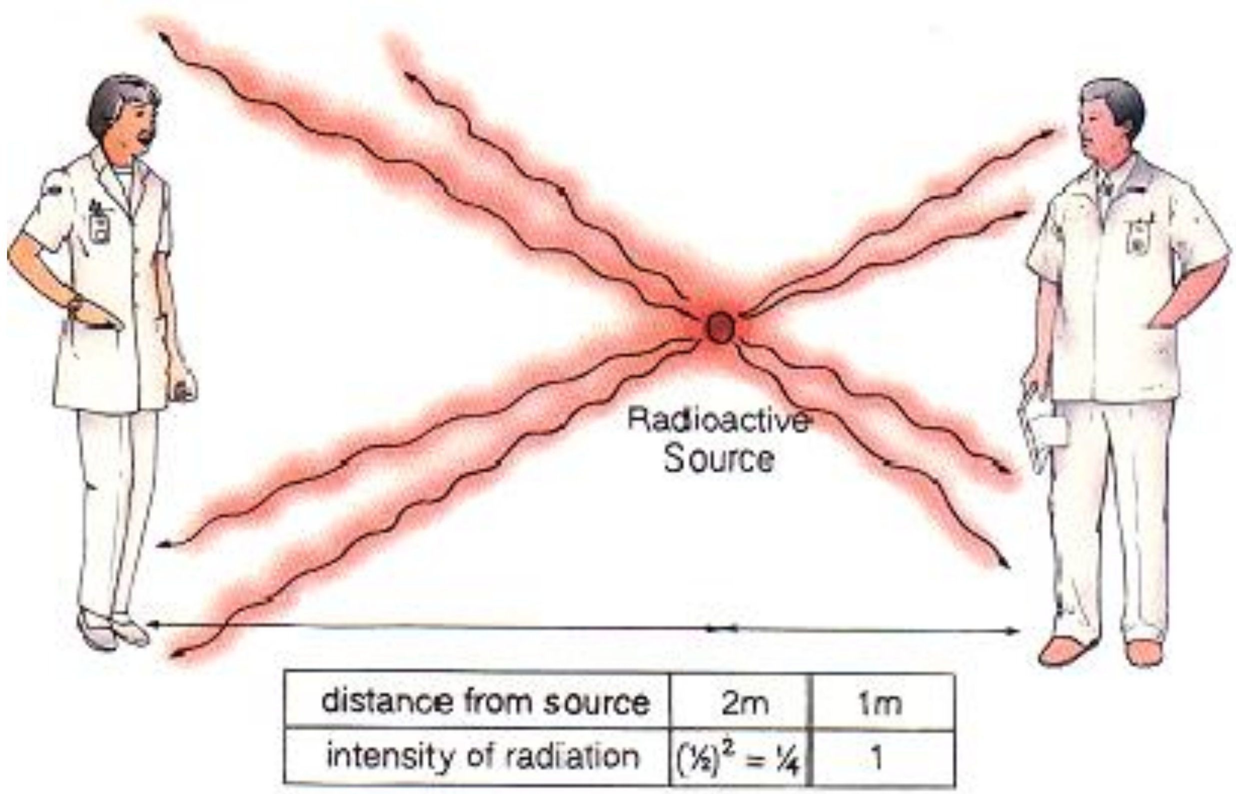
**Shielding** is proper protection from radiation. Different types of radiation require different types of shielding.

Alpha particles are the heaviest, travel only a few centimeters in air, and rarely penetrate into body tissue. They require the least amount of shielding. Paper, clothing, or skin can be protection. Lab coats and gloves are sufficient.

Beta particles have a very small mass and travel much faster and farther than alpha particles. They can pass through paper and penetrate as far as 4-5 mm into body tissue. Heavy clothing and gloves are needed for protection.

Gamma rays travel the greatest distance and can penetrate many materials.  Dense shielding including concrete and lead is needed.

Time and distance are important factors in radiation protection. Remaining in a radioactive area twice as long exposes a person to twice as much radiation.



# Alpha Emitters

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**Alpha emitters** are radioisotopes that decay by emitting alpha particles.

Total = 241

$$^{241}_{95}\text{Am} \longrightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\text{He}$$

Total = 95

# Beta Emitters

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A **beta emitter** is a radioisotope that decays by emitting beta particles.

Total = 14

$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$$

Total = 6

# Gamma Emitters



A **gamma emitter** is a radioisotope that changes from unstable to stable without the mass number or atomic number changing. The excited state is called a metastable state. In the case of technetium, it is written as technitium-99m or Tc-99m.

$$^{99m}_{43}\mathrm{Tc} \longrightarrow \, ^{99}_{43}\mathrm{Tc} + \gamma$$

# Radiation Detection and Measurement

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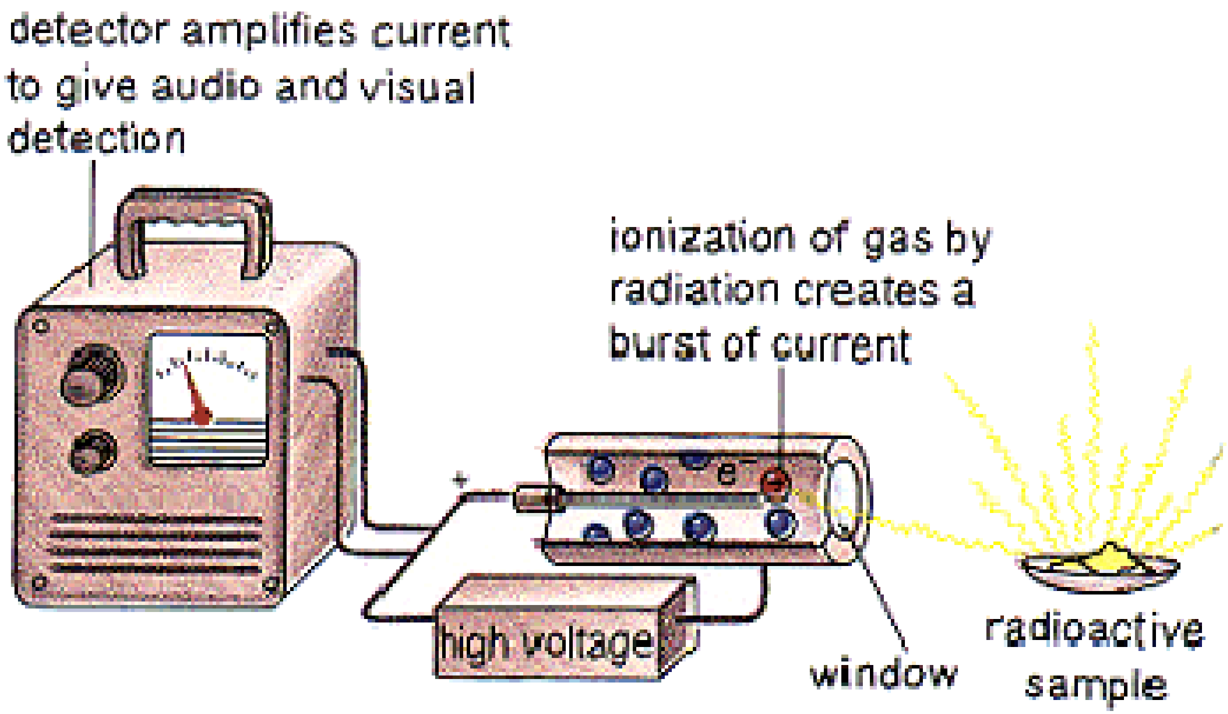
The **Geiger Counter** is one device that is used to detect beta and gamma radiation. It does this by detecting an electrical current that is produced when radiation ionizes a gas.



# Medical Applications



**Nuclear Medicine** uses radioisotopes in diagnostic procedures as well as in certain types of treatments for conditions such cancer. Radioactive atoms are important in medicine because they can be detected. They emit radiation as they move to the same organs as the nonradioactive atoms of an element.

A scanner is used to produce an image of an organ where the radiation has moved. A scan is the image that results when radiation (in the organ) is exposed to a photographic plate.

One way to determine thyroid function is the use of radioactive iodine uptake.  Iodine-131 is taken orally, then in 24 hours the amount of iodine taken up by the thyroid is determined. This uptake is directly related to the activity of the thyroid, thus indicating a hyperactive, normal, or hypoactive thyroid.

# Half-Life



**The half-life** of a radioisotope is the amount of time that it takes for one-half of a sample to decay. This can be expressed as seconds, minutes, hours, days, or years.

