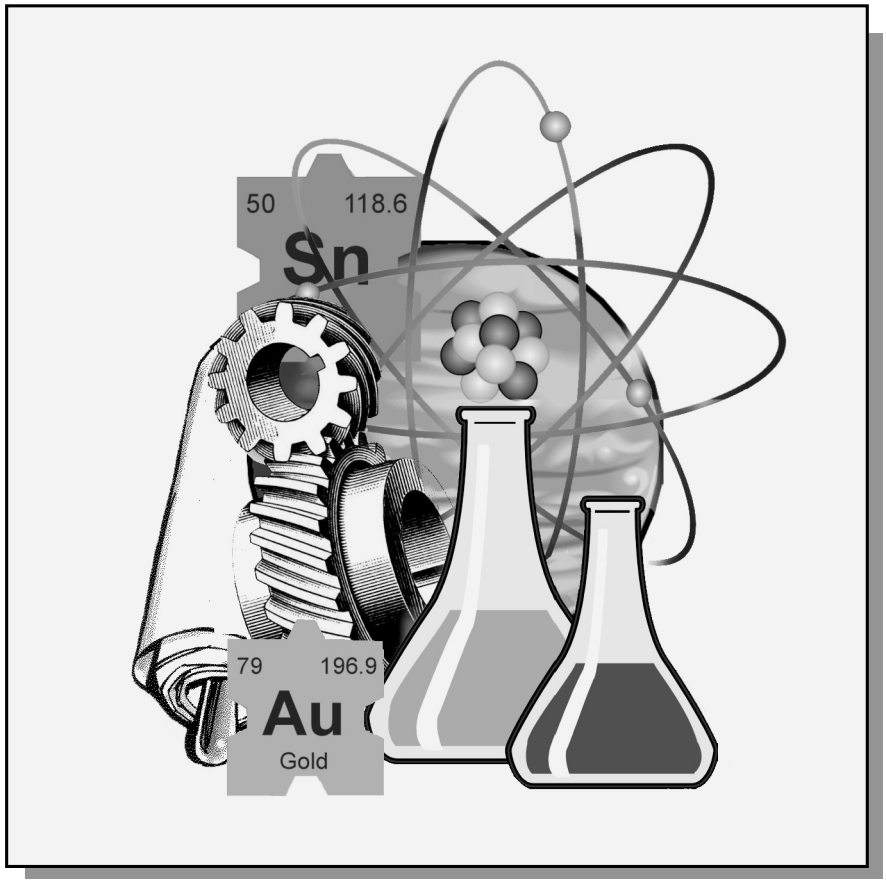
Integrated Physics & Chemistry

This chapter requires a companion activity book in which students respond to questions on text content. Answers are found in the *Teacher's Resource Kit*.



Chapter 8

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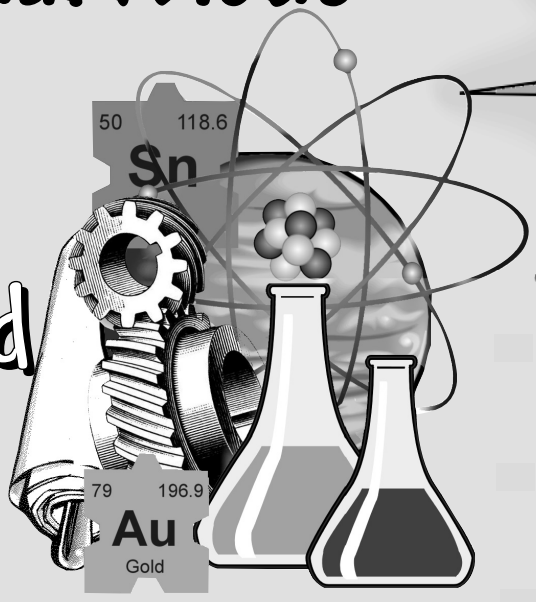
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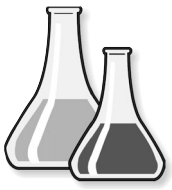
"The study of science is the chronicle of man's quest to discover the essence of life and how the marvelous laws of creation are applied to human needs."



—Ronald Johnson, Ph.D.

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Integrated Physics & Chemistry



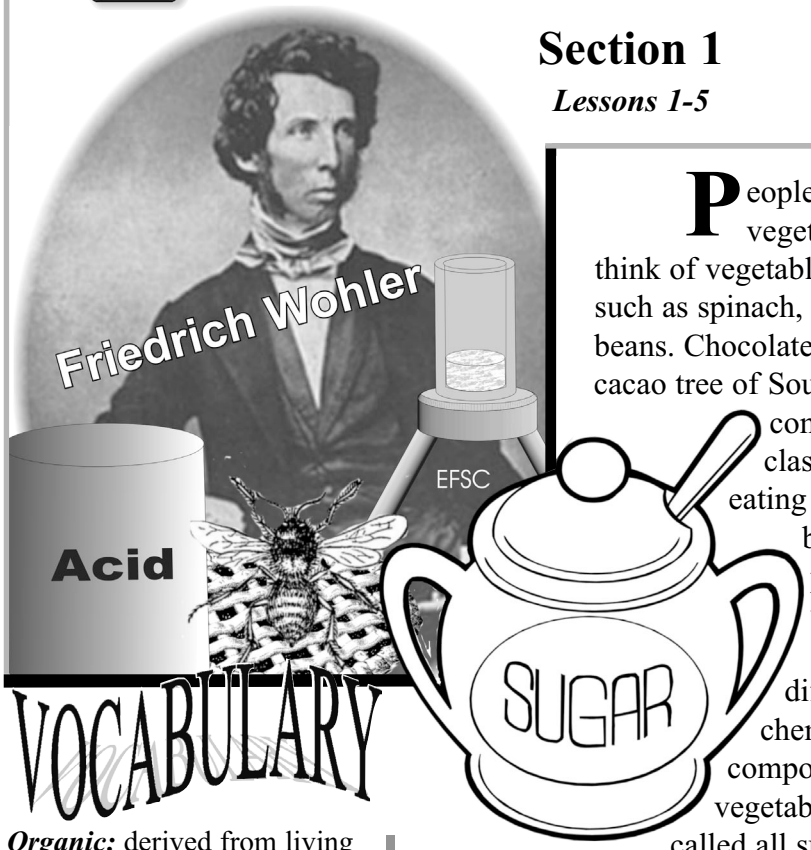
Lesson 1
Compounds

Chapter 8

ORGANIC CHEMISTRY

Section 1

Lessons 1-5



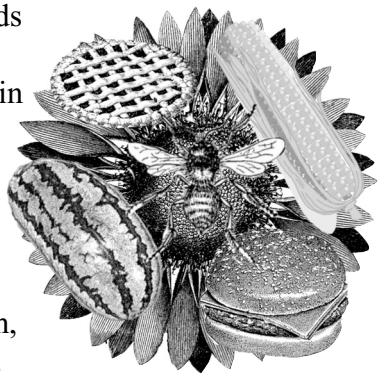
VOCABULARY

Organic: derived from living organisms, a carbon compound
Inorganic: compounds that are not based on carbon compounds
Analysis: the separation of a compound into its elements
Synthesis: the formation of a compound by simpler compounds or the elements
Partial synthesis: the formation of a substance from compounds of about the same complexity as the substance being made
Total synthesis: building a complex compound from the elements
Organic compound: a carbon compound

People often classify matter as animal, vegetable, or mineral. We normally think of vegetables as the edible parts of plants such as spinach, broccoli, cauliflower, corn or beans. Chocolate is made from the seeds of the cacao tree of South America. Because chocolate comes from a plant, it can be classified as a vegetable. However, eating a chocolate bar rather than eating broccoli will probably not satisfy a person who is in need of more vegetables in his or her diet.

Chemists put matter in several different categories. For instance, chemists of the early 1800s put all compounds that came from animals or vegetables in a single category. Chemists called all such compounds ***organic***. The word *organic* means *from the organs*. Chemists also gave the name organic to any substance found in living tissue or derived from living tissue.

All other compounds that did not come from living organisms were called ***inorganic***. Inorganic compounds include: metals, rocks, minerals, acids, bases, salts, water and gases in the air. Inorganic compounds have a major role in our daily lives. Inorganic compounds can be found in the silicon chips in computers, building materials such as steel, concrete and glass, and compounds of chlorine and nitrogen.



Organic compounds include sugar, starch, glue, gelatin, silk, gum, oils, dyes and albumin (egg whites). Living things produce these substances. For instance, sugar

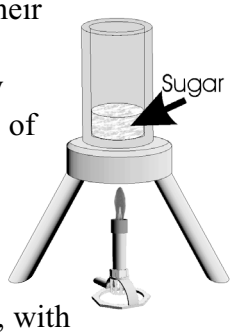
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comes from sugar cane, sugar beets or sugar maple trees. Sometimes an organic substance is readily apparent. The albumin, or egg white, is organic because it comes from an egg made by a chicken. Organic compounds also include the remains of vegetable matter that was once alive. Coal and petroleum are organic because they came from things that lived in the past.

Today, the everyday usage of the word *organic* implies that no artificial color, artificial flavor or human-made chemicals are used. A sign at a produce market may read "organically grown tomatoes." The sign implies that no pesticides, insecticides, fertilizers or growth hormones were used in growing the tomatoes. This use of the term organic is not entirely the same as the one used by chemists.

Jons Jakob Berzelius coined the term *organic* in 1807. He was the Swedish chemist who used letters to represent the names of elements. According to Berzelius, organic substances came from plants or animals but not from nonliving matter. He used the term inorganic for substances found in the nonliving environment, such as water or salt.

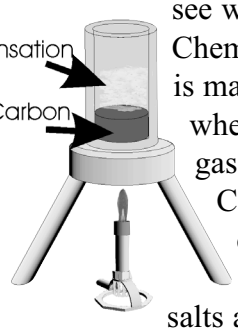
Inorganic and organic compounds differ considerably in their properties. Organic compounds can be very complex with hundreds of atoms. Inorganic compounds are usually simpler with only a few atoms. Compare salt, which is inorganic, with sugar, which is organic. Salt contains only two atoms, *NaCl*, and each atom is used only once. Sugar contains three types of atoms, each atom found in much greater numbers: $C_{12}H_{22}O_{11}$. In all, sugar has 12 carbon atoms, 22 hydrogen atoms and 11 oxygen atoms, a total of 45 atoms.



Inorganic and organic compounds also differ in their reaction to harsh treatment. Inorganic substances can withstand high temperatures. A chemist can heat salt until it becomes red hot. Once cooled, it is still salt. Most inorganic compounds such as salt are difficult to burn; whereas, organic substances are easily damaged by heat. When a chemist heats sugar, it turns black. Once cooled, the sugar is no longer considered sugar because it breaks down into carbon and water. Most organic compounds will burn, and can be used as fuels, such as wood, fat and oil.

Analysis is the separation of a compound into its elements. Chemists take molecules apart to learn their composition. Both inorganic and organic compounds can be broken down into their elements. Sugar, for instance, can be burned to give carbon and water. Salt can be separated by electrolysis to give sodium and chlorine. The analysis of organic compounds shows that all of the compounds contain carbon (C) along with a few other elements, usually hydrogen (H), oxygen (O) and nitrogen (N).

Synthesis is the formation of a compound by simpler compounds or elements. Chemists can use smaller building blocks to see what makes a molecule. Chemists first learned that water is made of hydrogen and oxygen when the reaction of those two gases produced water. Combining sodium and chlorine makes ordinary table salt. Acids, bases, salts and all of the other inorganic compounds can be synthesized in the laboratory.

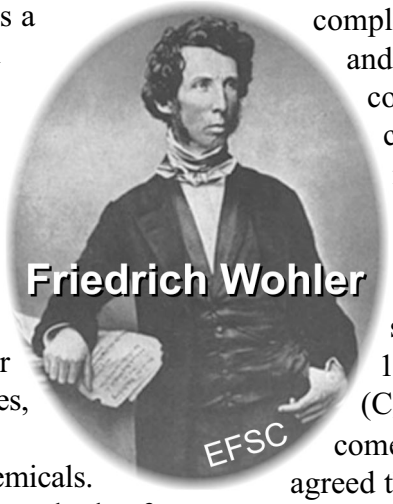


Yet, chemists of the early 1800s could not make any organic compounds. The chemists could synthesize many inorganic compounds, but they could not synthesize even one of the organic compounds. Sugar,

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one of the simplest organic compounds, could not be made in the laboratory, and the only way to get it was from a living source, such as sugar cane. This was very frustrating for chemists. They could take apart organic molecules and see that they were made of a few simple and readily available elements, usually carbon and a few others such as hydrogen, oxygen or nitrogen. When chemists tried to combine those same elements, they could not produce an organic compound. The chemists knew of no way to combine inorganic compounds to give organic ones. Because they could not change inorganic compounds into organic compounds, some chemists decided the project was impossible. Chemists also believed that the chemical laws that operated with nonliving compounds differed from those that took place in living organisms. Scientists concluded that an unknown vital force, present only in living cells, was necessary to make organic compounds. Several leading chemists, including Berzelius, stated that making an organic compound in the laboratory was impossible.

One of Berzelius' former students was Friedrich Wohler. He was a German chemist who studied medicine and became a surgeon. One of Friedrich Wohler's teachers inspired him to switch to chemistry and travel to Stockholm to study under Jon Jakob Berzelius. The two chemists became lifelong friends. After completing his chemical studies, Wohler returned to Berlin to experiment with inorganic chemicals. Friedrich Wohler worked out methods of isolating aluminum and beryllium from their ores. He also discovered calcium carbide, a substance that reacts with water to give acetylene gas, which is used in cutting torches.



In 1828, Friedrich Wohler heated a compound called ammonium cyanate (NH_4CNO), which most chemists labeled as inorganic. When heated, the compound formed crystals that looked like crystals of urea ($CO(NH_2)_2$). Wohler tested the crystals and found that they were urea. Everyone agreed that urea was an organic substance and was separated from the blood by the kidneys and then passed out of the body as liquid waste. Wohler had made a product of the living processes of animals from a compound generally considered as inorganic. Friedrich Wohler immediately notified Berzelius of this discovery and convinced Berzelius that an organic compound had been synthesized. Soon other chemists learned of the discovery and raised some objections. The chemists argued that ammonium cyanate was not truly organic. Others pointed out that Wohler had accomplished only ***partial synthesis***, for he had not taken the smaller building blocks and put them together to make a larger structure. Instead, Wohler had taken a complex compound and rearranged it to form another compound of about the same complexity. Chemists challenged Wohler and other chemists to form organic compounds beginning with only carbon, hydrogen, oxygen and nitrogen.

All of these objections were set to rest in 1845 by Adolph Kolbe, a German chemist, who had studied under Friedrich Wohler. In 1845, Kolbe produced acetic acid ($C_2H_4O_2$). The sour taste of vinegar comes from acetic acid. All chemists agreed that acetic acid was an organic substance. Kolbe began with hydrogen, carbon and oxygen atoms and worked up to acetic acid as the final product. Starting with the elements to make a complex molecule is

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known as ***total synthesis***. Soon, other chemists made organic compounds in the laboratory, such as methyl alcohol, ethyl alcohol, methane, benzene and acetylene.

Chemists did not need to be concerned any longer that chemical laws in living things might be different from chemical laws in nature or the laboratory. Chemical laws applied equally well to organic compounds as to inorganic compounds. Elements can be combined in the nonliving environment, inside living tissue or in the laboratory. Regardless of where the reactions occur, chemical reactions follow the same set of chemical laws.

Adolph Kolbe himself produced an organic acid known as salicylic acid ($C_7H_6O_3$), which is found in many fruits and used in making aspirin.

As time passed, chemists made compounds that had all the properties of organic compounds but had not been produced by any living organisms. Examples of these laboratory produced organic compounds included dyes, perfumes and plastics. The term organic could also be used to describe such compounds. In 1861, August Kekule, a German chemist, pointed out that almost all organic compounds contained carbon. Chemists agreed with August Kekule that the suggested term *organic* be used for any compound that contained carbon.

An ***organic compound***, according to the modern definition, is any compound that contains carbon. Exceptions are carbon oxides, carbonates and a few other simple molecules. Carbon dioxide (CO_2), carbon monoxide (CO) and carbonates such as calcium carbonate ($CaCO_3$) and a few others are inorganic. With these limited exceptions, all other compounds that contain carbon are classified as organic. Organic chemistry is the chemistry of carbon compounds. Those compounds are an essential part of our daily lives. Food, vitamins, drugs, medicines, fuels, dyes, perfumes, flavors, detergents, plastics, rubber and fibers are all organic compounds because they contain carbon. Salt (NaCl), sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH) are not organic because they do not contain carbon. Sugar ($C_{12}H_{22}O_{11}$), urea ($CO(NH_2)_2$) and acetic acid ($C_2H_4O_2$) are all organic compounds because they contain carbon.



"This most beautiful system [The Solar System] could only proceed from the dominion of an intelligent and powerful Being."