Iodine-131

$T_{1/2}$ = 8 days

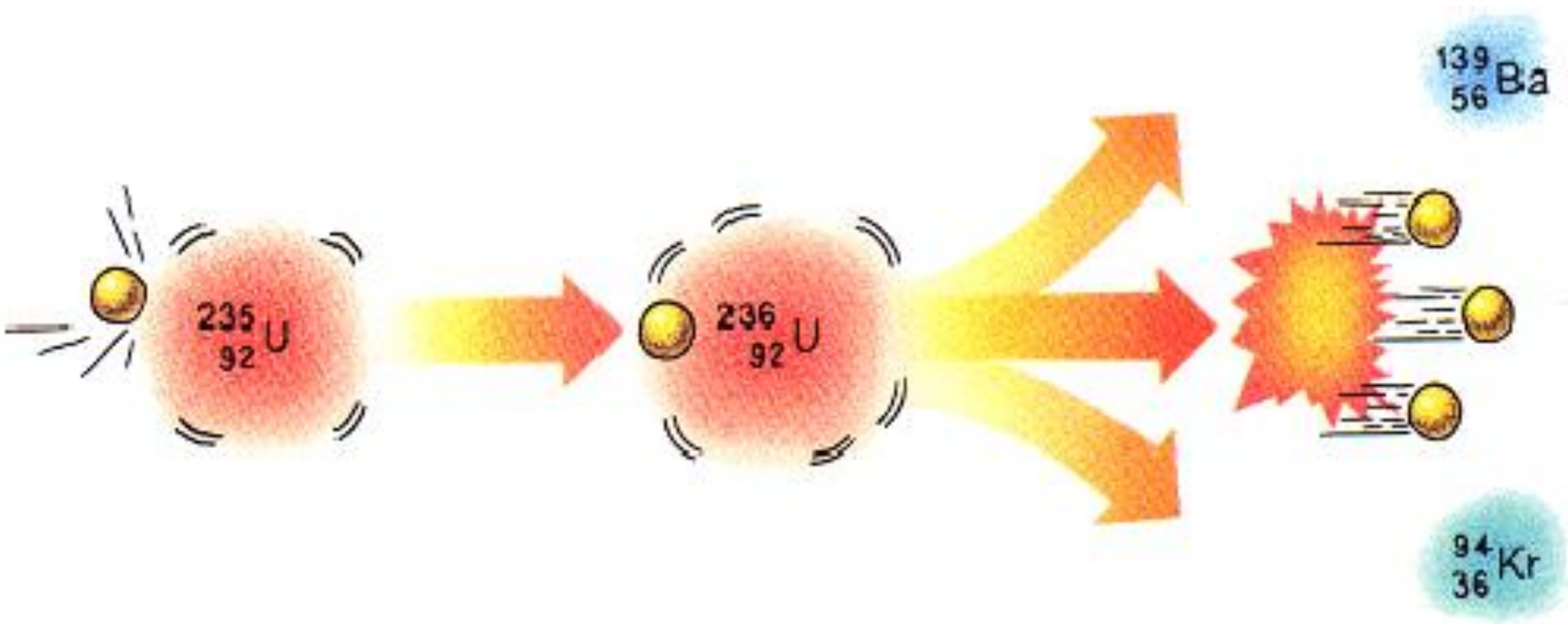
How much of a 20 g sample is left after 2 half-lives?

| | | |
|---|---|---|
| **20 g** | **0 days** | |
| | | 1 half-life |
| **10 g** | **8 days** | |
| | | 1 half-life |
| **5 g** | **16 days** | |

# Nuclear Fission



In the 1930's, scientists bombarding uranium-235 with neutrons discovered that two medium-weight nuclei were produced along with the release of a great amount of energy. This type of nuclear reaction is called a **fission reaction**, the splitting of a large nucleus into smaller nuclei.



# Nuclear Power Plants

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Uranium-235 is used in nuclear power plants to produce large amounts of heat under controlled conditions. This heat is used to produce steam, which drives a generator, which produces electricity.

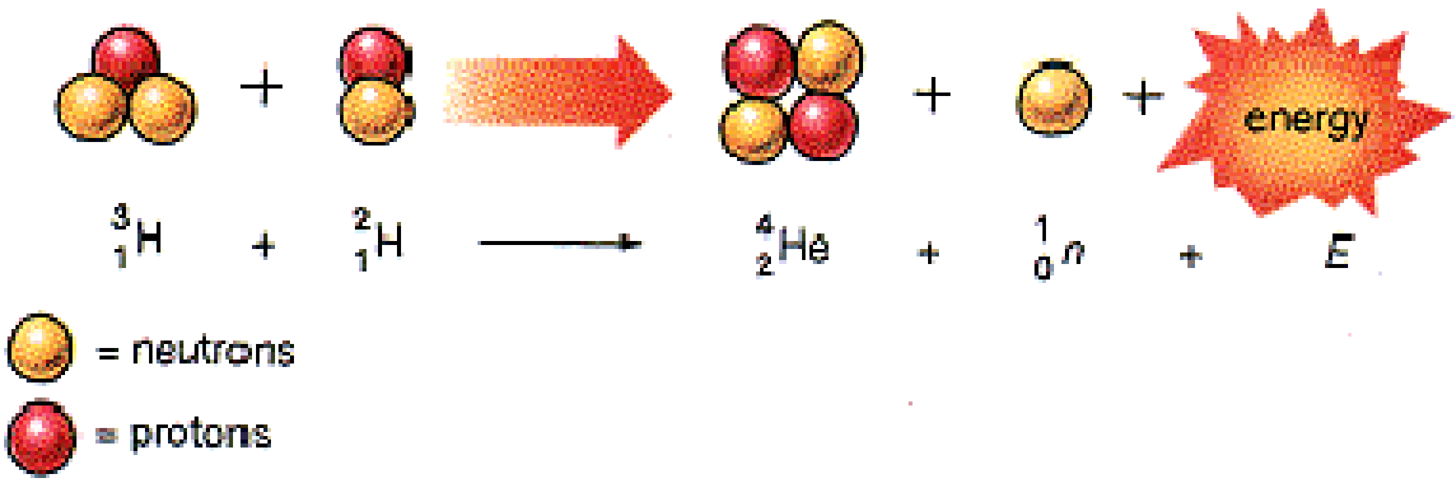
The fission reaction is controlled with control rods that are used to absorb some of the fast-moving neutrons. Less fission occurs, and there is a slower, controlled production of energy.

Even though nuclear power plants help meet some of our energy needs, major problems exist. One of the most serious is that the radioactive isotopes produced have very long half-lifes. Thus the waste must be stored for a very long time.

# Nuclear Fusion



In **fusion**, two small nuclei, such as hydrogen atoms, combine to form a larger nucleus. Mass is lost and a large amount of energy is released. Very high temperatures (100,000,000  C) are needed for this type of reaction. This occurs in the sun and other stars, thus giving us heat and light. The fusion reaction shows potential as a possible source of energy for future energy needs.



# Summary




## Section 2

In this section, you learned about:

- Nuclear Chemistry
- Natural Radioactivity
- The Alpha Particle, Beta Particle, and Gamma Ray
- Radiation Protection
- Alpha, Beta, and Gamma Emitters
- Radiation Measurement and Protection
- Medical Applications
- Half-lives
- Nuclear Fission and Fusion

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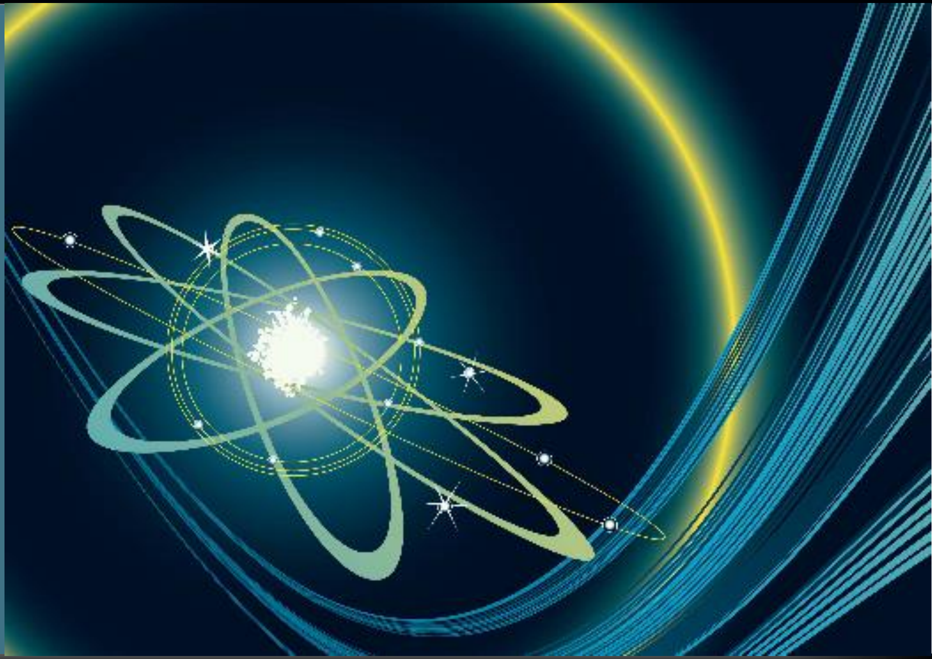
# Section 3

## Organic Chemistry



# Section Three Objectives

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## Section 3

In this section, you will learn about:

- Organic Chemistry
- Hydrocarbons and Functional Groups
- Alkanes, Alkynes, and Alkynes
- Alcohols and Ethers
- Aldehydes and Ketones

# What is Organic Chemistry?

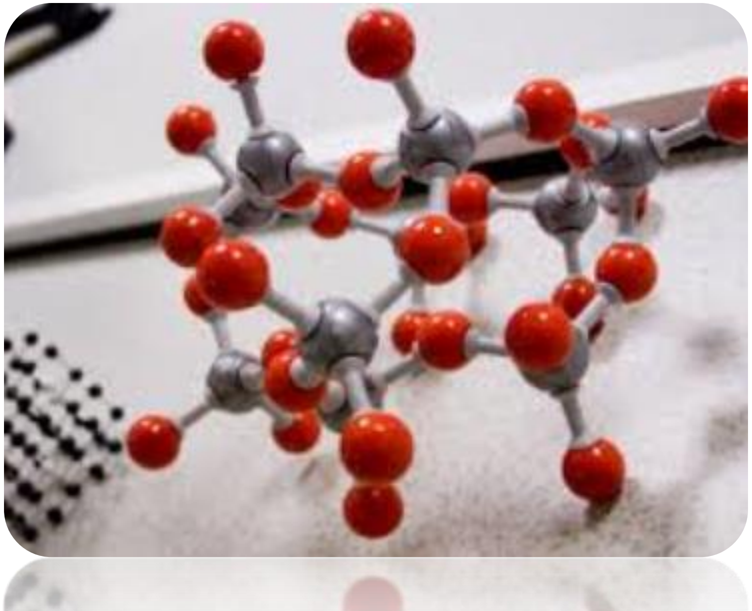


**Organic chemistry** is the study of compounds containing carbon. Carbon is ideal as the major element for biological compounds.

In organic compounds, carbon is bonded mostly to hydrogen and sometimes to oxygen, nitrogen, sulfur, phosphorus, and the halogens.

A few carbon compounds are classified as inorganic such as carbon dioxide and carbonic acid. Others are salts of the carbonate and bicarbonate ions.

There are a great number of organic compounds (more than 18 million!) because of carbon's ability to bond covalently with other carbon atoms and with other nonmetals.