—Isaac Newton

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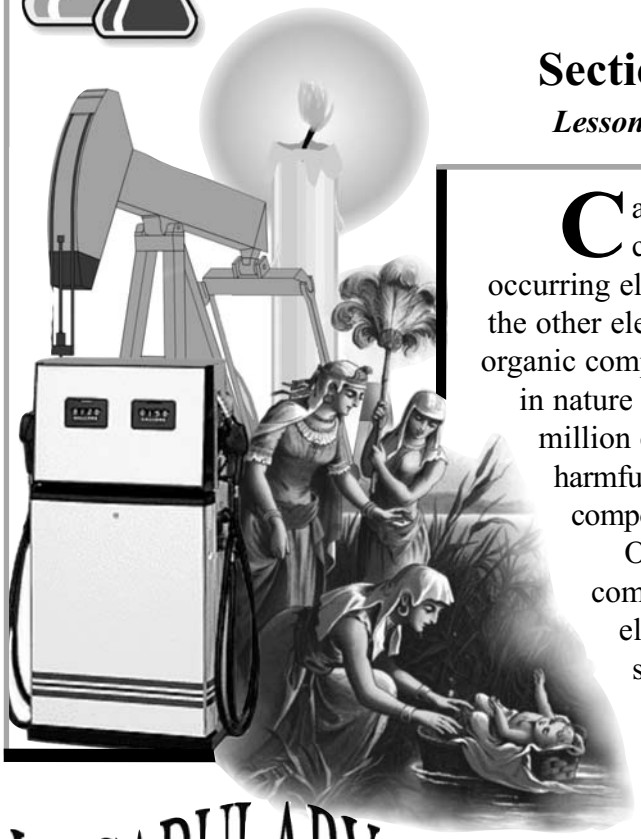
Lesson 2
Compounds

Chapter 8

HYDROCARBONS

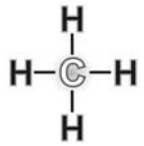
Section 1

Lessons 1-5



Carbon is the essential element in all organic compounds. Carbon is but one of the 92 naturally occurring elements. Yet, it forms more compounds than all the other elements together. The total number of known organic compounds increases every year as they are isolated in nature and synthesized in the laboratory. Today, 11 million chemicals have been studied for their benefits and harmful effects. The vast majority of these are carbon compounds.

One of the reasons carbon forms so many compounds is the way it forms bonds with other elements. Carbon has four electrons in the outer shell, and forms covalent compounds by sharing electrons. The simplest carbon compounds are ***hydrocarbons***, compounds containing only carbon and hydrogen. The simplest hydrocarbon is methane (CH_4), which contains one carbon atom and four hydrogen atoms.



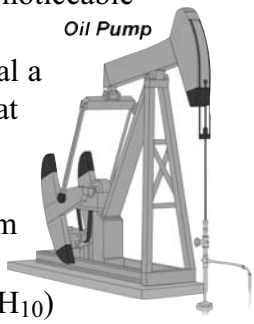
Methane (CH_4)

The diagram of methane (CH_4) is a ***structural formula***. It attempts to portray in two dimensions, how the three-dimensional methane molecule looks. Structural formulas show the type of atoms present, their numbers and how the atoms are arranged. Notice that the carbon atom in methane has four dashes around it. Each dash represents two shared electrons. By sharing with hydrogen, the carbon atom has eight electrons. The stable arrangement is like that of neon. Each hydrogen atom has one dash connecting it to carbon. By sharing with carbon, each hydrogen atom has two electrons. This stable arrangement is like that of helium.

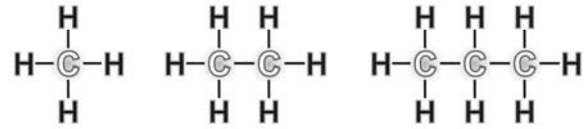
VOCABULARY

Hydrocarbon: an organic compound that contains only carbon and hydrogen
Structural formula: a diagram that shows how the atoms and the bonds of a molecule are arranged
Petroleum: crude oil, the source of natural gas, gasoline, fuel oils, lubricating oils, paraffin, petroleum jelly and asphalt
Pitch: a thick, sticky hydrocarbon substance; pitch occurs naturally and has been used as a waterproofing sealant and for torches

Methane is lighter than air, colorless, odorless and burns with a steady blue flame. It burns cleanly and completely. The product of the reaction of methane with oxygen is carbon dioxide and water. Methane is found in oil wells as natural gas and is a by-product of petroleum refining. Because it has so many desirable properties, methane is used as a home heating oil and fuel. A small amount of another substance with a noticeable odor, such as a sulfur compound, is added to reveal a possible leak in gas lines that supply fuel to homes.


Oil Pump

Hydrocarbons form chains. Next up the line from methane is ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) and so on. Adding one more carbon atom and two more hydrogen atoms to the previous molecule makes all of the elements in the series of hydrocarbons that begins with methane. If one carbon atom and two hydrogen atoms are added to methane (CH_4), the result is ethane (C_2H_6). Adding another carbon atom and two more hydrogen atoms gives propane (C_3H_8).


Methane (CH_4) Ethane (C_2H_6) Propane (C_3H_8)

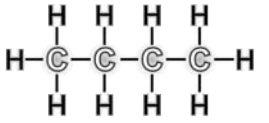
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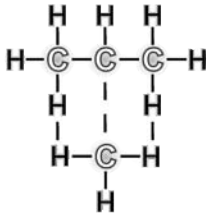
Methane family: the series of hydrocarbon chains that include methane, ethane, butane, propane, heptane and octane

Crack: to break longer hydrocarbon molecules into shorter ones, usually by heat

Methane, ethane, propane and those beyond them are examples of hydrocarbon chains. As the chains become longer, their properties change slowly. The first four are gases at room temperature. Those in the range of five to fifteen carbon atoms are liquids at room temperature. Those with sixteen or more carbon atoms are solids at room temperature. The chemical properties slowly undergo change, too. The gases are much more active chemically than the liquids and solids.

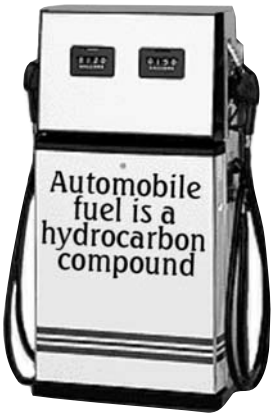
As the hydrocarbon chains get longer, they can have side branches. For instance, butane has four carbon atoms and ten hydrogen atoms. All of the carbon atoms can be arranged in a straight line, or some of the carbon atoms can form side chains. *Isomers* are compounds that contain the same elements in the same numbers but have different structural formulas. The two forms of butane, normal butane (C_4H_{10}) and isobutane (C_4H_{10}) are examples of isomers.


Normal Butane (C_4H_{10})


Isobutane (C_4H_{10})

As the number of carbon atoms increase, the number of possible isomers increases, too. Octane (C_8H_{18}) has eighteen isomers. The eight carbon atoms and eighteen hydrogen atoms can be put together eighteen different ways. A hydrocarbon chain with twenty carbon atoms and forty-two hydrogen atoms has more than a third of a million possible arrangements. The chain is so long that its side chains can have side chains. Forming isomers is one way that the number of carbon compounds is practically endless. Each one of these different arrangements is a different compound of carbon with slightly different

chemical properties. Hydrocarbon compounds, such as automobile fuel, diesel fuel, lubrication oil, petroleum jelly and paraffin are all hydrocarbon chains whose properties depend on the length of the chains and the number and type of isomers. Side branches cause slight changes in how the compounds react. Isomers of the same compound have chemical and physical properties that differ from one another.



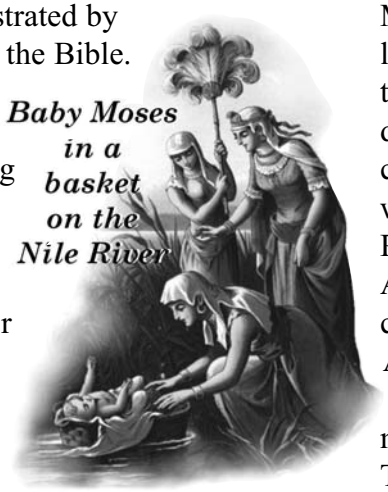
Motor fuels are mixtures of liquid hydrocarbon chains of the methane family. A part on the motor called a carburetor mixes the gasoline with air, and then the mixture is drawn into the cylinder and ignited by a spark. The expansion of the burning gases in the cylinder drives the piston. The air and fuel mixture can ignite too soon or too violently, causing some fuels to burn so rapidly that they cause a pinging sound, known as *engine knock*. This can damage the engine and reduce engine power. Engine knock can be avoided. Heptane is one of the hydrocarbons in gasoline. Heptane has seven carbon atoms and sixteen hydrogen atoms (C_7H_{16}). The prefix *hep* means *seven.* Heptane alone burns much too quickly. To avoid engine knock, an isomer of octane is blended with heptane. Isooctane has eight carbon atoms and eighteen hydrogen atoms (C_8H_{18}). The prefix *iso* shows that it is an isomer, and the letters *oct* mean *eight.* Isooctane has three side chains. It burns hot and without a sudden explosion. Compared to heptane alone, blending isooctane with heptane improves the performance of gasoline. Isooctane burns briskly and at the right moment.

The *octane rating* of a fuel measures how well it performs compared to a standard mixture of heptane and isooctane. Normal heptane has an octane rating of zero, and pure isooctane has an octane rating of one hundred. Chemists found that they could improve the octane rating of a fuel, without using the more expensive isooctane, by introducing other chemicals such as tetraethyl lead. The fuel burned better without containing as much of the more expensive isooctane. Special purpose gasolines may have octane ratings higher than one hundred.

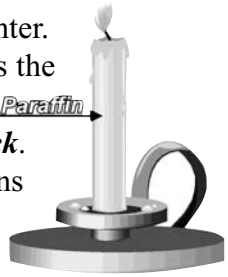
As an engine runs, the burning of the fuel may be incomplete. Rather than producing carbon dioxide and water, the reaction may release unburned hydrocarbon and carbon monoxide into the exhaust. In the 1970s, catalytic converters were installed in automobiles to help eliminate unburned hydrocarbons. The catalytic converter completes the combustion and converts unburned hydrocarbons and carbon monoxide into less harmful compounds. The catalytic converters did not function properly with fuels containing tetraethyl lead. Lead-free gasoline was then introduced to overcome this problem. At the same time, lead was identified as a significant air pollutant. Today, all automobiles manufactured in the United States must be able to burn lead-free fuels.

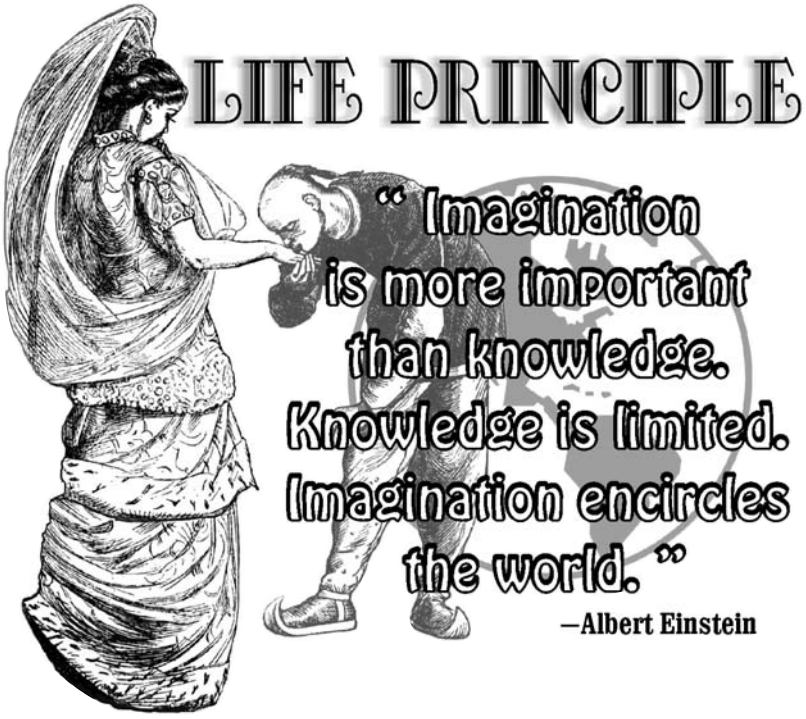
Gasoline is refined from ***petroleum***. Petroleum is a liquid that is usually found underground. Sometimes pressure drives petroleum to the surface, and it dries in the sunlight. The lighter hydrocarbon molecules vaporize leaving behind ***pitch***, a thick, sticky tar-like substance. Pitch was noticed thousands of years ago and put into use as a sealant. Pitch was smeared on roofs to keep out rain and put in seams of boats to keep them from leaking. Pitch also would burn. As a result people dipped sticks in the substance to make torches.

The fact that pitch was being used in ancient times is illustrated by two stories found in the Bible. The story of Noah and the Ark describes Noah using pitch to seal the ark. Also, when the Egyptian Pharaoh ordered the slaughter of all newborn Hebrew boys. Baby Moses was then concealed in a basket floating on the Nile. The basket was made of bulrushes and sealed with pitch to make it waterproof.



The ***methane family*** of hydrocarbons is also known as the paraffin series. The word *paraffin* comes from two Latin words that mean *does not mix well with others.* Most people use the word paraffin for the longer molecules that are solid at room temperature. Paraffin is relatively inert and does not stick to other substances. Paper is coated with paraffin to make a nonstick, waterproof covering known as wax paper. Paraffin is also used today to make candles. A candle is a stick of paraffin with a cotton cord or wick down its center. As a wick burns, the heat causes the longer hydrocarbon molecules to break apart or ***crack***. These molecules of shorter chains vaporize and rise to the candle flame and burn.





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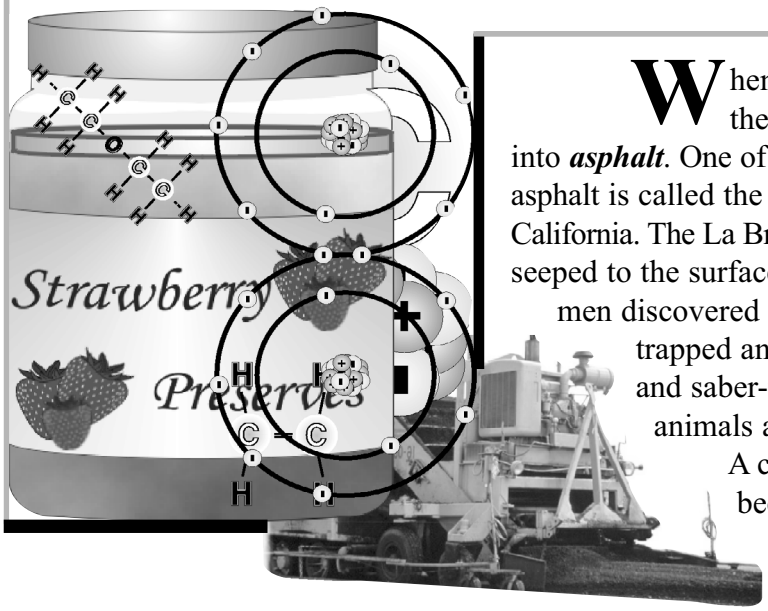
Lesson 3
Compounds

Chapter 8

SATURATED AND UNSATURATED HYDROCARBONS

Section 1

Lessons 1-5



When crude oil (petroleum) is exposed to the air and sunlight, petroleum changes into ***asphalt***. One of the best known natural deposits of asphalt is called the La Brea tar pits in Los Angeles, California. The La Brea tar pits were formed when petroleum seeped to the surface. The tar pits became famous when men discovered ancient animals that had become trapped and preserved in the pits. Mastodons and saber-toothed tigers as well as other animals are preserved in the thick hydrocarbon. A common belief is that smaller animals became trapped in the sticky oil, and then when larger predators tried to attack the small prey, the predators also became trapped.

Although asphalt does come to the surface in some places, most asphalt comes from the refining of hydrocarbon products. Asphalt is what remains after petroleum has been refined into gasoline and other products. Asphalt is a solid or semisolid at room temperature. Asphalt becomes a liquid when heated and can be poured to make roofing material, surfaces of roads, floor tile and linoleum. Asphalt is also used to seal the inner surface of water reservoirs. About three-fourths of the asphalt produced in the United States goes into highway construction.

Hydrocarbons are compounds made entirely of carbon and hydrogen atoms. The simplest hydrocarbon is methane (CH_4) made of one carbon atom and four hydrogen atoms. The second member of the methane series is ethane (C_2H_6) with two carbon atoms and six hydrogen atoms. As hydrocarbon chains become longer, the molecules become heavier and change from gases at room temperature into liquids and finally into solids. Longer molecules have higher boiling temperatures. As the boiling temperatures of molecules increase, their

VOCABULARY

Asphalt: a tar-like heavy petroleum product used in paving, roofing and waterproofing
Insoluble: incapable of being dissolved in water
Alkane series: hydrocarbon chains with no double or triple bonds between carbon atoms, including methane (CH_4)
Saturated: a hydrocarbon that cannot accept any more hydrogen atoms, a saturated hydrocarbon has only single bonds

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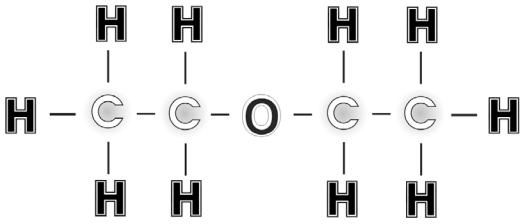
chemical activity decreases. The molecules become more inert. Molecules with sixteen or more carbon atoms ($C_{16}H_{34}$ and longer) are solids at room temperature. They are inert, waxy solids known as paraffin.

The entire series of hydrocarbons that begins with methane is sometimes called the paraffin series. The paraffin series is the least reactive group of all hydrocarbon compounds. The series from methane to the long molecules has only a slight tendency to mix with water. Paraffin is waterproof; so hydrocarbons such as paraffin are ***insoluble*** in water, which means they will not dissolve in water. Women sometimes preserve homemade jams and jellies in jars sealed with paraffin. After filling the jar nearly to the top with the food to be preserved, a layer of melted paraffin is poured in, which floats on top and then hardens to seal the contents. Paraffin is so inert, it does not react with the jam or jelly being preserved. While not recommended, paraffin itself is not harmful if eaten.



Suppose gasoline, a hydrocarbon which contains mostly heptane and octane, is mixed with water and shaken. Once it is allowed to stand, the gasoline separates. The gasoline and water will then form two layers. The gasoline floats on top because it is less dense than water. Gasoline molecules, like all of the hydrocarbon molecules, are not polar. Electrical properties are evenly distributed. They have no positive or negative regions that give water a place to grip to tear them apart.

When grease drips on clothing, dabbing it with water will not remove the grease because it does not react with water; however, other carbon compounds will react with grease. The best known solvent of hydrocarbons is diethyl ether $(C_2H_5)_2O$ which reacts with the grease on clothing without harming the clothing. The reaction turns the hydrocarbon into a volatile gas that evaporates. Once the grease spot is treated with diethyl ether (which is also a volatile gas), the ether and the grease turn to a vapor and float away. The only danger is that diethyl ether is more explosive than gasoline and has to be treated with care.



diethyl ether $(C_2H_5)_20$)

The methane series is also known as the ***alkane series***. The alkane series is the name preferred by chemists. The name *alkane*, like the names for the members of the series, ends with the three letters *ane*. Examples of the alkane series are methane, ethane and butane. An alkane is fully ***saturated*** with hydrogen atoms. It cannot accept any more hydrogen atoms. In a saturated molecule, every carbon atom has

VOCABULARY

Unsaturated: a hydrocarbon that has at least one double or triple bond and can accept additional hydrogen atoms
Alkene series: hydrocarbon chains with at least one double bond between two carbon atoms, alkenes are unsaturated, and the lightest alkene is ethylene (C_2H_4)
Polyethylene: a large molecule that is built of ethylene molecules
Plastic: a substance that can be formed when hot and retains that shape when cooled

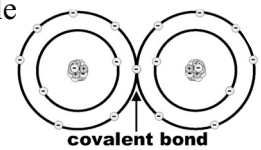
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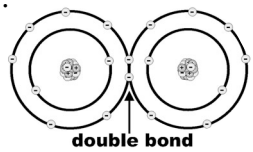
single bonds, either to other carbon atoms or to hydrogen atoms. All of the bonds in an alkane molecule are made of single pairs of shared electrons.

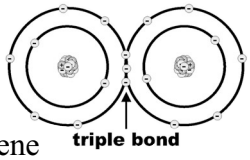
The next member in the alkane series always has one additional carbon atom and two additional hydrogen atoms. For instance, heptane is C_7H_{16}, and octane is C_8H_{18}. The general formula for an alkane is C_nH_{2n+2} with *n* the number of carbon atoms and 2n+2 the number of hydrogen atoms. Octane has eight carbon atoms. The number of hydrogen atoms is 2*8 + 2 = 18. This formula is easy to understand. Every carbon atom in the middle of the chain connects to two hydrogen atoms. The two carbon atoms at the ends of the chain connect to a third hydrogen atom. To calculate the number of hydrogen atoms in an alkane, multiply the number of carbon atoms by two and then add two more atoms.

Example: A long alkane hydrocarbon has 24 carbon atoms. By using a formula, the number of hydrogen atoms can be found. The number of carbon atoms is $n = 24$, and the number of hydrogen atoms is 2*n + 2 = 2 * 24 + 2 = 48 + 2 = 50. The formula is $C_{24}H_{50}$.

Saturated hydrocarbons such as ethane (C_2H_6) have only single covalent bonds between carbon atoms, *C* — *C*. An ***unsaturated*** molecule still has room for hydrogen atoms. Some of the carbon atoms must have double bonds with their neighbors. An unsaturated hydrocarbon has double, *C*=*C*, or triple, *C* ≡ *C*, covalent bonds between carbon atoms. The first member of this family is ethylene (C_2H_4). The structural formula uses the double dash = to show a double bond between the two carbon atoms. The double bond represents two pairs of electrons (four electrons total)

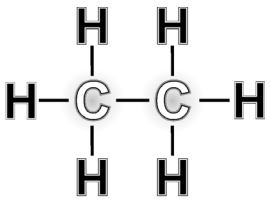




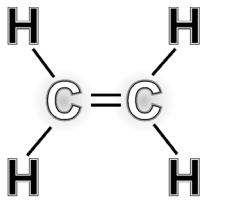


that are being shared between the two carbon atoms. Compare the structural formula of ethane, which is saturated with ethylene, which is unsaturated:

The double bond puts more strain on



ethane (C_2H_6)



ethylene (C_2H_4)

the electrons holding the carbon atoms together than does the single bond. In the ethane molecule, the electrons are evenly distributed around the carbon atom. In ethylene, the electrons are warped out of their more stable location. For that reason, the double bond is more likely to be broken during chemical reactions. Ethylene is more chemically active than ethane.

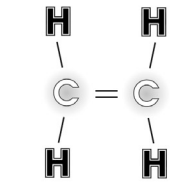
The ***alkene*** series is made of hydrocarbon chains with at least one double bond between carbon atoms, C = C. The names for the alkene members are similar to the names for the alkanes, except they match alkene by ending in *ene*: ethylene (C_2H_4), propene (C_3H_6), butene (C_4H_8) and so on. The general formula is C_nH_{2n} with *n* the number of carbon atoms and *2n* the number of hydrogen atoms. Every carbon atom is matched with two hydrogen atoms.

One double bond is required to form an alkene. The alkene series can be a long chain, or the series can have isomers with side chains. The double bond can be located anywhere along the main chain or on the side chains. The location of the double bond changes the chemical properties of the molecule. Longer molecules can have thousands of structures, and each structure can have the double bond in hundreds of

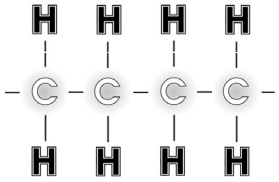
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different places. This helps explain why the organic (carbon) compounds can be so numerous.

Suppose the double bond of ethylene is broken, and the carbon atoms form bonds with carbon atoms in neighboring ethylene molecules. Rather than a string of individual ethylene hydrocarbon chains, the result would be a gigantic series of chains all woven together. This is how the plastic ***polyethylene*** is formed. Ethylene molecules are put under high heat and pressure, causing the double bond to break. The high pressure forces the molecules closer together as the ethylene molecules link to their neighbors.



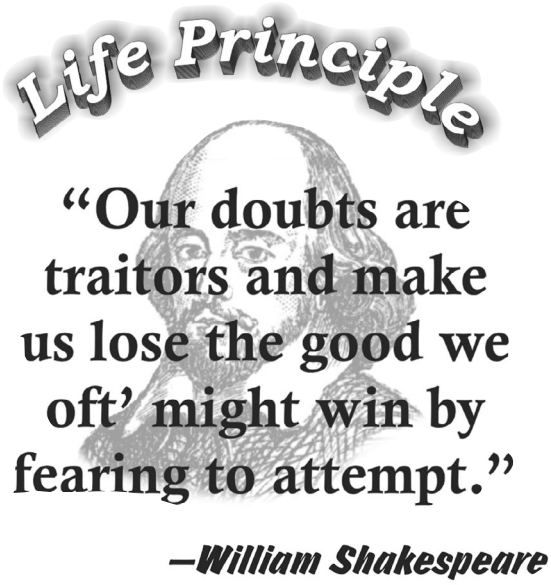
ethylene (C_2H_4)



polyethylene (C_2H_4)

The result is polyethylene. The word *poly* means *many*. Polyethylene is made of many ethylene molecules connected together.

Polyethylene is a cloudy white solid with a waxy feel. It is flexible, tough and inert. Polyethylene can be softened by heating and can be reformed into a variety of shapes. Once cooled, it keeps the new shape. Polyethylene is a plastic, which means *capable of being molded*. Polyethylene can be formed into plastic toys, plastic bags and containers. For example milk is sold in white, translucent plastic jugs made of polyethylene. It is also used for grocery bags, pipes and gasoline tanks for automobiles. Polyethylene was manufactured in the laboratory by chemists. Although polyethylene is an organic (carbon) compound, it does not occur naturally.



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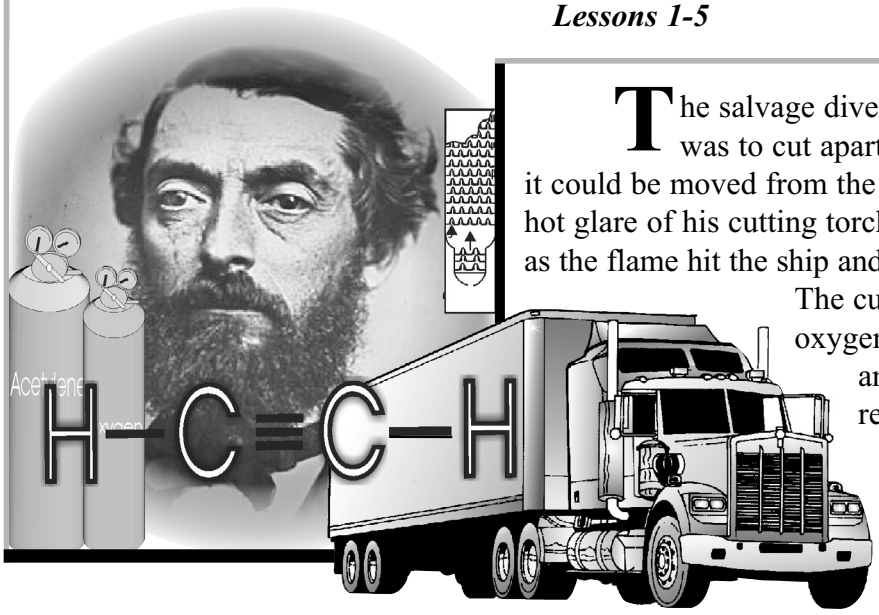
Chapter 8

Lesson 4
Compounds

BLACK GOLD

Section 1

Lessons 1-5



The salvage diver worked underwater; his job was to cut apart the hull of a sunken ship so it could be moved from the shipping lane. In the white-hot glare of his cutting torch, the water turned to steam as the flame hit the ship and sliced through the steel hull. The cutting torch used a mixture of oxygen and acetylene gas. Oxygen and acetylene gas react so readily they burn underwater.

Acetylene is a hydrocarbon. Although the name *acetylene* ends in *ene,* it is not a member of the alkene series. Chemist prefer to call acetylene by its more correct chemical name, *ethyne*. It has a simple structural formula:



acetylene (ethyne (C_2H_2)

Acetylene is highly unsaturated and has a minimum number of hydrogen atoms. It has too few hydrogen atoms to provide four single bonds for each carbon atom. Acetylene is even more unsaturated than ethylene. A lot of energy is contained in the triple bond that holds the acetylene carbon atoms together. When the triple bond is broken, the energy is then released as heat. Acetylene burns hotter than either ethylene or ethane. When burned with oxygen gas, acetylene makes one of the hottest flames known.

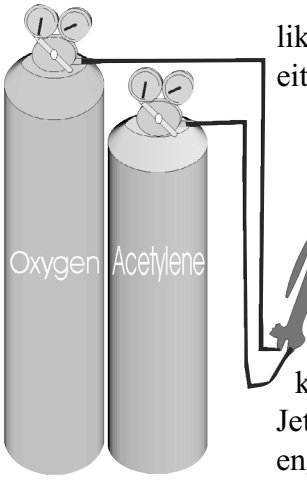
An oxyacetylene torch combines oxygen gas and acetylene gas in the right mixture. When the mixture is set on fire, the flame reaches about 2,700ºC. Oxyacetylene can be used for welding and cutting because the heat that it produces will melt through steel. Because oxygen is supplied to the

VOCABULARY

Crude oil: comes from the ground as petroleum, not refined
Tonic: a medication that is sold with the claim that it provides a variety of health benefits and restores body tone
Shale: a rock that separates into sheets, kerosene was originally extracted from shale by heat and pressure
Kerosene: a liquid hydrocarbon petroleum derivative used as a fuel for heating, cooking and in lamps, kerosene is heavier than gasoline but lighter than fuel oil
Impervious: cannot be penetrated

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acetylene, it can operate under water. When acetylene is mixed with oxygen in the air, acetylene can explode violently. It is seldom used for lighting today; however, it is used in cutting torches and making other organic products.



Organic compounds are an essential part of everyday life and can be found in motor fuel, heating oil, coal, food, cotton, man-made fibers, plastic, rubber, dyes, pigments and cosmetics. Almost all are organic, and all of them contain carbon. Many compounds occur naturally, while others are synthetic. Some of the naturally occurring compounds are not abundant. Although available in nature, they are often made synthetically, too.

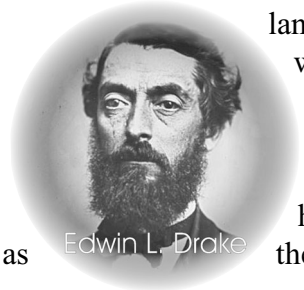
One important raw material from which carbon products are made is petroleum or ***crude oil***. Until the middle of the 1800s, crude oil served few useful purposes. In a few places, pressure forced the crude oil to the surface, where it collected into pools. Farmers considered the sticky, foul smelling substance a nuisance. A few ambitious salesmen bottled the oil and sold it as a ***tonic***, claiming that it would restore the body to better health by treating a variety of ailments.

Lamps of that day burned oil made from the fat of whales. In 1847, James Young, a Scotsman, made oil for lamps from coal. He called it *coal oil*. At about the same time, a geologist in Canada heated ***shale*** and extracted the oil. This product became known as ***kerosene***. Both kerosene and coal oil are liquid hydrocarbons. The hydrocarbon chains in kerosene are slightly longer and heavier than those in gasoline. Kerosene is slightly harder to ignite than gasoline, and is not quite as likely to burn or explode. Lamps could burn either coal oil or kerosene in place of whale oil. Kerosene was cheaper, burned brighter, smelled cleaner and was less messy than whale oil. Beginning in the 1850s, kerosene replaced whale oil in lamps. Kerosene was used extensively in rural areas until well into the 1940s. Portable kerosene heaters, also known as space heaters, are still used today. Jet aircraft engines burn kerosene in their engines.

Today, most kerosene is made from petroleum, as are most other motor fuels, heating oils, and other products such as lubrication oil and candle wax. Crude oil, or petroleum, is the second most common liquid on earth, behind water. The word *petroleum* comes from *petro,* meaning *rock* and *leum* meaning *oil*. Petroleum is rock oil.

Petroleum is believed by many scientists to be formed by the decomposition of tiny organisms in the sea. The sea organisms are trapped in the sediment as the mud hardens into shale. The crude oil forms in the shale. Forces acting on the rock push the crude oil up until it reaches an ***impervious*** layer of rock. A pocket of crude oil forms when it cannot rise through an impervious layer of rock. Usually, the pressure causes the rock to form a dome like an upside down saucer.

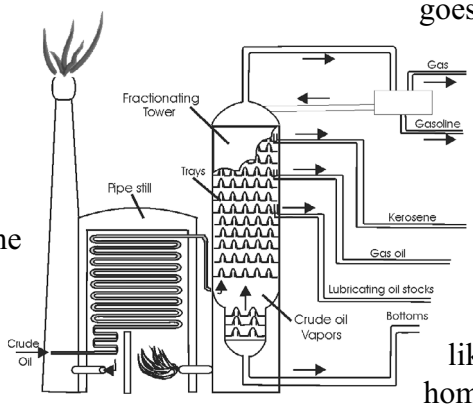
In the 1850s, the success of kerosene began a search for other sources of crude oil. Until then, folks kept away from land with oil on the surface. The black slime turned the water bad and killed crops. The same land suddenly became valuable when Edwin L. Drake invested in a firm that collected oil from seepage near Titusville, Pennsylvania. Mr. Drake believed he could pump oil from below the ground. Drake began drilling



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in June 1859 along Oil Creek in Titusville, Pennsylvania. The creek had a few oil seeps along its course.

On August 27, 1859, Drake struck oil at a shallow depth of only 69.5 feet. Drake's well was the first successful oil well in the United States and produced 25 barrels of oil a day. As a result, other prospectors began drilling, too. They refined the petroleum for lamps and heating oil. Kerosene remained the main product of petroleum until the invention of the automobile.



Internal combustion engines in automobiles ran better on a lighter weight, more volatile version of the hydrocarbon chains that come from petroleum. Gasoline, like kerosene, can be derived from petroleum. Because of its value, people have given crude oil the name *black gold*.

Petroleum contains molecules of all lengths, from short methane to heavy molecules with more than 30 carbon atoms. Rather than separating petroleum based on each individual molecule length, crude oil is separated by groups of molecules based on their use. Each group is a fraction or part of the total. The purpose of an *oil refinery* is to separate the petroleum fractions and process the fractions into useful products.

Natural gas is the lightest fraction. It is made of methane, propane and other hydrocarbons that are gases. Some of these gases are released when the oil is first pumped from the well. The gases are caught and distributed by natural gas pipelines throughout the United States. Homes use natural gas for heating and cooking. Because natural gases are clean burning, some fleets of city delivery vehicles and buses have been converted to burn natural gas.

Gasoline is the first liquid fraction. Gasoline is a liquid at room temperature and is made of hydrocarbons with five to ten carbon atoms. About half of all petroleum goes into making gasoline.