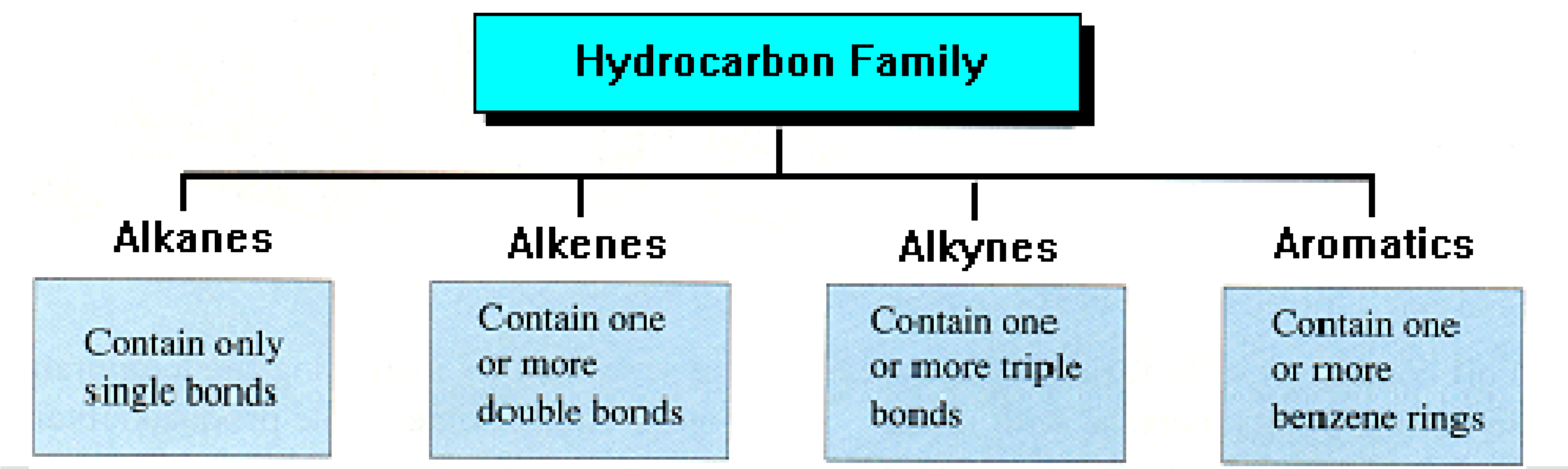


# Hydrocarbons



Organic compounds have been organized into families according to common features. The first of these families is the hydrocarbon family.

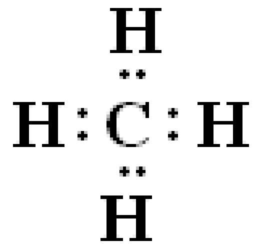
**Hydrocarbons** are organic compounds that contain only the elements carbon and hydrogen. The simplest class of this type of compound is the **alkanes**. The alkanes are called saturated hydrocarbons because they only contain single bonds. Compounds with double bonds (alkenes) and triple bonds (alkynes) are unsaturated hydrocarbons.

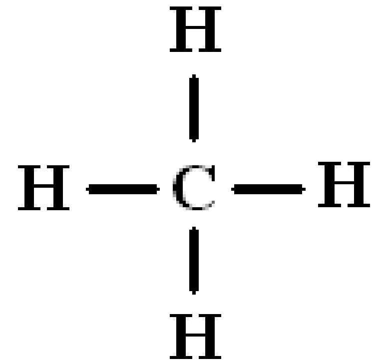


# Bonding in Hydrocarbons



The simplest hydrocarbon class is the **alkanes**. Recall that alkanes are called saturated hydrocarbons because they only contain single bonds.



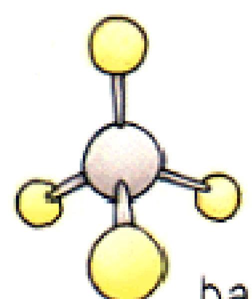




Since carbon has four electrons in its outer shell, it can covalently bond with four hydrogen atoms to form methane, the simplest of the alkanes.

$CH_4$

**Methane** (shown here) actually has a three-dimensional shape called a **tetrahedral** structure. The carbon atom is at the center and is bonded to four hydrogen atoms at

the corners of the tetrahedron.



ball-and-stick model of methane

# Combustion of Alkanes



Alkanes burn in oxygen to produce carbon dioxide, water, and heat energy.

This is what we refer to as **combustion**.

$$\text{alkane} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{heat}$$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{heat}$$

$$CH_3CH_2CH_3 + 5O_2 \longrightarrow 3CO_2 + 4H_2O + \text{heat}$$

# Functional Groups

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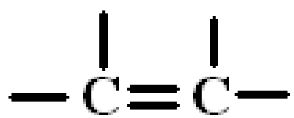
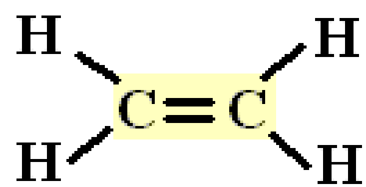
The Alkanes shown previous had single bonds. The next few slides will show organic compounds that have multiple bonds along with boding with halogens.

| Family | Functional Group | Example |
|---|---|---|
| Alkenes |  |  |
| Alkynes | $-C\equiv C-$ | $HC\equiv CH$ |
| Haloalkanes | F, Cl, Br, or I | $CH_3-Cl$ |

# More Functional Groups

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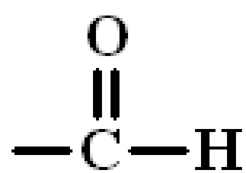
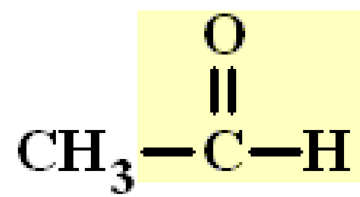
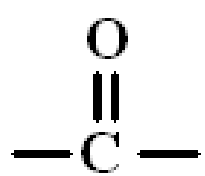
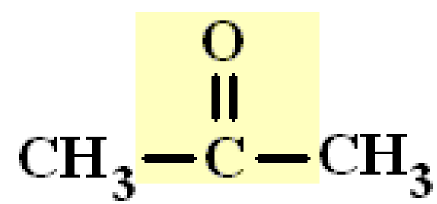
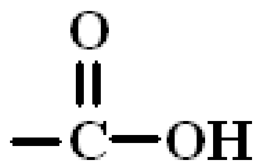
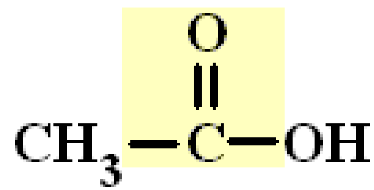
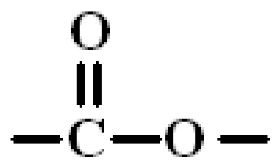
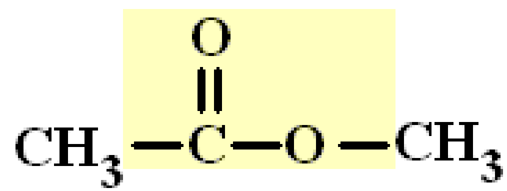
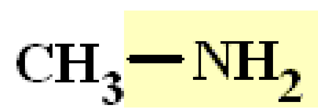
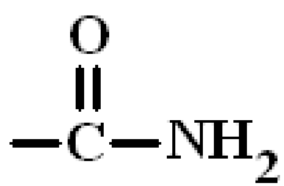
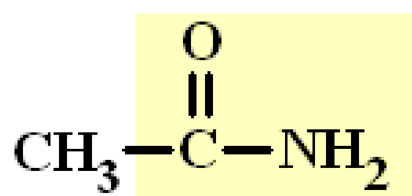
| Family | Functional Group | Example |
|---|---|---|
| Alcohols | $-OH$ | $CH_3-OH$ |
| Ethers | $-O-$ | $CH_3-O-CH_3$ |
| Thiols | $-SH$ | $CH_3-SH$ |
| Aldehydes |  |  |
| Ketones |  |  |

# More Functional Groups



| Family | Functional Group | Example |
|---|---|---|
| Carboxylic acids |  |  |
| Esters |  |  |
| Amines |  |  |
| Amides |  |  |

# Alkenes and Alkynes

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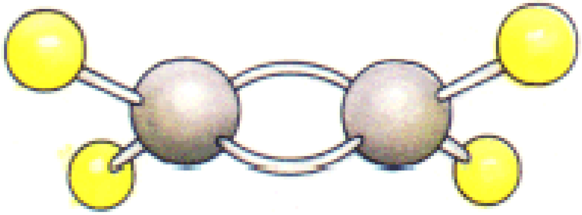
**Alkenes** and **alkynes** are families of hydrocarbons that contain double or triple bonds.

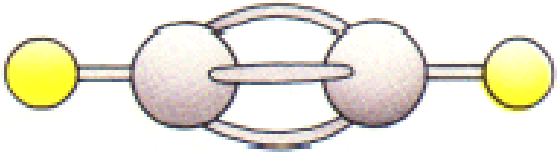
Alkenes and alkynes are considered to be unsaturated because they have multiple bonds (double or triple bonds).

Recall that alkanes are called saturated hydrocarbons because they contain the maximum number of hydrogen atoms attached to each carbon atom.

Model of ethene, a two-carbon alkene:



Model of ethyne, a two-carbon alkyne:



# Alcohols




**Alcohols** are a family of organic compounds that contain the hydroxyl group.

The **hydroxyl group** looks like this:

$$-OH$$

The hydroxyl group takes the place of a hydrogen atom in an alkane.

**General Formula**

$$R-OH$$

**Examples**

$$CH_3-OH \qquad CH_3CH_2-OH$$

# Methanol

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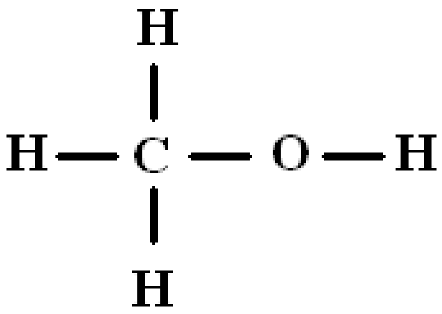
The simplest alcohol contains one carbon atom. The IUPAC name is **methanol**. The common name is **methyl alcohol**.

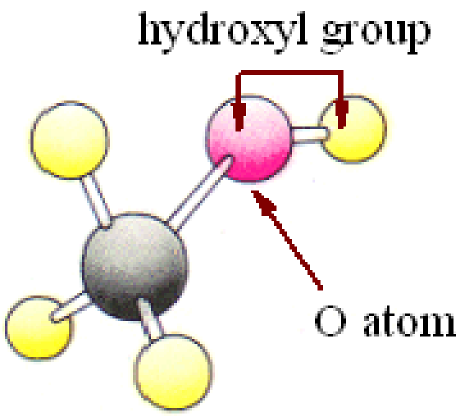


**Structural Formula**

$$CH_3-OH$$

**Condensed Formula**

**Model**



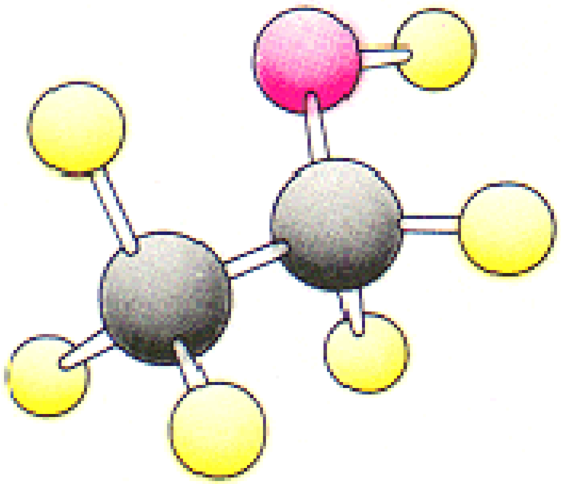
# Ethanol



The IUPAC name of the alcohol with two carbon atoms is **ethanol**. The common name is **ethyl alcohol**.

$CH_3CH_2—OH$

**Condensed Formula**



**Model**

# Ethers



An **ether** contains an oxygen atom attached by single bonds to two alkyl or aromatic groups.

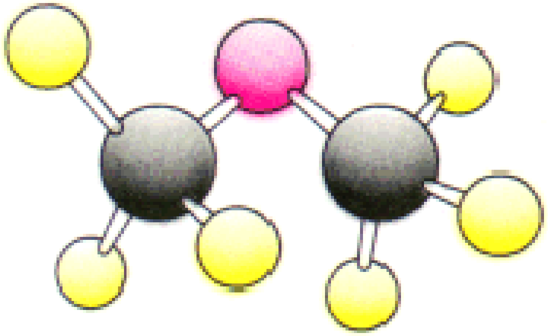
$$R_1 - O - R_2$$

Ethers are generally referred to by their common names. You must use the names of the alkyl groups and alphabetize them if they are different. If the groups are identical, use the di prefix.

The simplest ether:

$$CH_3 - O - CH_3$$

**Dimethyl ether**

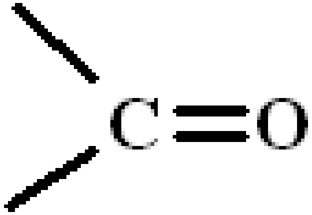


# Aldehydes and Ketones



Many important organic and biochemical compounds contain a carbonyl group, a carbon joined to an oxygen with by a double bond. The carbonyl group is found in **aldehydes** and **ketones**.

The double bond is represented by two lines instead of one.



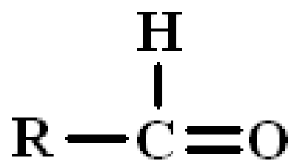

Remember that the double bond represents two shared pairs of electrons. This means that the carbon can still be bonded to two other atoms covalently.

# A Simple Aldehyde

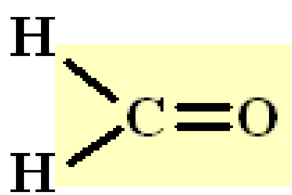


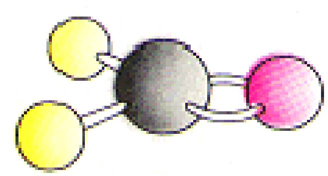
In an **aldehyde**, the carbon of the carbonyl group is attached to at least one hydrogen atom.

General formula:




Example:



Common name: formaldehyde

# A Simple Ketone

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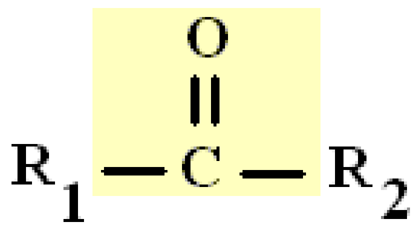
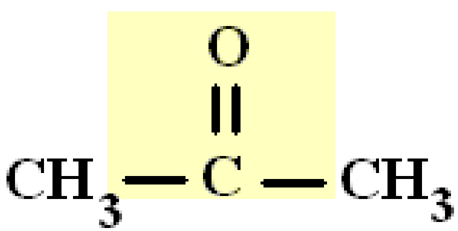
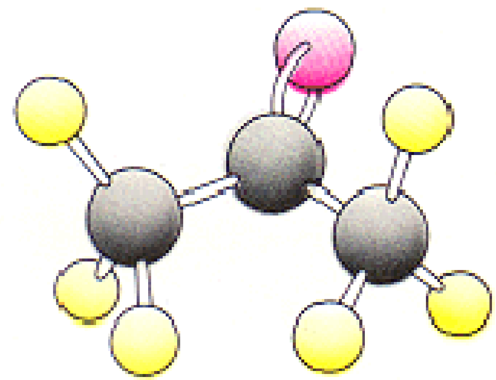
In a **ketone**, the carbon of the carbonyl group is attached to two carbon atoms. Thus the carbonyl group of a ketone is found within the carbon chain, whereas it is found at the end of a chain with an aldehyde.

General formula:




Example:



Common name: acetone

# Summary




## Section 3

In this section, you learned about:

- Organic Chemistry
- Hydrocarbons and Functional Groups
- Alkanes, Alkynes, and Alkynes
- Alcohols and Ethers
- Aldehydes and Ketones

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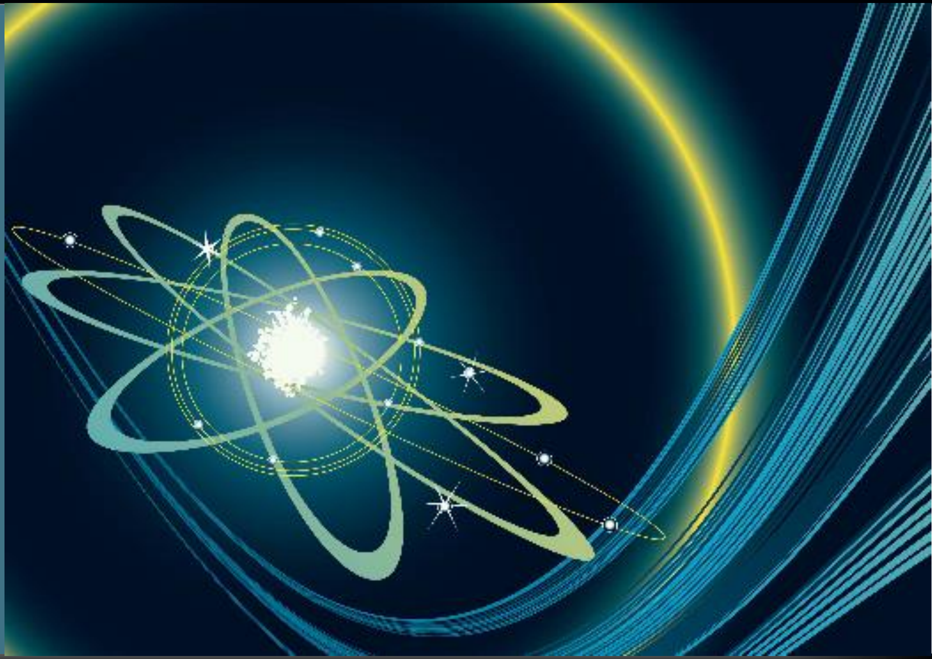
# Section 4

## Biochemistry



# Section Four Objectives



## Section 4

In this section, you will learn about:

- Biochemistry
- Carbohydrates
- Monosaccharides, Disaccharides, and Polysaccharides
- Lipids
- Triglycerides
- Steroids
- Fatty Acids
- Cholesterol
- Hormones

# What is Biochemistry?



**Biochemistry**, sometimes called **biological chemistry**, is the study of chemical processes within and relating to, living organisms.

This section will cover some of the basic chemical components in Biochemistry including an introduction to **Carbohydrates**, **Lipids**, and **Proteins**.

# Carbohydrates

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**Carbohydrates** such as table sugar, lactose, and cellulose are a class of compounds composed of carbon, hydrogen, and oxygen. They are also known as **saccharides**. We often just refer to them as sugars.

We obtain these materials from such things as bread, potatoes, beans, and rice along with those foodstuffs that give us a variety of sugars.

Simple sugars, such as glucose and fructose, were once thought to be hydrates of carbon, thus the name carbohydrate.