Kerosene is the next liquid fraction. Kerosene molecules are longer than those in gasoline and have from about eleven to fourteen carbon atoms. Kerosene is used as jet fuel and as heating oil in home furnaces. Heating oil does not burn as easily as gasoline, and it is less likely to explode, making it better for home use.

Fuel oils, such as diesel fuel, are heavier still. These fuel oils are normally liquids but are so heavy that in cold weather the fuels can turn to a jelly-like substance. Diesel fuel is not as flammable as gasoline or kerosene, making diesel difficult to ignite, especially in winter. To overcome this problem, each combustion chamber of a diesel engine has a glow plug. Electricity runs through the wires in the glow plug to heat the chamber, making the diesel motor easier to start in cold weather.



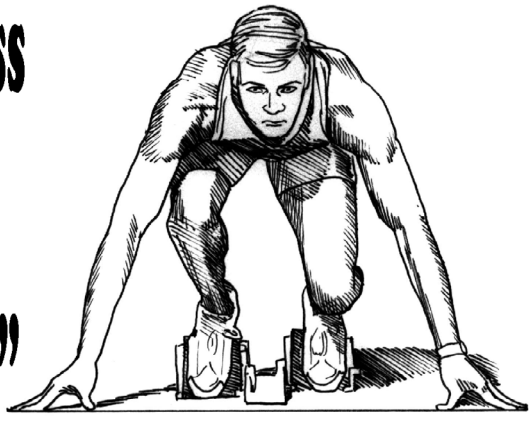
Lubricating oils and greases are solids or semisolids. These thicker oils act as a cushion between the moving parts of an engine. Grease keeps the metal surfaces from rubbing against one another, reducing friction. Petroleum jelly, known by the brand name of Vaseline, is even thicker than grease and is a solid. It is an odorless and tasteless jelly-like substance. People rub petroleum jelly on dry skin and chapped lips as ointment.

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Asphalt for roads, roofing shingles and paraffin used to make candles are the heaviest fraction because they are solids. The difference between paraffin and asphalt is that paraffin is made of saturated hydrocarbons. Paraffin has no double or triple bonds among the carbon atoms. Asphalt contains unsaturated hydrocarbons. Molecules of asphalt have double and triple bonds.

Life Principle

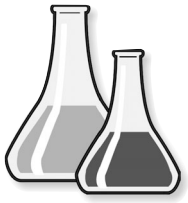
"You will never possess what you are unwilling to pursue."



—Anonymous

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Integrated Physics & Chemistry



Lesson 5
Compounds

Chapter 8

BENZENE

Section 1

Lessons 1-5



Of all the hydrocarbons, *benzene* presented the greatest mystery to chemists who tried to understand its structure. The formula for benzene is simple: C_6H_6. With only hydrogen atoms to bond with six carbon atoms, benzene was clearly *unsaturated*. It had to have some ***double bonds*** or ***triple bonds***. Benzene should be an active compound because double and triple bonds cause greater chemical activity. Yet, benzene is less active than other carbon compounds with single bonds. No matter how chemists arranged the atoms, the resulting structural formula did not match the properties of benzene.

Michael Faraday discovered benzene in 1825. He had just become director of the chemical laboratory that was started by Humphry Davy. Faraday isolated benzene from crude oil that had come to the surface. Pure benzene is a colorless liquid with a pleasant odor and a burnt taste. Although it would not dissolve in water, benzene proved to be an excellent solvent for other organic compounds. As he experimented, Faraday found other organic compounds that contained benzene. Because of their unusual properties, Faraday placed all benzene containing compounds in a category by themselves. The natural compounds had a noticeable and pleasant aroma, so Michael Faraday called them *aromatic compounds*. The word *aromatic* means *pleasant smelling*. As other benzene compounds were found or made in the laboratory, many of them had no smell. Aromatic compounds as a category were named for the aroma of the compound, but, today, they are called aromatic compounds because they contain benzene.

Benzene could be refined from coal. In earlier days, coal was baked in ovens to change it to *coke* for use in the steel industry. The vapors that were released were collected and

VOCABULARY

Double bond: a covalent bond in which two pairs of electrons (four electrons) are shared between two atoms
Triple bond: a covalent bond in which three pairs of electrons (six electrons) are shared between two atoms
Dye: a substance, usually organic, that gives a fabric a color that does not fade or wash out easily
Derive: to produce one compound from another
Quinine: an organic compound derived from the bark of a South American tree, used to treat malaria

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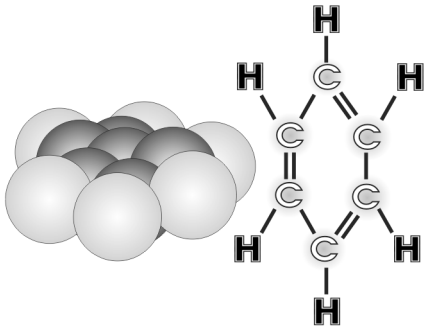
condensed to give an oily residue that contained benzene. Only a small amount of benzene could be taken from a ton of coal. However, benzene was a by-product that had previously been discarded.

As time passed, chemists found more uses for benzene. William Henry Perkin was an English chemistry student who experimented in his home laboratory during vacation from school. He made the first artificial ***dye*** from *aniline*, a compound that is built from benzene. Perkin's experiment and success began a rush of other chemists to make artificial dyes, flavors and perfumes. Almost all of these products were ***derived*** from benzene. The need for chemists to understand benzene became increasingly important.



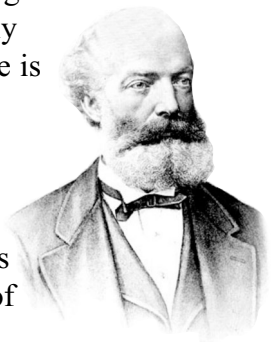


Friedrich Kekule, a German chemist, suggested that the term organic be used for carbon compounds. He was immersed in the idea of drawing the structure of organic compounds. Kekule worked with his structural diagrams for countless weeks. He could almost do it in his sleep. In fact, that is how he found the structure of benzene. After weary hours of working on the problem of benzene, Friedrich decided to put aside his drawings and go ride in a horse drawn bus through the city streets of Heidelberg. When he began to fall asleep, visions of carbon and hydrogen atoms whirled around in his mind. They took on a life of their own and became six little monkey-like animals mocking his failure. Then, according to Kekule's own telling of the story, the monkeys began whirling around and around. One monkey grabbed the tail of the other and soon the six monkey-like animals formed a spinning ring. Friedrich awoke with a start and drew the diagram given to him in the dream:



benzene (C_6H_6)

Benzene is a closed loop with six carbon atoms, having three double bonds that alternate with three single bonds. A single hydrogen bond is attached to each carbon atom. Even today, chemists still argue about how the electrons are shared among the six carbon atoms. Some chemists have done tests that seem to show that the double bonds are temporary and move from one pair of carbon atoms to the next. Other chemists interpret their experiments to mean that the electrons are never under the control of a single pair of carbon atoms but instead flow all the way around the molecule. Although the details are not yet completely settled, undoubtedly benzene is a ring.



Friedrich Kekule announced his model of the benzene structure in 1865. Within a few years, chemists synthesized a large variety of

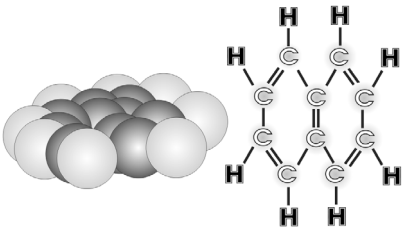
VOCABULARY

Malaria: a tropical disease whose victims suffer cycles of chills followed by fevers and profuse sweating

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artificial compounds such as dyes, perfumes, drugs and plastics. Benzene serves as the starting resource for a great number of other organic compounds. Each hydrogen atom can be replaced with another atom or group of atoms. Each benzene ring can connect to a neighboring ring or to a ring that has been modified in another way. The number of benzene based molecules is as limitless as the number of carbon molecules that are in chains. In fact, about half of all organic (carbon) compounds have ring structures.

Two or more rings of benzene can join like the cells in a honeycomb. Naphthalene ($C_{10}H_8$) is the simplest such compound. It is derived from two benzene rings that are pushed together so they share a common side. Naphthalene is a white solid that was first used as mothballs. In a closed container, mothballs release vapors that kill moth larvae. Naphthalene is an important ingredient in plastics, dyes and insecticides.



naphthalene ($C_{10}H_8$)

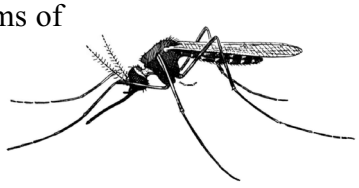
Another example of a modified benzene ring is aniline. In this compound, a single hydrogen atom is removed from benzene (C_6H_6) and the NH_2 group ($C_6H_5NH_2$) takes its place. William Henry Perkin made the first artificial dye, *aniline purple*, from aniline. Today aniline is still used in making dyes. Aniline also goes into polyurethane plastics and is the starting point for the sulfa drug sulfanilamide.

A *synthetic* compound is a compound that is made in the laboratory by combining elements or groups of elements. A synthetic compound is one that does not exist in nature. It is a new compound with properties never before seen. Other synthetic compounds are identical to ones found in nature. Some clothing items are made from natural substances such as cotton, wool, linen, silk, leather and rubber. Other clothing is synthetic or man-made, such as polyester, nylon and neoprene. Making a compound in the laboratory may be preferred because it can be generated more cheaply and in greater abundance with less impact on the environment, or it is not available any other way.

Sometimes synthetic compounds have to be made because a country has no other option. During World War II, Germany's fuel supply decreased as a result of the Allied troops cutting off the country's usual sources of petroleum. Germany resorted to a synthetic fuel made from potatoes. When the United States lost access to rubber plantations in the South Pacific, she in turn began a program of developing synthetic products that could be substituted for rubber which was used to make tires and hoses.

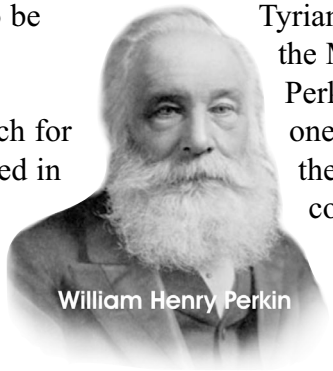
The first person to start an entire industry based on a synthetic product was William Henry Perkin in 1856. Perkin grew interested in chemistry after attending lectures presented by Michael Faraday. After the lectures, William Henry Perkin decided to become a chemist. He attended classes taught by August Hofmann, a German chemist, who taught at the Royal College of Chemistry in London. Like Michael Faraday, August Hofmann gave exciting lectures and sparked the imagination of his students.

One day, August Hofmann suggested that ***quinine*** could be made synthetically. Quinine is a valuable drug used to reduce the fever and symptoms of ***malaria***, a severe disease passed on by mosquitoes.



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Quinine is made from the bark of a South American tree. So much of the bark had been stripped from the trees to make quinine that the trees had begun to die. The price for quinine medication became excessive. England needed a synthetic supply that was cheaper and more readily available, should the natural supply continue to be reduced.


William Henry Perkin

During vacation from school, Perkin began the search for a quinine substitute. He worked in the laboratory he had built at his home when he was still a teenager. Chemists know now that making synthetic quinine is extremely difficult. More than 80 years would pass before it could be made in sufficient quantity and at a low enough price to replace the natural variety.

William Henry Perkin did not know his quest was doomed to failure, so he continued to experiment. In one trial, Perkin treated aniline ($C_6H_5NH_2$) with potassium dichromate ($K_2Cr_2O_7$). The reaction created a gummy mess. As he started to toss out the products of the reaction, he noticed a purple color. He extracted the color by soaking it in alcohol. The alcohol solution turned an intense purple color. He sent a sample to a textile company in Scotland and asked if it would serve as a dye.

A dye colors fabric and does not wash out. All dyes used previously came from insects, roots and leaves of plants and marine animals. The best-known purple dye was Tyrian purple that came from a shellfish in the Mediterranean Sea. William Henry Perkin's dye was as vivid as the natural one. The textile company in Scotland said they would buy the dye from him if he could manufacture it in quantity.

William Henry Perkin put aside his plans to make quinine. He and his father began the task of building an entire factory to manufacture the first synthetic dye called *aniline purple*. Perkin worked out the process of making the dye starting with benzene. For almost twenty years, Perkin devoted his time to the dye factory. He became independently wealthy. Chemists greatly admired his skill and success. The highlight for William Henry Perkin came when he was asked to deliver a lecture to the London Chemical Society. In attendance to hear him speak was Michael Faraday, the famous chemist whose lectures had inspired Perkins to become a chemist.

Life Principle

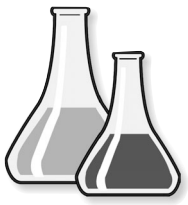
"Little minds are tamed and subdued by misfortune; but great minds rise above them."

–Washington Irving



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Integrated Physics & Chemistry



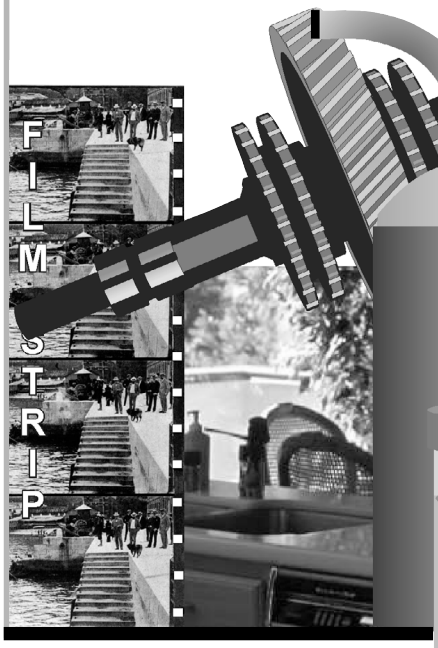
Lesson 6
Compounds

Chapter 8

ORGANIC ACIDS AND ETHERS

Section 2

Lessons 6-10



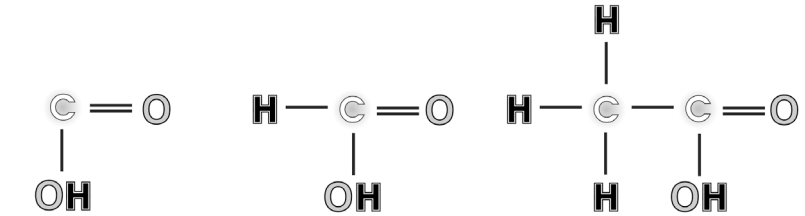


For some people, a bee sting is nothing more than an irritating nuisance. For others who are allergic to the chemical in the sting, it can cause breathing problems or even death. The bite of an ant can also range from a slight burning sensation to a medical emergency. In the United States, one of the most harmful pests among insects is the fire ant, noted for its aggressive behavior and painful sting. Fire ants are slowly making their way north after being imported from South America. In some southern states, the ants are so aggressive that they kill livestock.

The sting of bees and wasps and bites of fire ants all contain an *organic acid*. Organic acids have a formula that contains *OH*, but they are not alcohols. The complete functional group in organic acids is not *OH* but *COOH*, the ***carboxyl group***. The carbon has a double bond with the oxygen and a single bond with the hydroxyl. Acids in this series include formic acid and acetic acid.

VOCABULARY

Carboxyl group: the group *COOH* that is the characteristic of an organic acid
Formica: Latin word for ant, Formica is a brand name for a plastic derived from formic acid
Acetone: an organic solvent, C_3H_6O; a ketone that has the oxygen in the middle of the molecule; not an organic acid
Acetate: a type of plastic derived from acetic acid
Lactic acid: the organic acid that gives spoiled milk its sour taste



Formic acid (HCOOH) is the simplest of the organic acids. It is best known as the chemical that causes the pain from a bee or wasp sting and the burning caused by ant bites. Formic acid is a liquid that has a sour taste, a sharp smell and irritates the skin. It was first prepared from ants. The Latin name for ant is ***formica***.

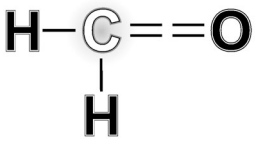
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The plants known as stinging nettles have stems filled with formic acid, which can irritate exposed skin. A hiker who brushes against them hard enough to break the needles will feel a burning sensation as the acid gets in the scratches.

Formic acid is used in the chemical industry for tanning hides, for dyeing fabrics, and for producing of the plastic Formica. Formica gives a durable finish to kitchen and bathroom counter tops. It is heat resistant, chemically inert and impervious to water. Clean up of spills and stains is easy.



Closely related to formic acid is *formaldehyde* (HCHO). It has a structural formula similar to formic acid, but with an *H* where the *OH* is located. It is not an organic acid because it is lacking the *COOH* group.

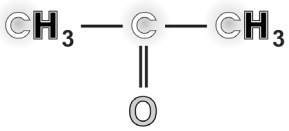


formaldehyde (CH_2O)

Because of the double bond in formaldehyde, it is chemically active. Formaldehyde is a gas with a very strong, irritating odor. It irritates the membranes of the eyes, nose and throat. Formaldehyde gas can be dissolved in water to give a solution that is particularly effective in preserving tissues and organs. The solution kills the cells, hardens the tissue and kills any microorganisms that might attack the tissue. Formaldehyde is used in embalming fluids and in zoology and anatomy laboratories to preserve specimens. The tissues become hard like wood and can be cut into thin sections for study with a microscope. Formaldehyde is also used in laminated wood paneling. The area where formaldehyde is used should be well ventilated if used indoors because formaldehyde is very poisonous.



Acetone has an oxygen atom double bonded with carbon, but it is connected to the carbon in the middle of the chain rather than at the end as in formaldehyde. The structure for acetone can be shown as:



acetone (C_3H_6O)

Acetone is a good solvent of organic material and is completely soluble in water. It is the main ingredient in fingernail polish remover. Acetone is also used in the chemical laboratory to clean test tubes and beakers. It will dissolve a wide variety of organic compounds that resist the action of water. Acetone is volatile and evaporates quickly. Glassware rinsed in acetone dries quickly.



Acetone cleans greasy car parts very effectively. However, one must use it in a well ventilated area, wear protective gear and take precautions to avoid fire.

VOCABULARY

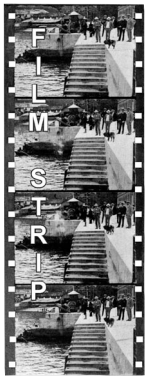
Butyric acid: the organic acid that gives butter its rancid smell
Ether: an organic compound with an oxygen molecule between two hydrocarbon chains

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Neither formaldehyde nor acetone is an organic acid. They do not possess the *COOH* functional group that is a characteristic of an organic acid.

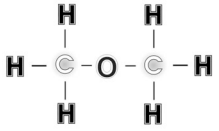
Returning to the organic acids, the next one in complexity is *acetic acid* (CH_3COOH) with the structural formula shown earlier. It is related to ethanol (ethyl alcohol, grain alcohol, C_2H_5OH). When grain alcohol is exposed to the air, certain bacteria change the alcohol to acetic acid. Acetic acid is what gives vinegar its sour taste. Although strong for an organic acid, acetic acid is weak compared to an inorganic acid such as sulfuric acid.

Acetic acid is used in greater amounts than any other organic acid. A variety of products are derived from it, including ***acetate***, a type of plastic. Acetate is the plastic that carries the emulsion used for photographic film. The negatives returned from a photofinisher are made of acetate as are movie films projected in theaters.

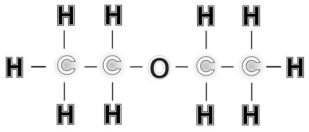


Two other organic acids are ***lactic acid***, which gives spoiled milk its sour taste, and ***butyric acid***, which gives spoiled milk and butter their rancid odor. Until one has encountered the rancid smell of butyric acid, a person is not aware that something can smell so awful. One bus driver had a rule that no milk products could be brought on the bus. A passenger who ignored this rule brought on board some ice cream, which is high in butterfat. It spilled and was left in the closed bus on a hot day. When the passengers tried to re-board, the rancid smell was so strong they could not stand the smell without becoming ill. The bus had to air out and then be thoroughly cleaned before it could be used again.

Ethers are another large class of organic compounds. An ether has an oxygen atom bonded between two hydrocarbon chains. The two simplest ethers are dimethyl ether and diethyl ether. The prefix *di* means *two*. *Dimethyl ether* is derived from two methane molecules that have lost one hydrogen atom each in order to bond with the oxygen atom. Diethyl ether is derived from two ethylene molecules that have lost one hydrogen atom each in order to bond with the oxygen atom. Notice that all of the bonds are single. This means the molecules are saturated.



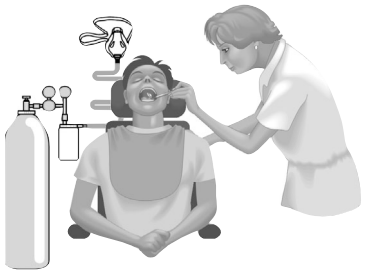
dimethyl ether (CH_3OCH_3)



diethyl ether ($C_2H_5OC_2H_5$)

Diethyl ether is the best known of the ethers. A person who speaks of *ether* is understood to mean *diethyl ether*. It is a volatile and flammable liquid. Ether mixed with oxygen will explode when exposed to a flame or spark.

Diethyl ether was the first anesthesia used in surgery. Laughing gas (nitrous oxide) had been used earlier during tooth extraction. Although it deadened pain, it did not entirely eliminate discomfort, and the patient remained awake while it was being used. Some compounds produce local anesthesia. *Local anesthesia* affects only one specific part of the body.



Nitrous oxide (laughing gas) once was commonly used in dental surgery but has now been largely supplanted by diethyl ether and other methods.

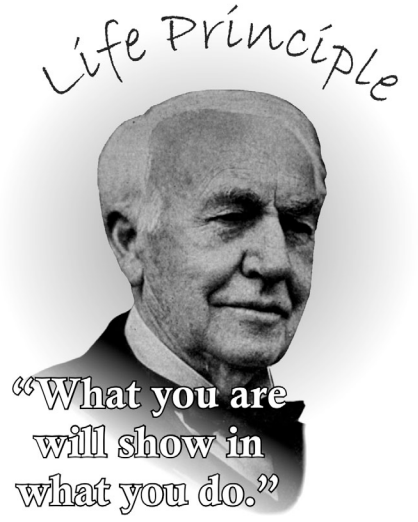
For surgery, however, a stronger painkiller is required. A *general anesthesia* is used. In 1842, Crawford W. Long, an American surgeon in Georgia, used diethyl ether while removing a

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tumor from the neck of a patient. He successfully carried out other anesthetic surgeries with the ether. However, by the time he published his results, William Morton had already made the procedure public. Crawford W. Long did not receive full recognition for his discovery because he did not publish his results soon enough.

William Morton was a Boston dentist who tested ether first on himself then on a patient who had an abscessed tooth that would have been painful to extract. With that success, Morton arranged for a surgeon to give a public demonstration of ether. John C. Warren, an American surgeon, carried out the first public surgery at the Massachusetts General Hospital in Boston.

Exactly how an anesthesia works is not clearly understood. A common belief is that the ether affects the fatty material around the nerve cells and disrupts impulses that flow along the nerves. Today, a number of agents are used to make a patient insensitive to pain during surgery. The process may begin with a mild sedative the night before the surgery, followed by a stronger *barbiturate* on the morning of the surgery. One chemical may be used to make the patient unconscious and another one used to maintain that condition. A specially trained physician or health worker administers the anesthesia during surgery.



—Thomas Edison

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Integrated Physics & Chemistry



Lesson 7
Inventions & Discoveries

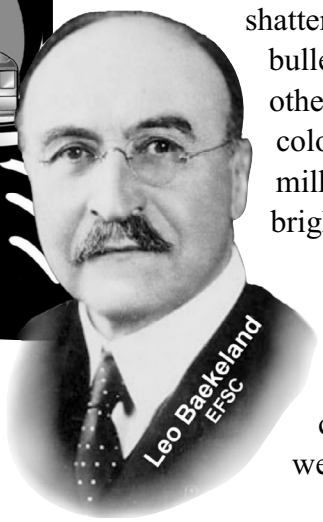
Chapter 8

PLASTICS

Section 2

Lessons 6-10





Plastics are found everywhere. Some are as hard as ivory, others as flexible as rubber. Some plastics are pound for pound stronger than steel, while others are as soft as feathers. Some plastics are transparent like glass yet do not shatter when struck by a high speed bullet. Some will resist scratching while others can be carved like wood. The color of some plastics is an ordinary milky white, while others come in bright colors.

Unlike wood or steel, plastic does not rot or rust. Since 1976, the United States has produced more plastic than steel. Automobiles contain about 12 percent plastic by weight.

Plastics do have some features in common. The word *plastic* means *capable of being molded*. All plastics can be formed into useful shapes when hot. Once they cool, they retain that shape. Plastics are made of long organic (carbon) molecules. The single unit that makes the building block of the plastic is a ***monomer***. *Mono* means *one* and *mer* means *part*. A monomer is one part. After the monomers are put together, the result is a ***polymer***. *Poly* means *many*. A polymer is made of many identical parts.

The discovery of the first modern plastic was made by Leo Baekeland, a Belgian chemist who visited the United States and decided to stay. Photography, a chemical process, was Baekeland's hobby. In 1891, Baekeland invented a photographic paper that could be viewed by artificial light during development. George Eastman of the Eastman Kodak Company paid one million dollars for Baekeland's invention.

VOCABULARY

Plastic: a substance that is capable of being molded when hot but sets as it cools, most plastics are organic
Monomer: made of one part
Polymer: made of many identical parts
Thermosetting: a plastic that can be molded when hot but sets when it cools and does not become soft when reheated
Rubber: a natural organic polymer obtained from rubber trees
Latex: the tree sap from which natural rubber is made

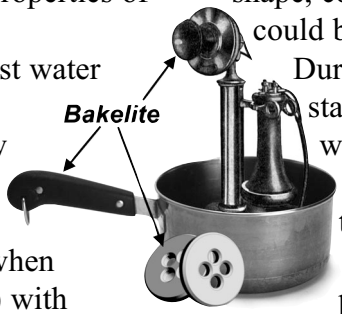
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Leo Baekeland used the money to build his own private laboratory. Baekeland searched for a substitute for shellac, a type of sealing wax. Shellac is an organic compound that is secreted by a certain type of insect and deposited on trees. Shellac can be dissolved in alcohol and then spread to give wood a glossy finish. Shellac protects the wood from water and spills. Baekeland searched for a synthetic compound that had the properties of shellac.

A substance that could resist water when it dried might make a good shellac substitute. Baekeland knew that hydrocarbons are impervious to water, although most will dissolve in organic solvents. But when chemists heated phenol (C_6H_5OH) with formaldehyde (CH_2O) the reaction produced a solid that neither water nor any other common solvent would dissolve. The sticky solid could not easily be cleaned off glass. Chemists avoided repeating the experiment because the product clogged test tubes, which had to be thrown away.

Baekeland experimented with phenol and formaldehyde. His idea was to dissolve then spread the mixture on wood as a protective finish. He tried to find a way to dissolve the compound. Nothing worked. The substance resisted being dissolved. Once hardened in test tubes, reheating the mixture would not soften it. Baekeland had to toss out a lot of laboratory glassware.

Suddenly, Baekeland realized he had found something much more useful than shellac. He repeated the experiments. This time he worked to make the product even less likely to dissolve when cool. He heated it under pressure and produced a material quite unlike any other. It was truly synthetic. Molecules of Baekeland's plastic have no duplicate in nature. Baekeland called this new material Bakelite, naming it after himself. It was not the first plastic. Cellulose had been invented earlier from a compound that contained nitrogen. Cellulose based plastics burned easily and if mishandled could explode. Bakelite was the first modern plastic and had a host of desirable properties. It was light in weight and resisted heat, acids and weather. Bakelite was also an electrical insulator. Although hard, it could be cast into shape, colored and dyed. A block of it could be carved into a desired shape.



During the first half of the 1900s, the standard telephone receiver cover was made of black Bakelite. Bakelite is a successful plastic to this day. Buttons, switches and knobs on electrical appliances, pot handles, automobile parts and countertops are made of Bakelite.

The word *plastic* means *capable of being shaped or formed.* Plastics are synthetic materials that can be softened and molded into useful articles. Plastics are shaped when warm, and they retain the new shape when cooled. Plastics are either ***thermosetting*** or *thermoplastic* depending upon their response to reheating.

A *thermosetting* plastic is one that hardens permanently when it cools. It does not become soft when reheated. Bakelite is an example of a thermosetting plastic. While hot, it can be injected into a form. Once it cools, it keeps the shape of the form. When heated again, it does not become soft; its shape cannot be changed.

A *thermoplastic* becomes soft when reheated and can then be reshaped. It keeps its new shape when cooled. *Polyethylene* is an example of a thermoplastic. Polyethylene is a cloudy white solid with a slippery feel. When heated above the temperature of boiling water, polyethylene becomes soft. Once softened, it can be molded into any desired shape. If cooled, it will keep its new

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shape. Polyethylene can be easily molded into thin sheets, bowls, bottles or pipes and is an excellent electrical insulator.

Polyethylene is made from ethylene (C_2H_4) a hydrocarbon gas. It is unsaturated because the bond between the carbons is a double bond. When the gas is put under tremendous pressure (about 30,000 pounds per square inch) at a temperature of about 200ºC, the double bond breaks. New bonds form by linking to neighboring ethylene molecules. The resulting polyethylene is a long chain of as many as 200,000 units all connected by single bonds. Because the bonds in the molecules are all single, polyethylene is chemically inert.



Other plastics include celluloid, acetate, rayon, nylon and polyester. About fifty different plastic families are in use today. Most of the plastics contain carbon, hydrogen and oxygen. Some of them contain fluorine, chlorine or nitrogen.

Closely related to plastics is synthetic rubber. Natural ***rubber*** was unknown in Europe until Columbus discovered America. Native Americans used rubber as chewing gum and toys. No one in Europe found any particular use for the samples that Columbus brought back. Almost three hundred years passed before Joseph Priestley, the English chemist who discovered oxygen and described the properties of carbon dioxide, used rubber to erase pencil marks. The name *rubber* was chosen because the material was used to rub out pencil marks.



Untreated rubber had few uses because it was hard when cold, and sticky when hot. The discovery of vulcanization made rubber heat resistant and easy to shape. By the start of the 1900s, rubber was being used for automobile tires. Vulcanized rubber resists abrasion and gives cars a smooth ride and good traction. Today, more than half of all rubber goes into manufacturing tires for vehicles.

Rubber is a natural organic polymer obtained from rubber trees. The trees are tapped to yield their sap, ***latex***, a milky fluid. Latex is a polymer of isoprene (C_5H_8), the basic building unit. Isoprene contains only carbon and hydrogen. Despite being so simple, making an artificial substance with all of the desirable properties of rubber turned out to be difficult. The first synthetic rubber was based on neoprene, derived from acetylene and hydrochloric acid. Neoprene has some properties not shared with rubber. Neoprene resists heat better and is not attacked by oils and gasoline.



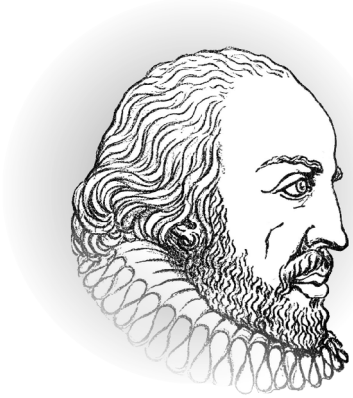
Neoprene is used for hoses that carry hydraulic oils and gasoline. Natural rubber swells and weakens when exposed to organic solvents such as gasoline, so neoprene is better in this regard. On the other hand, for automobile tires, natural rubber wears better and provides better traction. Chemists made another rubber substitute from butadiene (C_4H_6) which can be made from butane (C_4H_8). Butadiene will form a polymer when heated with sodium metal as a catalyst. The resulting synthetic rubber was called Buna; a name made of the *bu* from butadiene with *Na*, the symbol for sodium. Buna wore rapidly and did not have the elasticity of natural rubber. Chemists found a way to

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improve Buna. They combined it with styrene, which is a modified benzene ring. The resulting synthetic rubber, Buna S, made a satisfactory rubber for automobile tires. It wears well and provides good traction.

Both synthetic rubber and natural rubber can be recycled. Often the two are mixed together because a combination of natural rubber with synthetic rubber has properties that improve upon either one alone.

LIFE PRINCIPLE

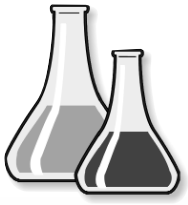


"The path is smooth that leads on to danger."

—William Shakespeare

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Integrated Physics & Chemistry



Lesson 8
Compounds

Chapter 8

ALCOHOL

Section 2

Lessons 6-10





T**op Alcohol* is one class in drag racing. Motorcycles, funny cars and dragsters in this class are all fueled by methanol. The fastest methanol burning dragsters can generate 3,000 horsepower and cover a quarter of a mile in 5.775 seconds. The fuel that powers these fast vehicles is methanol, a type of ***alcohol.

Alcohol is an organic compound that has the functional group *OH* connected to a carbon atom with a single bond. A functional group is made up of two or more atoms that remain together during chemical reactions. They can be treated as a unit as if they were a single element. ***Hydroxyl*** is the name of the *OH* functional group. When the *OH* group substitutes for one of the hydrogen atoms in methane (CH_4), the result is methyl alcohol (CH_3OH) also known as wood alcohol and methanol. It is the simplest of all alcohols.

Today, the primary way to produce methyl alcohol is to synthesize it from carbon monoxide and hydrogen under high pressure. Originally, methyl alcohol was made by the ***destructive distillation*** of wood, which is the reason methyl alcohol is called wood alcohol. It is still made this way in areas where wood wastes are available. In destructive distillation, wood is put in a closed container and heated. A chemical change occurs to the carbon in the wood. Vapors are released, collected and distilled to give methyl alcohol. Methyl alcohol is used in antifreeze solutions, special fuels and plastics. It is a ***solvent*** of fats and oils.