# Types of Carbohydrates



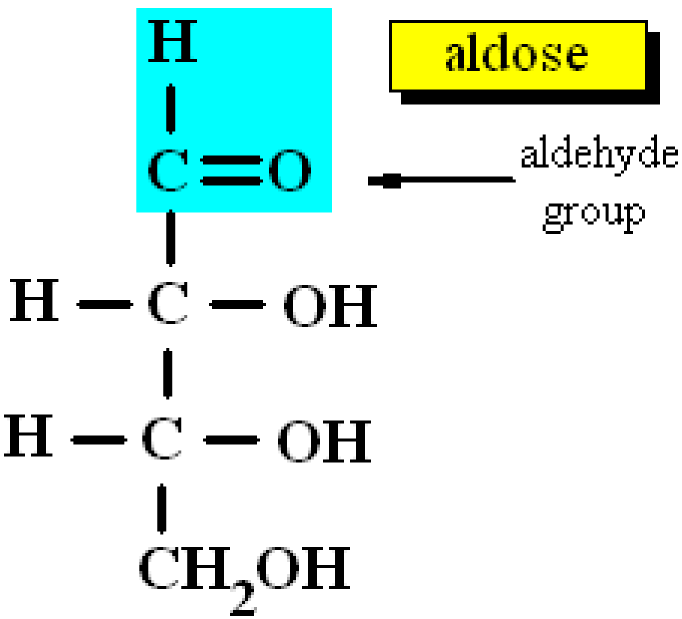

There are three basic types of carbohydrates:

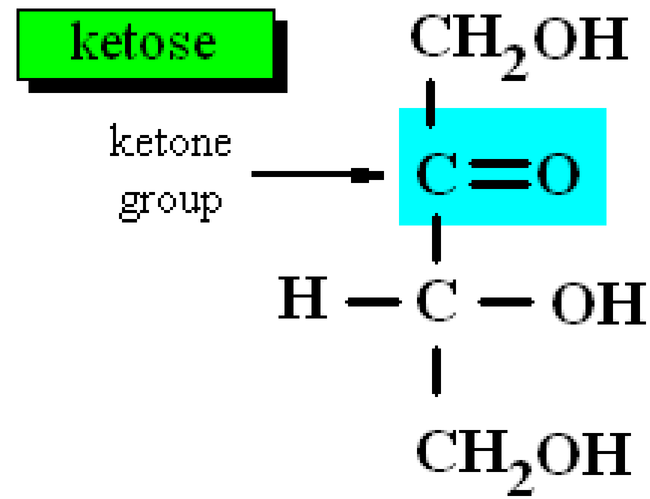
| | |
|---|---|
| Monosaccharides | These are the simple carbohydrates and are typically composed of 3 to 6 carbon atoms. |
| Disaccharides | These are carbohydrates that are composed of two monosaccharide units. |
| Polysaccharides | These are complex carbohydrates that are composed of many monosaccharide units. |

# Monosaccharides



**Monosaccharides** are simple sugars that have an unbranched chain of 3-8 carbon atoms, one of which is a carbonyl group and all the others have hydroxyl groups. A polyhydroxy aldehyde is called an **aldose**. In the aldose, the carbonyl group is on the first carbon. In a **ketose**, the carbonyl group is on the second carbon atom (as a ketone).



# Glucose

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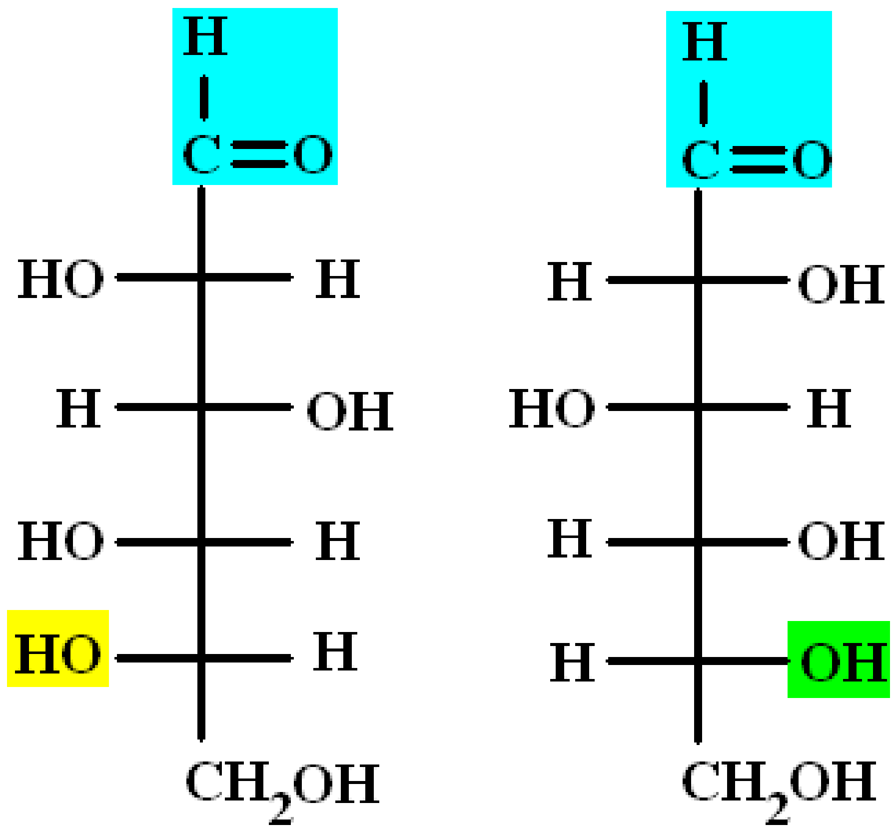
Here you see the two different formations of **glucose**, a monosaccharide.

L-glucose



D-glucose



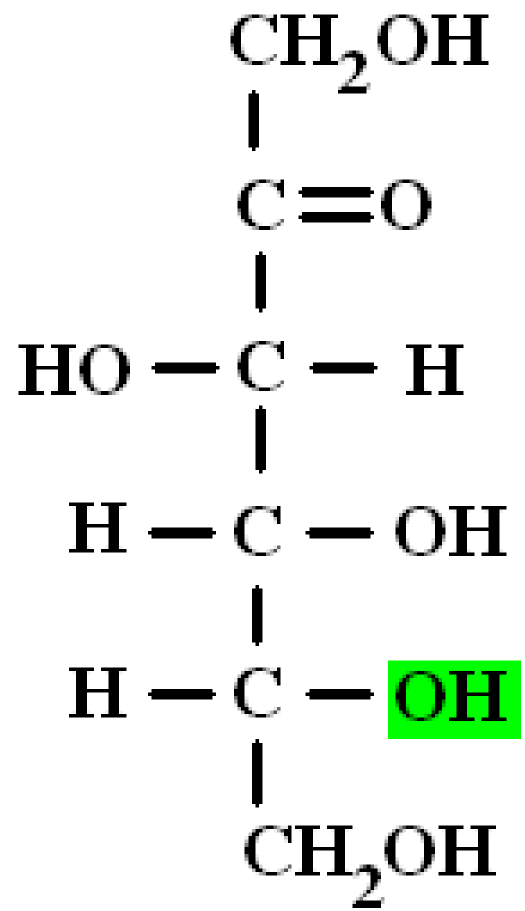
# Fructose

**Fructose** is the sweetest of the carbohydrates.

It is found in fruit juices and honey. It is popular with dieters since less fructose, and therefore fewer calories, is needed to provide a pleasant taste.

After fructose enters the bloodstream, it is converted to its isomer, glucose.

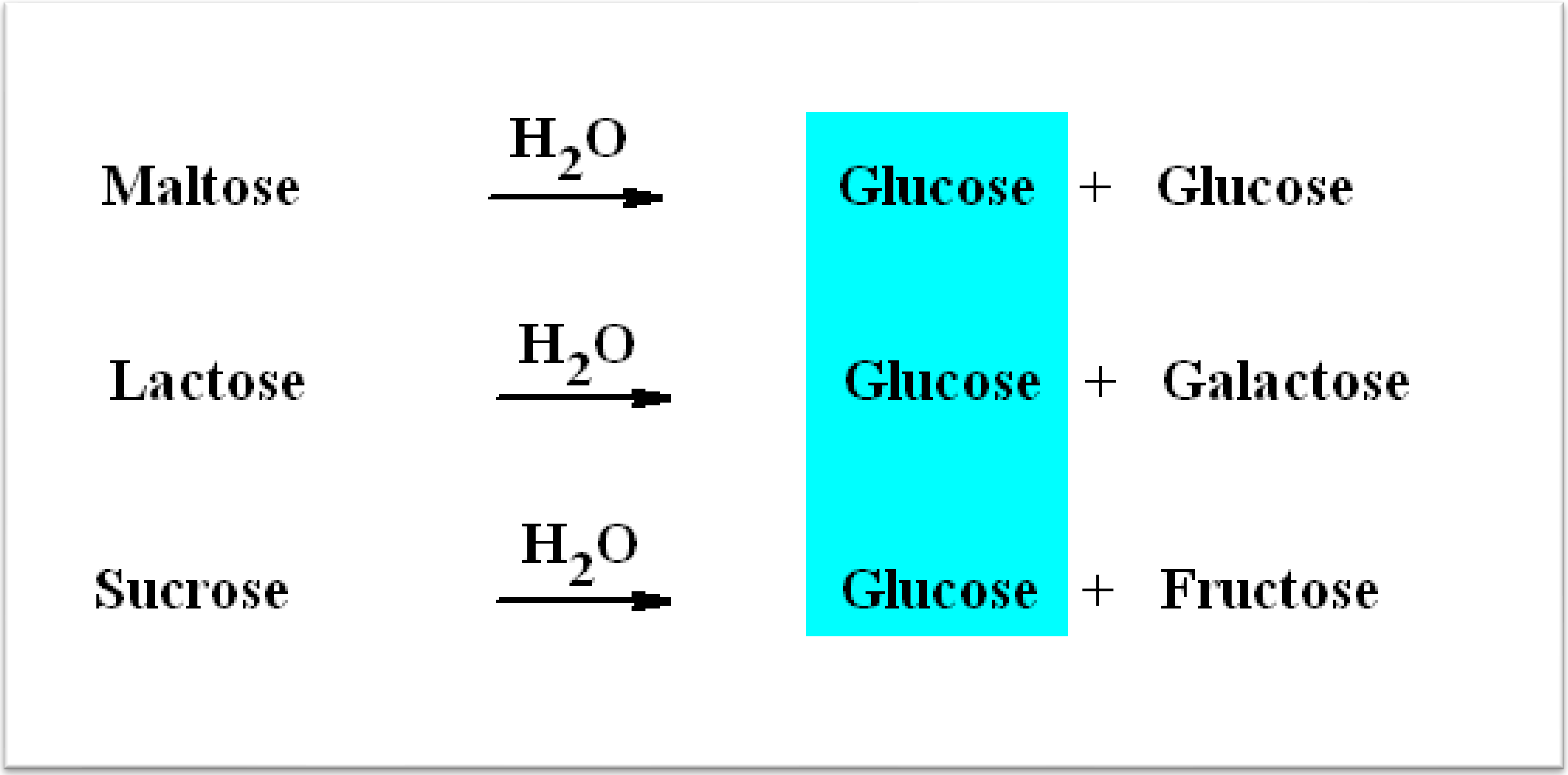
It is a product of the hydrolysis of sucrose (table sugar).