VOCABULARY

Alcohol: an organic compound that has one or more hydroxyl groups (OH) attached to a carbon atom

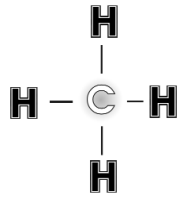
Hydroxyl: the functional group (OH)

Destructive distillation: heating an organic substance such as wood, coal or shale in the absence of air to decompose them and drive off useful products

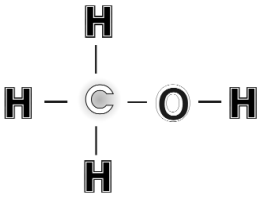
Solvent: a liquid that can dissolve other substances

Electrochemical: production of electricity by chemical means

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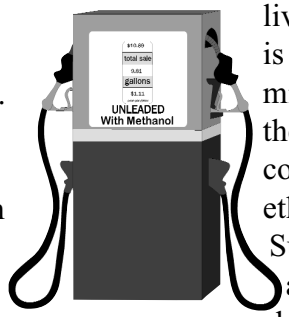
methane (CH_4)



methane alcohol (CH_4O) methanol, wood alcohol

Methyl alcohol is poisonous. Drinking it or inhaling the vapors is extremely dangerous. The alcohol interferes with the organic covering that surrounds body nerves to protect them. People who drink as little as a third of an ounce, hardly more than a thimble full, can experience permanent blindness. A full ounce can be fatal. The skin absorbs methyl alcohol therefore it is poisonous when rubbed on the skin.

Methanol can be used as a fuel. It is widely used in California as a transportation fuel. It is sold at more than 60 facilities around the state. The typical blend is a mixture of 85 percent methanol and 15 percent unleaded gasoline. Most methanol-powered vehicles can use gasoline should methanol not be available. The advantage is that methanol cuts exhaust emission by one-half when compared to regular gasoline. One disadvantage is that methanol is more toxic than regular gas and burns with an invisible flame. Mechanics who repair vehicles that use methanol must be specially trained to avoid health hazards.



An area of research in the use of methanol is *fuel cells*. These devices are ***electrochemical***. A chemical reaction produces a flow of electrons that can drive an electric motor. Fuel cells have a favorable impact on the environment. The waste product of the reaction is water. Fuel cells are still experimental because of production expenses.

When the *OH* group replaces one of the hydrogen atoms in ethylene (C_2H_6), the result is ethyl alcohol (C_2H_5OH*)*. In common usage, when a person speaks of alcohol, the person is talking about ethyl alcohol. Ethyl alcohol is the primary ingredient in intoxicating beverages such as beer, whiskey and wine. Ethyl alcohol is also known as grain alcohol and ethanol. Pure ethyl alcohol is a clear, colorless liquid with a burning taste. It has a low freezing point, so it is used as antifreeze and in thermometers. A "drunk" person behaves abnormally because the alcohol distorts normal brain cell operation. Habitual consumption ("drinking") can cause liver, brain and kidney damage. Ethyl alcohol is easily produced and inexpensive. It can be mixed with gasoline to produce *gasohol*. In the United States, gasohol fuels usually contain nine parts gasoline with one part ethyl alcohol made from grains such as corn. Such a blend requires no changes to the automobile engine and results in a slightly higher octane rating. Ethyl alcohol can be refined as motor fuel from grain, sugar, or any plant that contains starch, such as potatoes.



Starch is a carbohydrate made of carbon, hydrogen and oxygen. When used for human consumption, products containing ethyl

Vocabulary

Denature: to render unfit to eat or drink while allowing it to be used for other purposes

Glycol: an alcohol that contains two hydroxyl groups

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alcohol are heavily taxed. For other purposes, however, the ethyl alcohol is not taxed and is cheap. To prevent the untaxed alcohol from being consumed, poisonous and foul-tasting substances are deliberately mixed with it. Alcohol treated in this way to make it unfit to drink is called ***denatured*** alcohol.

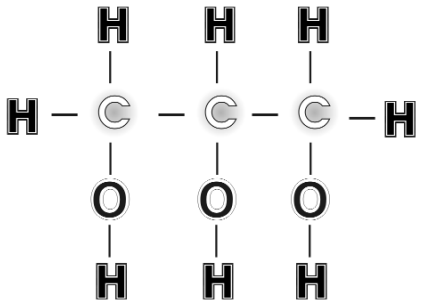
Any hydrocarbon chain can become an alcohol with the substitution of one or more hydroxyl groups for hydrogen atoms. However, as the chains become longer, the alcohol properties are overwhelmed by the hydrocarbon properties. The alcohols of low atomic weight have the usual properties of alcohols: colorless, volatile, flammable liquids that are soluble in water. Most of the alcohols with low atomic weights are commercially important.

An alcohol is identified by the sequence of one carbon atom attached to the *OH* group: *C – O – H*. All alcohols have one or more groups of *C – O – H*. An inorganic compound that contains the hydroxyl group is a base. Sodium hydroxide (NaOH) is a base. An organic compound that contains the hydroxyl group is an alcohol. Methyl alcohol (CH_3OH) is an alcohol.

Unlike hydrocarbons that do not mix well with water, alcohols mix completely with water. An alcohol boils at a higher temperature and freezes at a lower temperature than the corresponding hydrocarbon. Methane, for instance, is a gas at room temperature. Methyl alcohol, however, remains a liquid at room temperature and does not change into a gas until heated to 65ºC, about 149ºF.

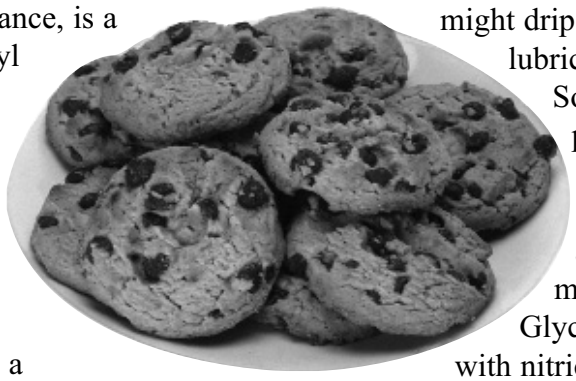
An alcohol may have more than one of the hydroxyl groups. Each one is attached to a different carbon atom. Alcohols with two hydroxyl groups per molecule are glycols. One of the best known glycols is ethylene glycol ($C_2H_4(OH)_2$). This compound is sweet tasting. The word ***glycol*** comes from a Greek word meaning *sweet.* The boiling temperature of ethylene glycol is even higher than for ethyl alcohol. A mixture of water and ethylene glycol makes a good anti-freeze and summer coolant for use in automobile radiators. When ethylene glycol is mixed with equal amounts of water, the solution has a freezing temperature of nearly –50ºC and a boiling temperature of 197ºC. Despite being pleasant tasting, ethylene glycol is poisonous.

Ethyl alcohol (ethanol) has one *OH* group, ethylene glycol has two *OH* groups and glycerol, ($C_3H_5(OH)_3$) also known as ***glycerin***, has three *OH* groups. Its structural formula shows how it is related to hydrocarbon chains:



glycerol ($C_3H_5(OH)_3$), glycerin

Glycerol is a colorless, odorless, thick, syrupy liquid. It has a sweet taste like ethylene glycol but is harmless. Food processing equipment that needs to be oiled but might drip on the food is lubricated with glycerin. Some foods such as packaged cookies and snack cakes have glycerin added as a moisturizing agent. Glycerin can be treated with nitric and sulfuric acids to convert into nitroglycerin, which is an explosive.



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LIFE PRINCIPLE

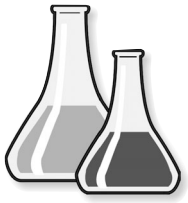


"Right is right, even if everyone is against it; and wrong is wrong, even if everyone is for it."

—William Penn

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Integrated Physics & Chemistry



Lesson 9
Compounds

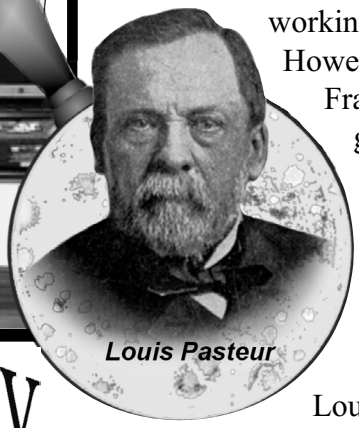
Chapter 8

Section 2

Lessons 6-10

CHANGING MOLECULES

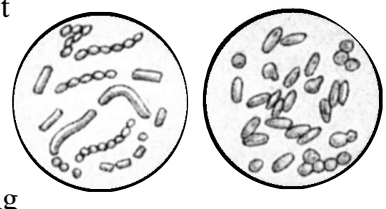




Louis Pasteur

Most alcohol processed for drinking is made by ***fermentation*** of sugars. Fermentation is a chemical process, but one that involves living organisms. Louis Pasteur was the first person to make a scientific study of fermentation. He was a chemist who enjoyed working on scientific problems in the laboratory. However, businessmen in the town of Lille, France, asked Pasteur to start a school. The goal of the school was to instruct young people in the practical uses of science. In one of his lectures, Pasteur demonstrated useful products from potatoes. He produced starch, sugar, alcohol and vinegar.

One student brought his father to see Louis Pasteur. The father had produced alcohol from beet root sugar, but something had gone wrong. The alcohol soured instead of fermenting, making it useless. Pasteur agreed to help the businessman. At that time, scientists believed fermentation to be solely a chemical process. Louis Pasteur studied fermentation through a microscope. He peered for hours at samples of beet root juice. He noticed that a drop of the juice swarmed with yeast cells. As Pasteur watched, a yeast cell sprouted a bud and grew larger. Then it broke away from the parent cell. Although yeast was used for baking and fermentation, scientists had not known until then that yeast cells were alive.



Yeast is a single celled living organism that has no chlorophyll. (Recall that chlorophyll is the chemical that makes plants green.) Yeast is a type of fungi, like mushrooms. Fermentation is caused as the yeast releases an ***enzyme*** to dissolve food that is absorbed through cell walls. The enzyme that yeast releases, ***zymase***, converts sugar into

VOCABULARY

Fermentation: a chemical reaction caused by living organisms that changes sugar into carbon dioxide and alcohol
Enzyme: an organic catalyst released by living organisms
Zymase: the enzyme that hastens fermentation
Lactose: sugar found in milk ($C_{12}H_{22}O_{11}$)
Lactase: the enzyme that begins the process of making milk sour
Pasteurization: heating a beverage or other food to kill microorganisms that could cause food to spoil

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ethyl alcohol and carbon dioxide. Pasteur studied the beet juice that had soured in the vats. In addition to the yeast cells, Pasteur found the soured juice swarming with rod shaped cells. They changed sugar and alcohol into lactic acid, which is sour.

In the drops of beet juice, war was being waged between two competing microorganisms. One type changed sugar into alcohol. As they finished, the other cells took control and produced lactic acid from the alcohol and excess sugar. To prevent the formation of lactic acid, Pasteur's remedy was to clean the vats, keep them covered and make certain only the right yeasts were allowed to start the fermentation process. Also, at the right moment after the yeast finished its work, the alcohol could be heated to kill the microorganism that caused the juice in the vat to go sour.

One morning Louis Pasteur's wife mentioned that she had to pour out some milk because it had spoiled. Louis Pasteur switched his study from beet juice to milk. As he suspected, he found tiny microorganisms that flourished when the milk soured. Pasteur could see organisms growing and multiplying. They lived on ***lactose***, a type of sugar found in milk. Microorganisms released the enzyme ***lactase***, which caused the milk to sour. The enzyme lactase changed the sugar lactose into lactic acid. Pasteur knew that microorganisms grew under favorable conditions. After a series of experiments, he learned that gentle heating of the milk destroyed the tiny life and kept the milk fresh. Gentle heating at the right moment would prevent chemical changes caused by microorganisms. Milk, cheese, butter and other foods can be kept fresh longer by killing the bacteria that cause products to spoil. The process of gentle heating to kill microorganisms became known as ***pasteurization***.



Cracking breaks longer molecules into shorter ones. When a candle burns, the heat of the flame breaks the longer, solid paraffin molecules into shorter, more volatile gases that rise and burn in the flame. Most petroleum is refined for motor fuel, but crude oil contains a greater proportion of longer molecules than are needed. The refinery cracks the longer molecules in petroleum to make shorter ones. This increases the fraction that is gasoline. During summer, automobiles are driven more frequently, thus increasing demand for fuel. Also, during summer, homes do not require as much heating oil. During those months, longer heating oil molecules are cracked into shorter gasoline molecules. Cracking can be accomplished with heat and pressure or by a catalyst. A barrel (42 gallons) of crude oil without treatment will yield about 11 gallons of gasoline. This proportion can be increased to 21 gallons by cracking.

Polymerization attaches identical smaller units together to make larger molecules. Most plastics and artificial fibers are made by

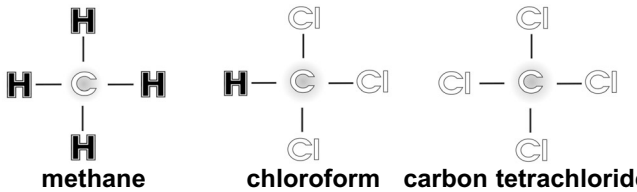
VOCABULARY

Cracking: to make hydrocarbon molecules shorter by heating, pressure or the action of a catalyst
Polymerization: to make a long molecule by combining identical shorter molecules
Substitution: to replace one atom or a group of atoms with another atom or group of atoms
Reforming: to rearrange the atoms of a molecule to produce a molecule with the same formula but different structure

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polymerization. For instance, the double bond of ethylene (C_2H_4) can be modified so that one molecule attaches to a molecule beside it. Polyethylene is formed. Nylon is long synthetic fibers made by polymerization.

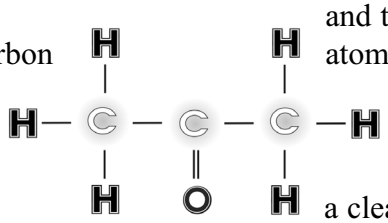
Substitution removes one atom or group of atoms and replaces it with another atom or group of atoms. For instance, if chlorine substitutes for hydrogen in methane, the result is chloroform. Chloroform was first used as a painkiller in the early 1850s. It no longer serves that purpose because of dangerous side effects. If all four hydrogen atoms are replaced with chlorine, the result is carbon tetrachloride. Carbon tetrachloride is a heavy colorless liquid with a distinctive odor. It is used in fire extinguishers, in laundries as a dry cleaner and as an ingredient in making other carbon compounds. Chloroform and carbon tetrachloride are examples of compounds made by substitution.



methane (CH_4) **chloroform ($CHCl_3$)** **carbon tetrachloride (CCl_4)**

Methane is a hydrocarbon because it contains only carbon and hydrogen. Neither chloroform nor carbon tetrachloride can be classified as hydrocarbons because each one contains elements other than carbon and hydrogen. However, methane, chloroform and carbon tetrachloride are all organic because they all contain carbon.

Acetone (C_3H_6O) is another organic compound that has a structure similar to a hydrocarbon. The structural formula for acetone has a carbon in the middle, an oxygen bonded with it, and *CH_3* groups on either side. Notice that acetone is very similar to propane (C_3H_8) but with oxygen replacing two of the hydrogen molecules. Acetone is a substitution compound because oxygen has been substituted for two hydrogen atoms. Freon and Teflon are fluorine substitution compounds of carbon. Substitution is another way that carbon can form so many compounds.



acetone (C_3H_6O)

Reforming is another way to change one molecule into another molecule. Reforming does not crack, add or substitute atoms. Instead, one isomer is changed into another isomer with different properties. Long hydrocarbon chains can be made so they have side chains. These isomers with side chains have properties that are more desirable than straight chains. For instance, isooctane burns better as a gasoline than the straight normal octane. Isomers such as normal octane and isooctane have the same number and type of atoms.

Butane (C_4H_{10}), for instance, has two isomers. Normal butane is a chain, while isobutane has a small side chain. Normal butane and isobutane differ slightly from one another. Isobutane burns less vigorously than normal butane, and it requires a higher pressure or colder temperature to change into a liquid.

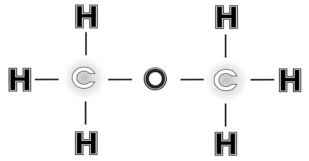


A gas grill powered by butane

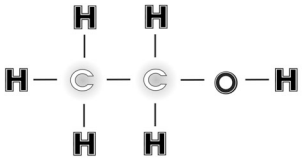
Sometimes the properties of isomers are vastly different from one another. For instance, ethyl alcohol and dimethyl ether have exactly the same number and type of atoms. Both have two carbon atoms, six hydrogen atoms and one oxygen atom. However, their properties are very different. Ethyl alcohol, also known as ethanol, is a clear, colorless liquid with a burning

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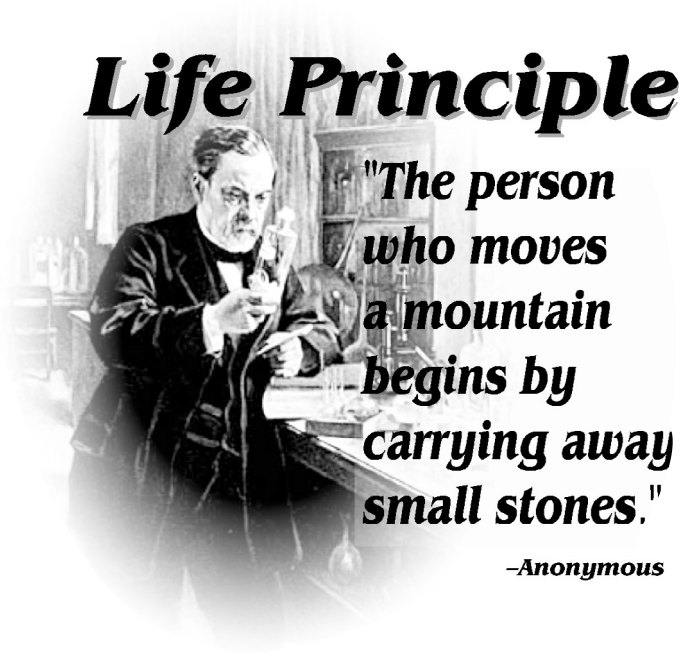
taste and noticeable odor. It is the alcohol in beverages such as beer and brandy. Ethyl alcohol is a liquid at room temperature; whereas, dimethyl ether is a gas at room temperature. The formula for ethyl alcohol and dimethyl ether can both be written as C_2H_6O. Their properties differ because of how their atoms are arranged. Sometimes this arrangement is implied by how the formula is written C_2H_5OH for ethyl alcohol and CH_3OCH_3 for dimethyl ether. The structural formula makes the differences even clearer.



dimethyl ether
(ethanol, CH_3OCH_3)

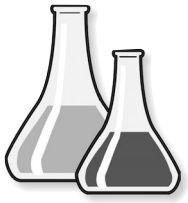


ethyl alcohol
(C_2H_5OH)



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Integrated Physics & Chemistry



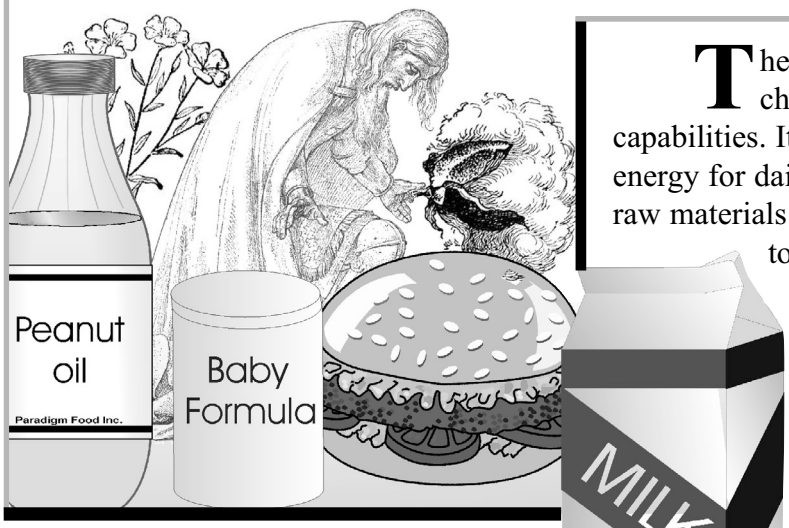
Lesson 10
Compounds

Chapter 8

CARBOHYDRATES

Section 2

Lessons 6-10



The human body is designed as a chemical factory of unparalleled capabilities. It grows, repairs tissue and provides energy for daily activities. The body processes raw materials that range from very simple ***sugars*** to extremely complex proteins. Chemists can make some organic compounds in the laboratory. Often the reaction requires high temperature and great pressure. Yet, your marvelous body processes make the same reactions take place at normal atmospheric pressure and at a moderate temperature of 98.6 degrees.

Carbohydrates are some of the organic raw ingredients that living cells use for growth and energy. Carbohydrates contain carbon, hydrogen and oxygen. Usually the hydrogen and oxygen are in the ratio of two to one, the same ratio as in water. Carbohydrates are the most abundant organic compounds found in nature. Plants produce carbohydrates by photosynthesis. Carbon dioxide is taken from the air and changed into carbohydrates using sunlight as the source of energy.

Carbohydrates in plants can take many forms. One common form of carbohydrates is ***cellulose***. Although not produced by animals, cellulose is the chief building material for plants. Cellulose gives strength to cell walls. Some of the giant redwood trees are more than 200 feet tall and weigh more than 2,000 tons. Without cellulose to keep them rigid, the giant redwood trees would sag under their own weight.

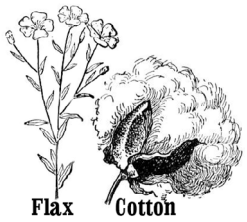
Wood is about one-half cellulose. Processing wood so that only the cellulose remains produces wood pulp. An inexpensive grade of paper used by newspapers is made of wood pulp. A better grade of paper results by adding cotton,

VOCABULARY

Sugar: a carbohydrate that has a sweet taste and is utilized for quick energy by the body
Cellulose: a carbohydrate that forms cell walls in plants
Enzyme: an organic catalyst that speeds chemical reactions in the body
Complex carbohydrate: a carbohydrate that must be modified before it can be directly used by the body
Insulin: a chemical messenger that regulates the amount of sugar in the blood
Glycogen: a molecule that the body uses to temporarily store an excess of glucose

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which is almost pure cellulose. Cotton is a natural fiber that can be woven to make cloth. Cotton and flax are two natural fibers that come from plants. A flax plant has long stems and only a few branches. The plant is uprooted and stacked in the field. Action of rain, heat and cold causes the stems to break down. Long cellulose fibers then are separated from the stems. The fibers are strong and are made into twine, fishnets and shoelaces. Weaving flax thread into linen is a very old practice. Some ancient Egyptian mummies were wrapped in linen made from flax.



The digestive systems of animals cannot utilize cellulose as food. Cows eat grass and termites eat wood. Both grass and wood have high cellulose content. Yet, neither cows nor termites digest the cellulose directly. Bacteria in their stomachs do the job. The bacteria release ***enzymes*** that change the cellulose into products that the animals can digest. Cattle have complicated digestive systems with four stomachs where the bacteria can work to modify cellulose into *glucose.* Glucose is a simple sugar necessary for life.

Starch is another form of carbohydrates that is formed by plants. Starch, unlike cellulose, can be digested by human beings.

VOCABULARY

Sucrose: sugar from sugar beets, sugar cane or maple trees, table sugar, cane sugar ($C_{12}H_{22}O_{11}$)

Fat: a compound of carbon, hydrogen and oxygen with less oxygen than carbohydrates, fat stores food energy more compactly than sugars

Starch is a major source of food and comes from cereal grains and potatoes. Foods such as whole-grain breads, cereals, pasta, rice and potatoes are high in starch. Food provides energy for the body. Most people groups receive about one-half of their food energy from starch in cereals, potatoes and rice. A major marvel of earth is that each geographic region is suited to produce energy food needed by human inhabitants.

The ratio of hydrogen atoms to oxygen atoms in carbohydrates is usually 2 to 1, the same as water. The formula for starch is $(C_6H_{10}O_5)_X$, with x showing that the entire group repeats. The starch molecule is very complex because x can be huge. A single starch molecule can have thousands of carbon, hydrogen and oxygen atoms. Human beings depend on carbohydrates for energy but cannot use the long molecules. Instead, the digestive system must break the huge starch molecule into simpler compounds. Because it must be modified for digestion, starch is called a ***complex carbohydrate***.

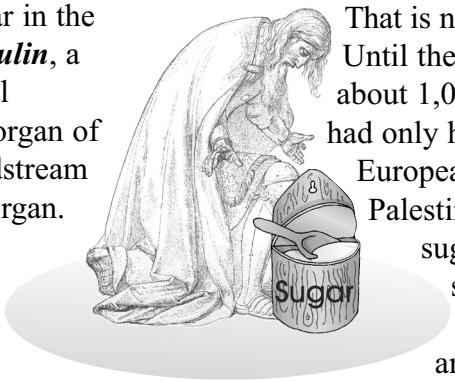
When eaten, acids and enzymes in the digestive tract break complex carbohydrates such as starch into glucose, a simple sugar ($C_6H_{12}O_6$). The glucose molecule is small and readily passes through the intestines into the blood stream. The sugar is taken throughout the body for cells to use as a source of energy. The cells combine glucose with water to release carbon dioxide, water and energy. The reaction normally would not take place at body temperature. Cells release enzymes to speed the action of oxygen upon sugar. The enzymes ensure that the reaction takes place at much lower temperatures and at a faster rate than would otherwise be the case. Glucose is the primary energy source for the body.

Because it is carried in the blood stream, glucose is also known as *blood sugar*. Should a person be unable to digest foods,

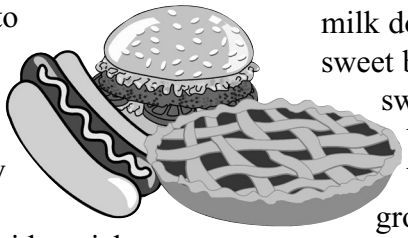
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hospitals feed the patient by putting glucose directly into the bloodstream. The glucose is dissolved in a water solution, and the speed of the intravenous feeding is adjusted to maintain the proper sugar level. This ensures the body is fueled at an even rate.

The blood of an adult contains about six grams (about one-fifth of an ounce) of glucose. If no sugar were created by the body or added intravenously, the body energy would be gone in about 15 minutes. The body regulates the amount of sugar in the blood stream by the release of ***insulin***, a hormone. A *hormone* is a chemical messenger. It is produced by one organ of the body and released in the bloodstream to change the activity of another organ. If too much sugar is in the blood, the production of insulin is increased. This stimulates cells in the liver and muscles to set aside some of the sugar as ***glycogen***, a polymer of glucose. Glycogen can quickly and efficiently be converted back to sugar when needed.

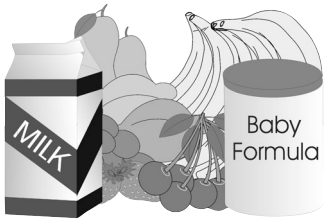


A healthy person fuels the body by making glucose from complex carbohydrates. As the body burns energy, the sugar is being continually replaced by more carbohydrates. Processed food and snacks contain glucose or other sugars that require very little physical exercise for the body to use. After eating a food high in simple sugars, the energy reaches the blood stream in a rush. This gives a burst of energy. Because no complex carbohydrates are eaten to maintain that energy, the energy level soon drops. Foods that are high in simple sugars are usually high in fats but low in vitamins. Foods that provide quick energy but little else are referred to as *empty calories*. Some people call these foods *junk food*.



Ordinary table sugar is ***sucrose*** ($C_{12}H_{22}O_{11}$). It is extracted mostly from sugar beets and sugarcane, which is known as *cane sugar*. The sugar maple tree is also a source of sucrose. When a person says, "Pass the sugar," he or she is asking for sucrose. Sucrose is the sugar that is sprinkled over cereal, stirred into coffee and lemonade, and used to bake cookies and make candy. One might think that table sugar to sprinkle on food has been around since ancient times. That is not the case for Europeans. Until the time of the Crusades, about 1,000 years ago, Europeans had only honey as a sweetener. European knights returning from Palestine carried samples of sugar imported from southwest Asia.

Three other sugars are often found in the foods we eat. *Fructose* ($C_6H_{12}O_6$) has the same formula as glucose, but the arrangement of the atoms is different. Fructose is known as fruit sugar because it is found in fruits such as apples and peaches. *Lactose* ($C_{12}H_{22}O_{11}$) is found in the milk of all mammals, including cow's milk and mother's milk. Lactose is called milk sugar. A glass of milk has about a tablespoon of lactose in it. The milk does not taste sweet because lactose has only a slightly sweet taste. *Maltose* ($C_{12}H_{22}O_{11}(H_2O)$) begins as a starch in plants but is broken down into a sugar as the plant grows. Maltose is easy to digest. Infants cannot digest cow's milk, but they can digest maltose. It is used to prepare infant formula and malted drinks. Maltose is also known as malt sugar.



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Although the typical person consumes sucrose, fructose and other sugars, the body can directly use none of these. They have to be converted to glucose, the only sugar that cells can incorporate into the body.

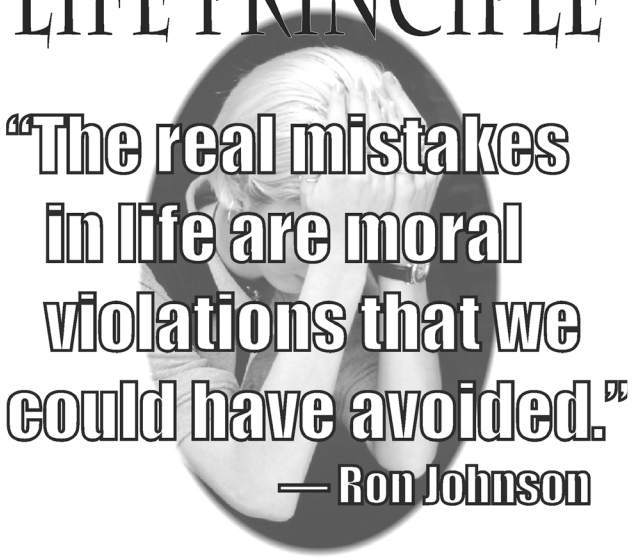
Fats contain carbon, hydrogen and oxygen but are not classified as carbohydrates because the ratio of hydrogen to oxygen is not two to one. The proportion of oxygen in fats is less than in carbohydrates. Sources for fats include butter, lard, olive oil, coconut oil and peanut oil. Liquid fats are *oils*. Fats and oils produce energy and heat when burned in the body. Because they contain a greater proportion of hydrogen and carbon, the energy output is greater than with carbohydrates.



Fats of the right kind and in the right proportions are essential to the diet. Excess sugar is efficiently stored in people and animals as fats. For the temporary storage of glucose, glycogen will serve. However, for the long-term storage, a fat molecule will store twice as much energy as a glycogen molecule of the same size. In addition to being used as food, fats insulate the stomach lining against the action of the acids used in digestion. Some organs are protected from injury by a layer of fat that acts as a cushion. Animals such as seals are insulated against the Arctic cold by layers of fat below the skin.

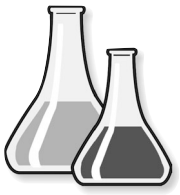
Lard is fat that comes from hogs. It becomes a liquid when heated and boiled at a temperature higher than 212 degrees. For that reason, some foods are cooked quickly by deep-frying in hot lard or other types of grease. Thin strips of potatoes cooked in this way make french fries. In addition to cooking the food quickly, deep-frying sears the surface to hold in juices and flavors. Some people like the greasy taste of fast food restaurants that feature fried chicken, potatoes, fish or beef. However, such saturated animal fats clog the arteries and contribute to heart disease. The term by-pass heart surgery refers to medical procedures to replace (or by-pass) arteries too clogged for normal blood circulation.

LIFE PRINCIPLE



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Integrated Physics & Chemistry



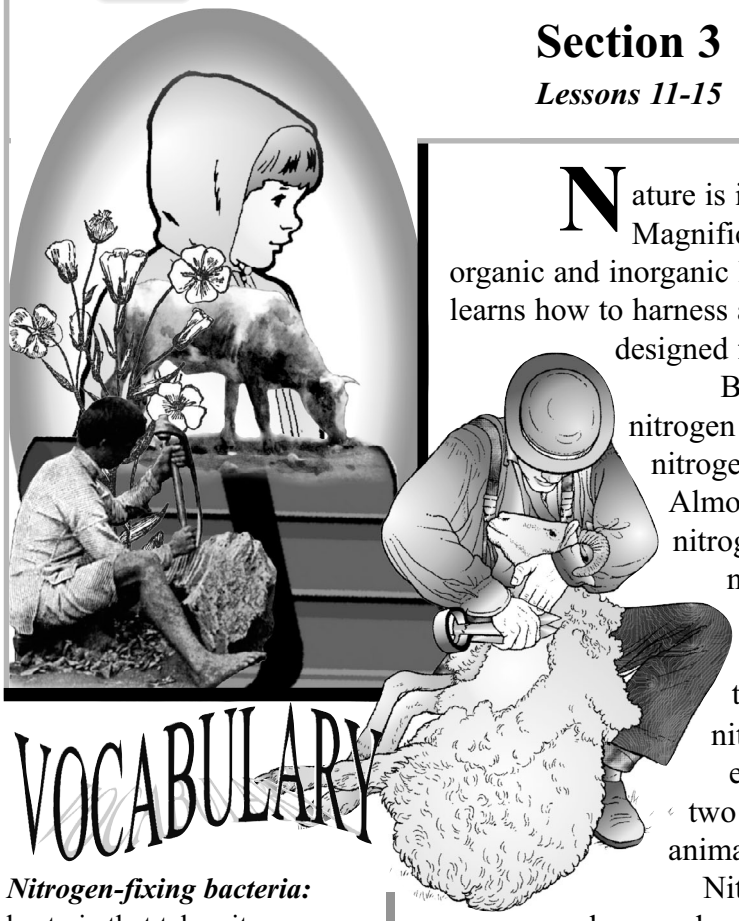
Lesson 11
Compounds

Chapter 8

NITROGEN COMPOUNDS AND FIBERS

Section 3

Lessons 11-15



Nature is intricately balanced to sustain life. Magnificent connections are evident among organic and inorganic life. Science merely discovers and learns how to harness and use materials and principles designed for man's use.

Both plants and animals must have nitrogen to survive. The good news is that nitrogen is in abundant supply on earth. Almost four-fifths of the atmosphere is nitrogen. The bad news is that neither plants nor animals can remove nitrogen from the atmosphere. Nitrogen atoms in the atmosphere combine with one another to make nitrogen gas (N_2). Although nitrogen forms weak bonds with other elements, the covalent bond between the two nitrogen atoms is strong. Plants and animals cannot pry bonds apart.

Nitrogen is a nonmetallic element that makes up about 78 percent of the atmosphere. Nitrogen is located between carbon and oxygen in the periodic table and normally has a valence of –3. Nitrogen needs three electrons to complete its valence shell. Usually nitrogen forms covalent compounds by sharing electrons. Most compounds of nitrogen dissolve in water. Natural deposits of nitrogen compounds are found only in dry climates or places protected against rain such as in dry caves. Sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3) are natural deposits of nitrogen compounds. They are raw materials for producing other nitrogen-based substances.