# Disaccharides

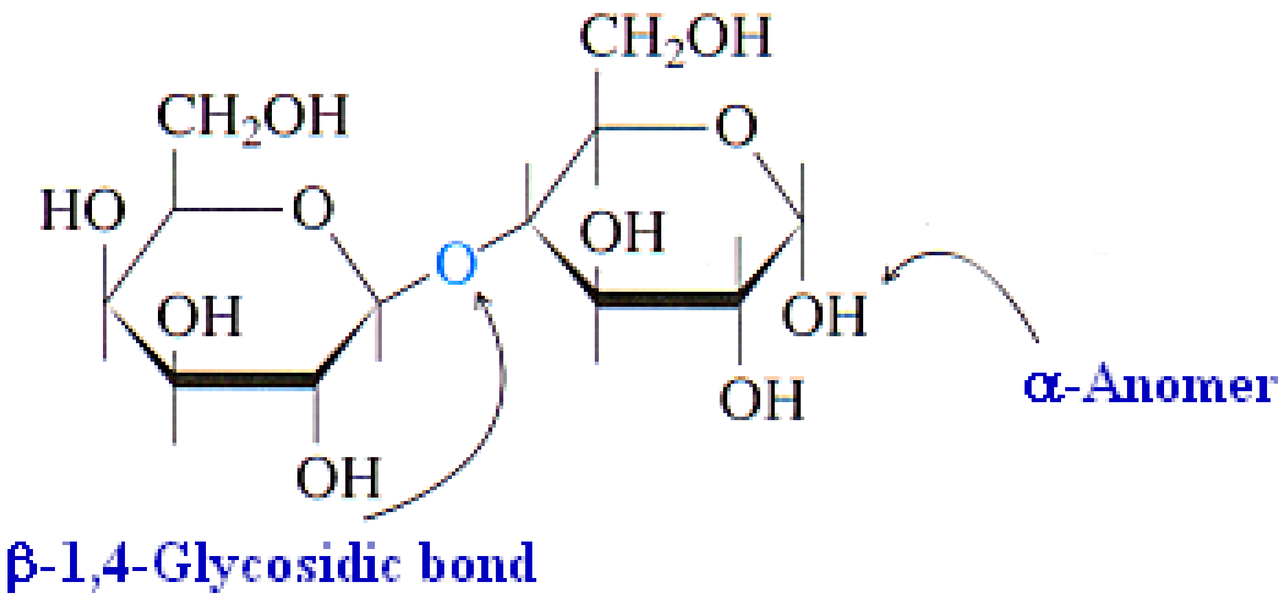


A **disaccharide** is composed of two monosaccharides linked together. The most common disaccharides are **maltose**, **lactose**, and **sucrose**. All three disaccharides hydrolyze or break down into one or more of the simple monosaccharides.





**Lactose** is an important disaccharide that is composed of the monosaccharide units **glucose** and **galactose**. It is found in milk and milk products. Lactose is also a reducing sugar.




α-Lactose, a disaccharide

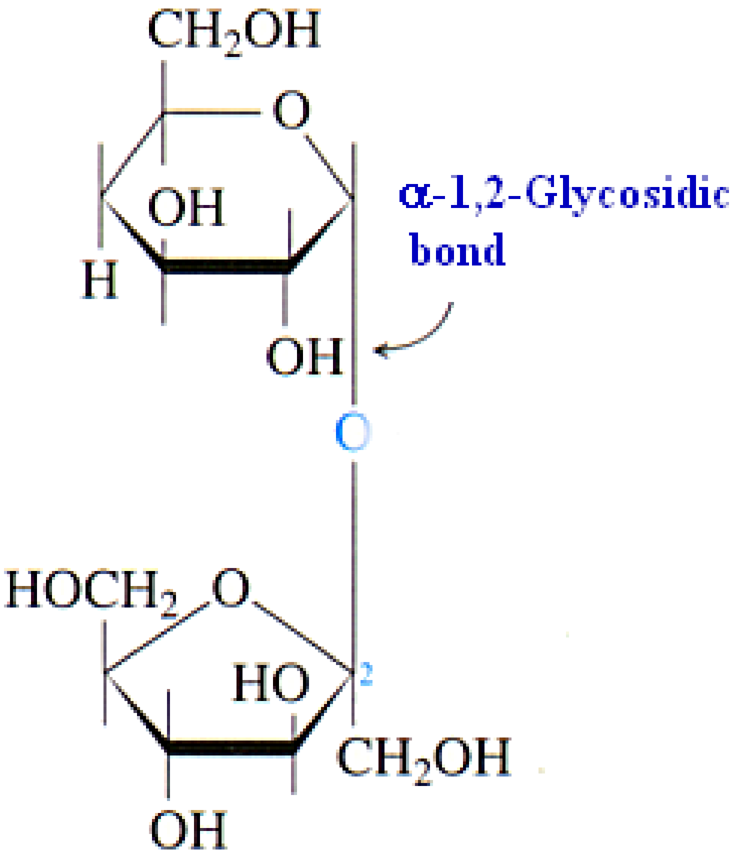
# Sucrose



**Sucrose** is the disaccharide that is composed of the monosaccharide units glucose and fructose.

Sucrose is commonly known as table sugar. It is found in sugar cane and sugar beets.

Sucrose is not a reducing sugar.



# Polysaccharides



A **polysaccharide** is a polymer of many monosaccharides joined together.

The three important polysaccharides are starch, cellulose, and glycogen.

All of these are polymers of D-glucose.

Polysaccharides differ only in the type of glycosidic bonds and the amount of branching in the molecule.

# Plant Starch

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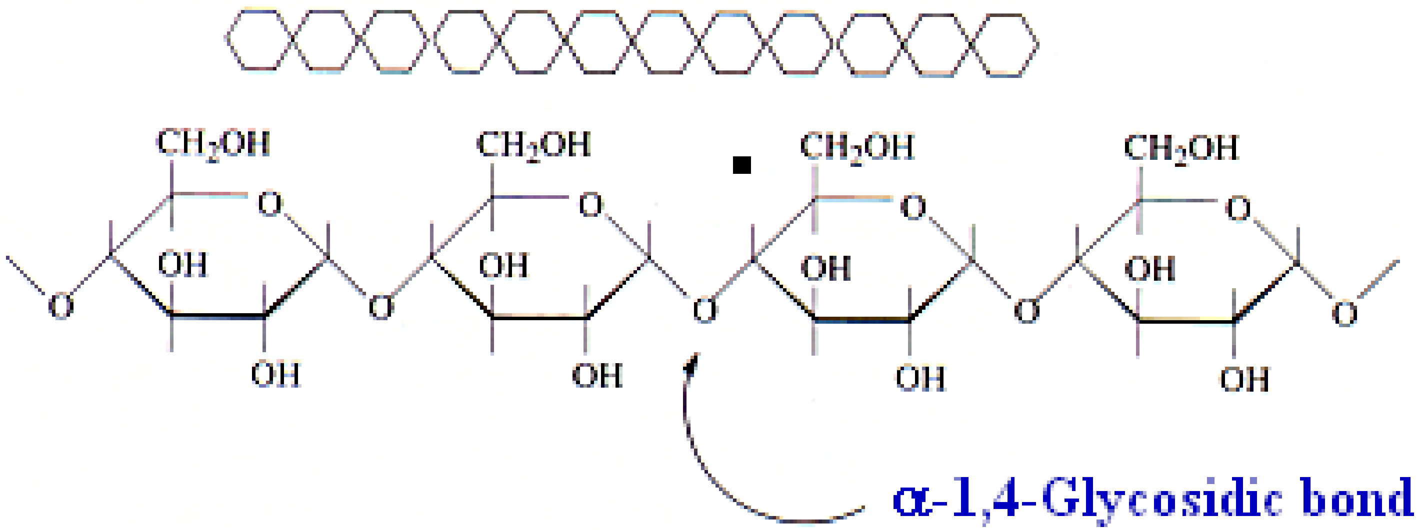
**Starch** is a storage form of glucose in plants. It is found as insoluble starch granules in rice, wheat, potatoes, beans and cereals.

Starch is composed of two kinds of polysaccharides: amylose (20%) and amylopectin (80%).

**Amylose** is the unbranched form of starch.



# Lipids



**Lipids** are a family of biomolecules that have the common property of being soluble in organic solvents, but not in water.

The lipid content of a plant cell can be extracted using an organic solvent such as ether, chloroform, or acetone.

# Classes of Lipids



| Lipids | Composition |
|---|---|
| Waxes | Fatty acid and long-chain alcohol |
| Fats and Oils (triglycerides) | 3 fatty acids and glycerol |
| Phospholipids | 2 fatty acids, glycerol, phosphate, and an amino alcohol |
| Sphingolipids | 1 fatty acid, sphingosine, phosphate, an amino alcohol |
| Glycolipids | 2 fatty acids, glycerol, and one or more monosaccharides (carbohydrates) |
| Steroids | A fused ring structure of three cyclohexanes and a cyclopentane |

# Triglycerides

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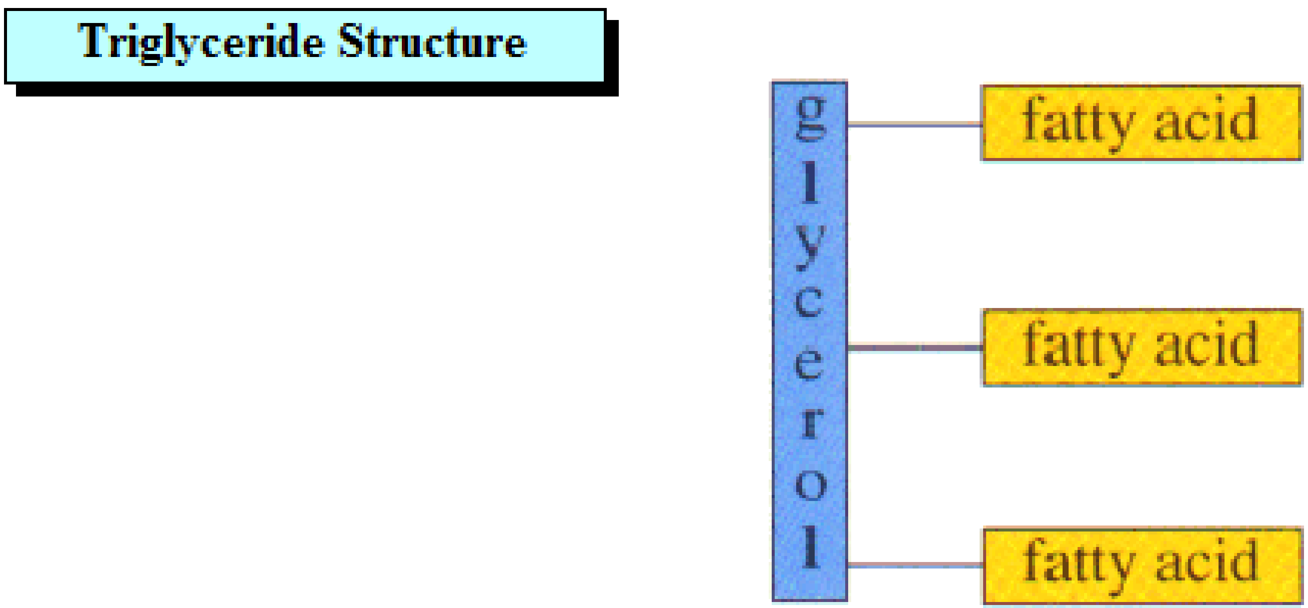
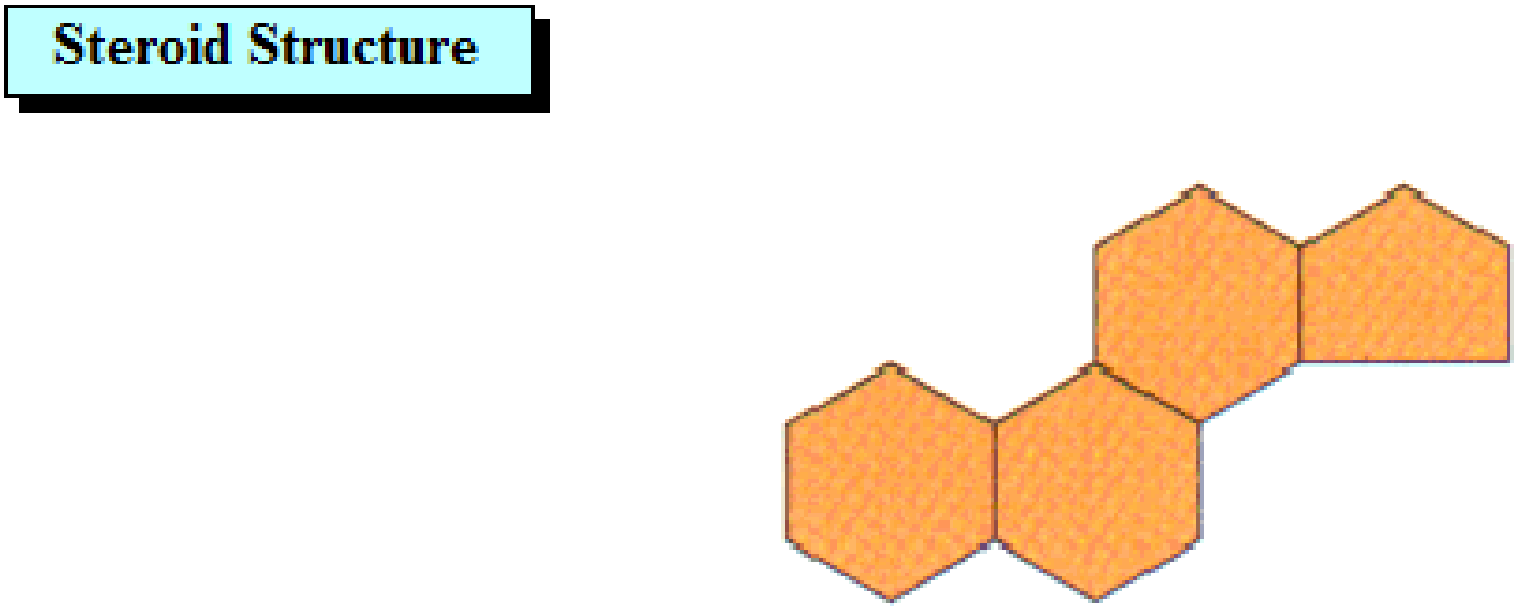
**Triglycerides** (also known as fats) are also esters and can be hydrolyzed. A triglyceride has three ester bonds.



# Steroids



**Steroids** cannot be hydrolyzed. **Cholesterol** is an important steroid in the body.

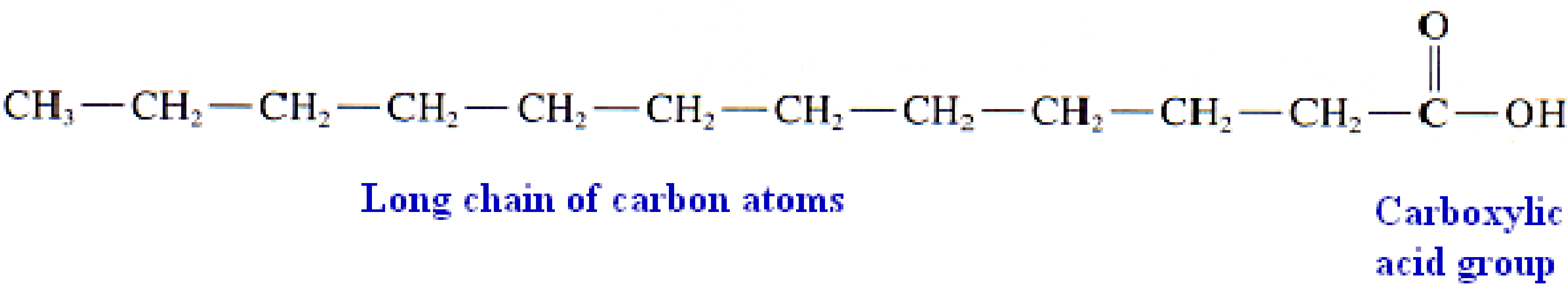


# Fatty Acids



**Fatty acids** are long-chain carboxylic acids that are insoluble in water. They typically have an even number of carbon atoms: 12-18 carbons for biological systems.

An example is lauric acid, a 12-carbon acid that is found in coconut oil.

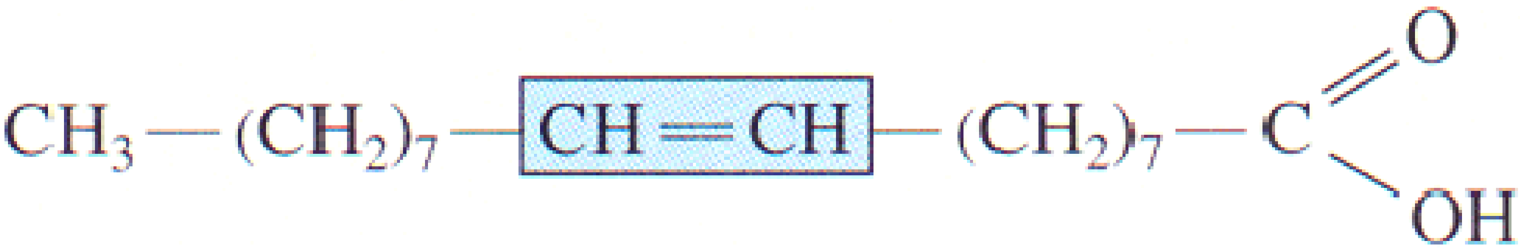


# Unsaturated Fatty Acids



**Monounsaturated fatty acids** have one double bond while polyunsaturated fatty acids have two or more double bonds.

**Oleic acid** is an unsaturated fatty acid with 18 carbon atoms and one double bond.




Oleic acid

# Physical Properties of Fatty Acids



**Saturated:**

- Straight-chain structures which allow the molecules to fit close together.
- This results in high melting points.
- This means that most saturated fats are usually solids.

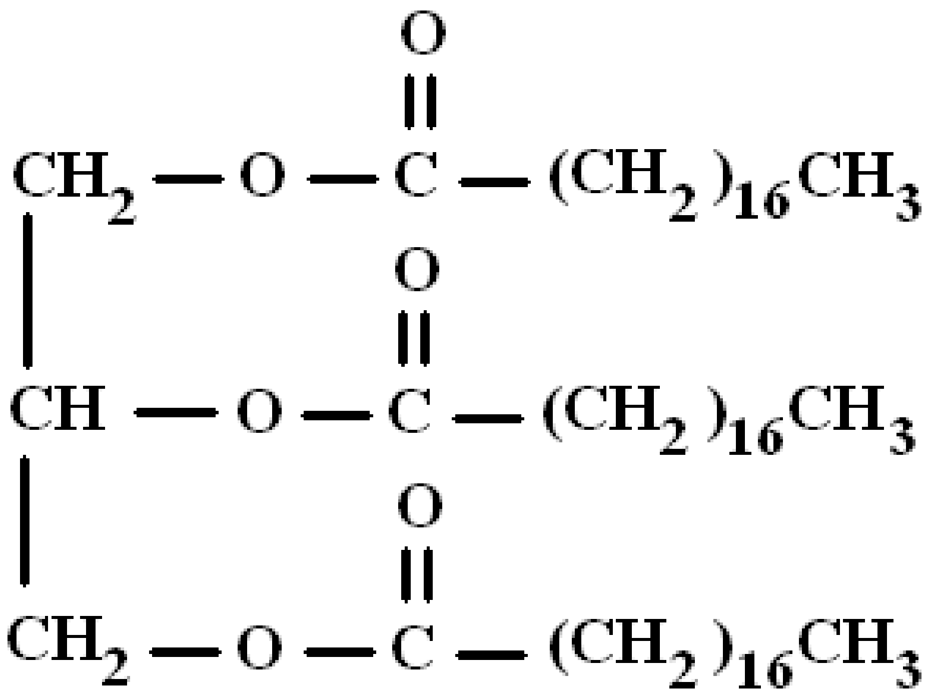
**Unsaturated:**

- The double bonds cause bends in the chain that give irregular shapes and cause molecules to be more spread out.
- This results in lower melting points.
- This means that most unsaturated fats are usually liquids or soft solids. More double bonds means lower melting points.

# A Typical Triglyceride



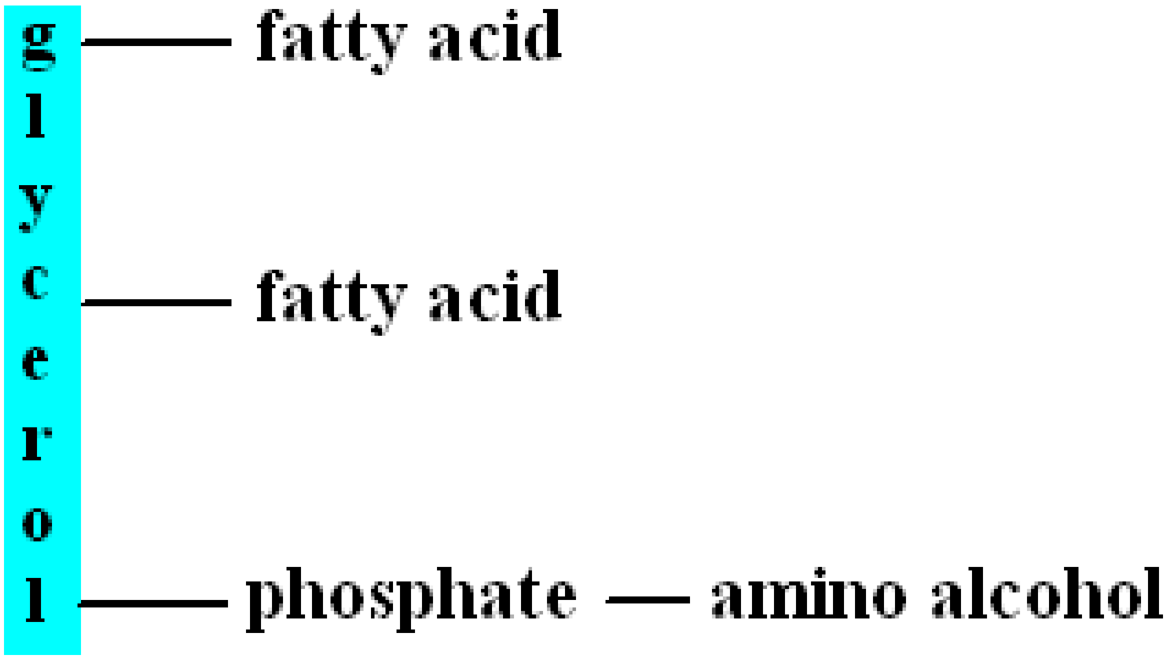
**Tristearin** is a triglyceride composed of three stearic acids and the glycerol unit. It is a saturated fat because the stearic acids have only single bonds.



# Phosphoglycerides



**Phosphoglycerides** are the most abundant lipids in cell membranes and play an important role in cell permeability. They make up much of the myelin sheath that protects nerve cells. Like triglycerides, these substances contain glycerol and fatty acids (both saturated and unsaturated). They also contain a phosphate group and an amino alcohol.



# Cholesterol

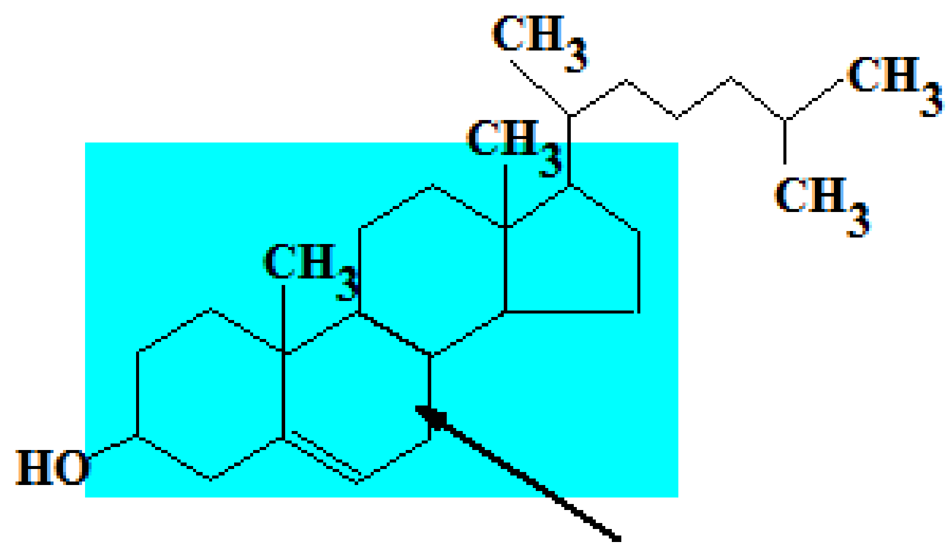


**Cholesterol** is the most abundant and important steroid compound in the body. It is a component of cellular membranes, myelin sheath, and brain and nerve tissue. It is also found in the liver, bile salts, and the skin.

It is called a sterol because it contains an alcohol group.

Cholesterol in the body is obtained by eating meats, milk, and eggs. It is also synthesized by the liver from fats, carbohydrates, and proteins.

Excess cholesterol forms plaque that eventually can block an artery, resulting in a heart attack.




The Steroid Nucleus

# Hormones

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**Hormones** are chemical messengers that serve as a kind of communication system in the body.  The steroid hormones are closely related in structure to cholesterol and depend upon it for their synthesis.

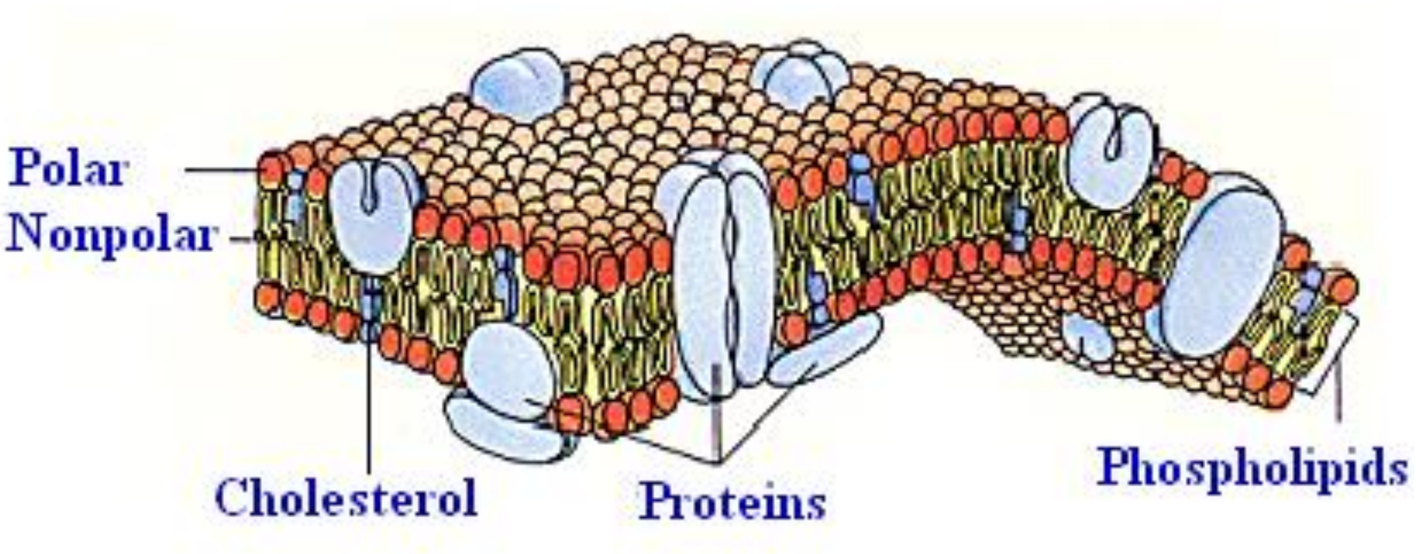
| Hormone | Organ | Biological Effects |
|---|---|---|
| Testosterone | Testes | Development of male sex organs, muscle, facial hair |
| Androsterone | Testes | Development of male sex organs, muscle, facial hair |
| Estradiol | Ovaries | Development of female sexual characteristics |
| Progesterone | Ovaries | Prepares uterus for implanation of a fertilization egg |

# The Lipid Bilayer



The nonpolar hydrocarbon tails which are hydrophobic (water fearing), form the center of the bilipid layer.

The polar sections (or heads) which are hydrophilic (water seeking) are aligned along the outside of the bilipid layer.  As a result, the polar and nonpolar sections create a wall that separates the aqueous contents inside a cell from the surrounding fluids.



# Summary

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## Section 4

In this section, you learned about:

- Biochemistry
- Carbohydrates
- Monosaccharides, Disaccharides, and Polysaccharides
- Lipids
- Triglycerides
- Steroids
- Fatty Acids
- Cholesterol
- Hormones

# Course Summary

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In this course you learned the differences between the various areas of chemistry and some basics in each of those areas.

The four areas you learned about included:

- Inorganic
- Nuclear
- Organic
- Biochemistry