All living organisms need nitrogen compounds. Plants and animals usually cannot use nitrogen unless its two atoms are pried apart and combined with oxygen. Extreme measures are needed to pry apart atoms of nitrogen gas in the atmosphere. Lightning is strong enough.

VOCABULARY

Nitrogen-fixing bacteria: bacteria that take nitrogen gas from the atmosphere and convert it into nitrogen compounds that plants can use

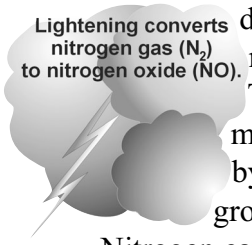
Fertilizer: natural or synthetic compounds that restore elements necessary for plant life to the soil

Quarrying: the blasting or cutting away of stone from a rock quarry pit to be used in construction work elsewhere

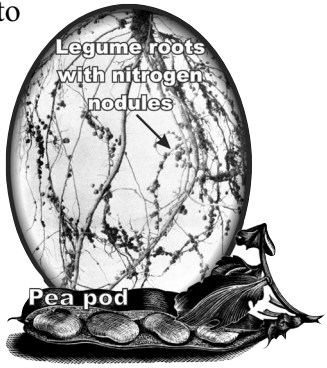
Camphor: an aromatic compound, $C_{10}H_{16}O$, from the camphor tree that is used in the production of celluloid

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As lightning passes through the atmosphere during storms, it converts nitrogen gas to its oxide. The nitrogen oxide molecule (NO) is absorbed by raindrops and falls to the ground.

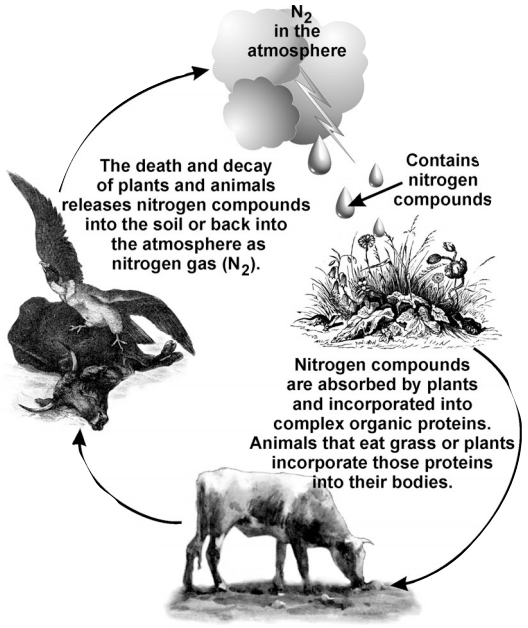


Nitrogen can also be put into the soil by bacteria around roots of legumes, plants of the pea family. The bacteria convert nitrogen from the air into nitrogen containing organic compounds. How bacteria accomplish this task is not clearly understood. Chemists can change nitrogen into ammonia (NH_3) but the process requires a catalyst, a temperature of 600ºC and a pressure of 200 atmospheres. The microscopic bacteria accomplish the same task at ordinary temperature and pressure. Bacteria that remove nitrogen gas from the atmosphere and convert it for plants are called ***nitrogen-fixing bacteria***. Nitrogen is fixed when it is in a compound that plants can use.



Unlike animals, plants can make complex organic compounds from simpler ones or from the elements themselves. For example, plants can remove carbon from carbon dioxide in the air. Oxygen is usually captured from the air, hydrogen from water, and other minerals are absorbed from the soil. Normally, plants fall where they die and restore the minerals to the soil to be used by the next generation. During farming, however, crops are harvested and carried away. Some minerals in the soil are not replaced. The three elements that become in short supply in soil through farming are potassium, phosphorus and nitrogen. Eventually, these minerals become exhausted. Farmers restore nitrogen and other minerals to soil with compounds such as potassium nitrate (KNO3), sodium nitrate ($NaNO_3$) and calcium phosphate ($Ca_3(PO_4)_2$). Chemicals such as these, whether natural or synthetic, that restore minerals to the soil are called ***fertilizers***.

The *nitrogen cycle* traces the path of nitrogen as it passes from the air and soil into plants and animals. Lightning or the action of nitrogen-fixing bacteria changes nitrogen gas in the atmosphere into nitrates and nitrites, which are simple nitrogen compounds. Nitrate and nitrite compounds are absorbed



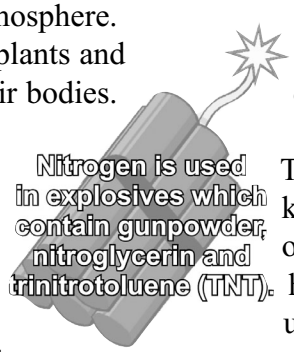
VOCABULARY

Celluloid: a clear, flammable material made from nitrocellulose and camphor, at one time it was used as the base for movie film
Cellophane: a clear, flexible, waterproof wrapping material made of cellulose from wood pulp
Synthetic fibers: man-made fibers such as rayon and nylon, not of natural origin
Sutures: joining the edges of a wound by means of a needle and thread, "stitches" to close a wound or incision

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by plants and incorporated into complex organic proteins. Should the plant die, bacteria will cause the decay and decomposition of the protein back into simpler nitrogen compounds. Living plants may take up some of those compounds. If not, the compounds break down entirely, and nitrogen is restored to the atmosphere.

Animals may eat the plants and incorporate the protein in their bodies. Some animals also get nitrogen compounds from other animals that they eat. During their regular life processes, animals will dispose of waste products including nitrogen compounds. These products and the bodies of dead animals also decay. The simple nitrogen compounds released by animal life are urea ($CO(NH_2)_2$), ammonia (NH_3) and amino group (NH_2). These compounds may stay in the ground where plants can use them. If bacteria break compounds down further, nitrogen will return to the air as nitrogen gas.


Nitrogen is used in explosives which contain gunpowder, nitroglycerin and trinitrotoluene (TNT).

Nitrogen is also used in explosives. Energy is needed to make an inert element such as nitrogen form a compound. The bonds holding the compound together are unstable and are easily broken. Compounds made with nitrogen come apart easily and release the energy that went into making them. Nitrogen compounds sometimes come apart so easily they produce an explosion. Explosives are used for ***quarrying*** stone, as demolition charges to remove old buildings and bridges, in fireworks, and to propel some rockets. Nitrogen based explosives include gunpowder, nitroglycerin and trinitrotoluene. Trinitrotoluene is better known by the abbreviation TNT, which comes from the letters of tri-nitro-toluene. TNT makes a compact molecule. It contains carbon, hydrogen, oxygen and nitrogen tightly packed together as a solid. All of the products of its detonation are gases. Some of the oxygen joins with the carbon to make carbon dioxide gas. The rest of the oxygen joins with hydrogen to convert water to steam. The nitrogen atoms join in pairs to make nitrogen gas. Because of the great heat generated by the reaction, all of these gases expand outward rapidly creating a destructive pressure wave.

Until shortly before World War II, TNT was the strongest chemical explosive known. Since then, it has been replaced with other chemicals that are more powerful and have special properties depending upon their use. Some chemicals work better underwater than TNT. Others are better for moving large amounts of material in quarrying. Unfortunately, certain agricultural fertilizers mixed with fuel oil are more powerful than TNT. Countries are challenged to protect against terrorists who can make highly destructive weapons from readily available chemicals.

Explosives are synthetic. None occur naturally in nature. Cellulose is often treated with nitric acid (HNO_3) to make nitrocellulose. Alcohol and ether dissolve cellulose nitrate and change it into a clear, jelly-like liquid. Mixing light sensitive chemicals in the jelly-like liquid made the first photographic emulsion. The liquid evaporated to leave behind a hard, colorless transparent film. The film was not strong enough to support itself, so the emulsion was spread on glass plates and used in bulky cameras mounted on tripods.

The strength and rigidity of cellulose nitrate improved by treating it with camphor ($C_{10}H_{16}O$). ***Camphor*** is made from the bark of a tree that grows in Asia and

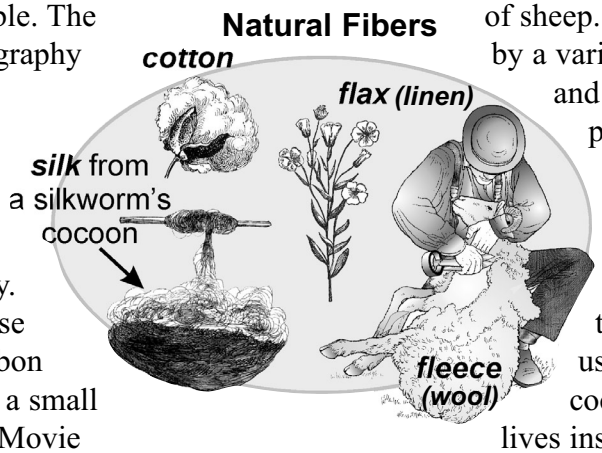

Man in Asia carving camphor wood

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South America. Camphor has a pleasant smell. After alcohol and ether dissolve cellulose, camphor is added. When it dries, the result is ***celluloid***, which is clear and strong like glass but more flexible. The glass plates used in early photography could be replaced with rolls of photographic film on spools of celluloid. The first motion pictures were recorded on celluloid. Because it is nitrated cellulose, celluloid burns briskly. The risk of fire increased because early movie projectors used carbon arc lights. The film passed only a small distance in front of the hot arc. Movie projectors were enclosed in a fireproof room at the back of the theater to prevent or to reduce the risk of fire. Even without a fire, movies on celluloid deteriorate because celluloid is not stable. Many of the master copies of older movies are on celluloid and are slowly deteriorating.

Cellophane is made from cellulose. Wood pulp is high in cellulose. It is treated with sodium hydroxide (NaOH) and then dissolved in carbon disulfide (CS_2). The solution is basic but can be neutralized with an acid. If it is extruded through a narrow slit into an acid bath, the result is cellophane. Cellophane is one of the few clear films that does not soften with heat. For most of the 1900s, it was used to wrap food products because it formed a waterproof seal. Cellophane has since been replaced with other clear plastics. Rayon is made in the same way as cellophane except rayon is extruded through a very small opening. Rayon is used to make a variety of fabrics, including carpet. Rayon was one of the first ***synthetic fibers***.

The first fibers were natural ones. The two most common plant fibers are cotton and flax. Both of these fibers contain cellulose. The two most common animal fibers are wool and silk. Both wool and silk are complex proteins, organic compounds that contain nitrogen. Wool is from the fleece of sheep. Silk is produced by a variety of insects and spiders. The primary source is the silkworm, the larval form of a moth. The silk is spun by the larva and is used to make a cocoon. The moth lives inside the cocoon during the pupa stage before emerging as an adult moth. Silk farmers collect the cocoons to extract the silk threads.



Natural inorganic fibers also exist. Asbestos, fine pieces of glass and thin metal wires, are examples of inorganic mineral fibers.

Nylon is a synthetic fiber. Although finer than silk, nylon has greater strength. It can be washed and dried quickly. Nylon was developed by the Du Pont Company to compete with silk. Nylon, however has such strength, toughness and elasticity, that it has found many other uses including underwear, raincoats, tennis rackets and parachutes. Doctors use nylon as medical ***sutures*** to close wounds or incisions.

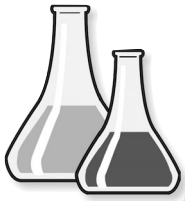
Life Principle

"We have barely scratched the surface in our exploration of the wonders of God's universe."

—Charles B. Shuman

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Integrated Physics & Chemistry



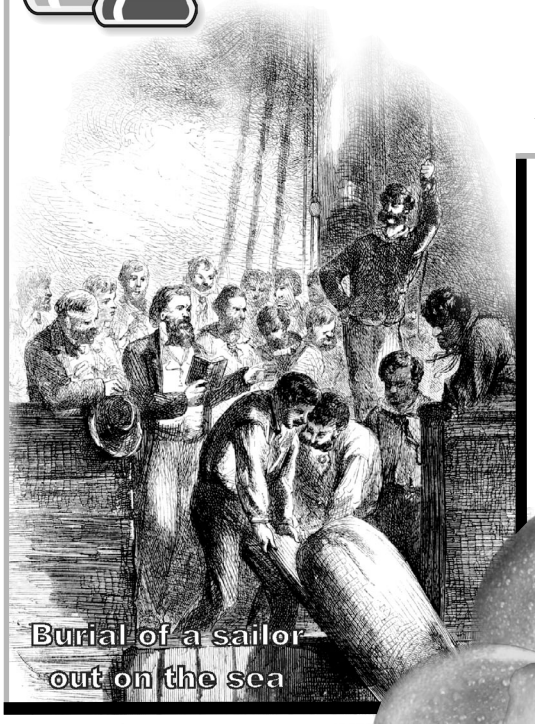
Lesson 12
Compounds

Chapter 8

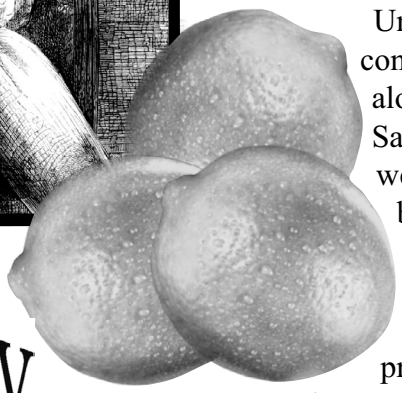
VITAMINS

Section 3

Lessons 11-15



For sailors on long sea voyages, one of the most feared diseases was ***scurvy***. The word *scurvy* means *scaly skin*. A sailor afflicted with the disease would become listless and weak, sores would not heal and teeth would loosen. The slightest injury would cause a bruise. Connective fibers that held the body together weakened. Severe cases of scurvy resulted in death.



Until the 1500s, most sea voyages were confined within the Mediterranean Sea or along the coast of Europe or Africa. Sailors were aboard ships for only a few weeks. With the worldwide expeditions by the Spanish, Portuguese, Dutch and British, voyages lasted three or more years, and the sailors visited land far less often. Scurvy became a real problem and became known as the plague of the sea.

Captains were unaware of the importance of a balanced diet. Space and lack of refrigeration hindered taking a variety of foods. The Spanish carried pigs and livestock to provide fresh meat. However, fresh fruits and vegetables spoiled long before the voyage was over. Some food was dried or preserved with salt. The everyday diet in the British Navy consisted of dry saltless biscuits called *hardtack* and pork preserved by salt.

The British Empire depended on its ships for both commerce and national security. Dr. James Lind, a Scottish physician, studied scurvy. He worked at a naval hospital on shore in Edinburgh, Scotland. What he read gave conflicting information about ways to treat the disease. Some reports claimed that cider would cure the symptoms. Others recommended garlic as an effective cure. Doctor Lind became convinced that a proper diet played a roll in the disease. In

VOCABULARY

Scurvy: a disease caused by the lack of vitamin C, ascorbic acid, in the diet; scurvy can be prevented by drinking citrus juices

Vitamin deficiency disease: a disease such as scurvy or rickets caused by the lack of certain vitamins in the diet

Collagen: the connective tissue in the human body

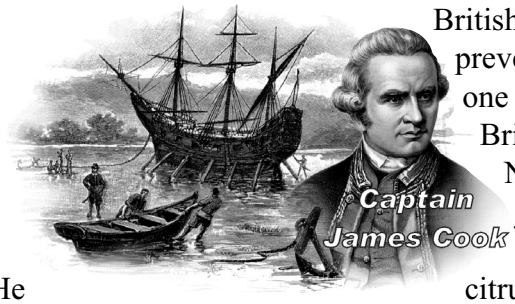
Rickets: a disease caused by an insufficient amount of vitamin D in the diet

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1749 he decided to conduct an experiment to learn which remedies worked. He selected twelve sailors who suffered from the disease. He divided the men into six pairs. Although the doctor put all the men on the same basic diet, he varied what the sailors ate. To one pair, Dr. Lind gave cider, to another spices, to another vinegar, and so on. To one pair, he gave two oranges and one lemon every day.

At the end of a week, the two sailors who ate oranges and lemons had improved considerably. One returned to work; the other man stayed and helped Doctor Lind with the experiment. Doctor Lind published his findings in 1754, but due to resistance from doctors, the results did not gain approval until almost twenty years later.

Captain James Cook, one of England's greatest captains, learned of Doctor Lind's experiment. Captain Cook had already made two voyages of discovery to the Pacific Ocean. He dreamed of a plan to explore the entire size and scope of the Pacific Ocean. Such a goal would take three years to complete. To accomplish the ambitious voyage, the crew would experience harsh conditions. A large number of scurvy cases would almost certainly develop.



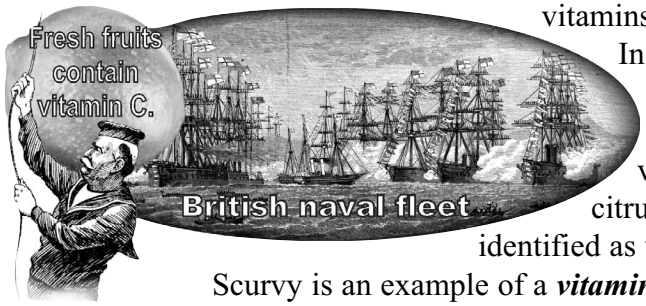
After consulting with Doctor Lind, Captain Cook began giving his crew juice from citrus fruits such as oranges, lemons and limes. The captain made landfall whenever possible to take on fresh food.

Captain Cook's voyage became one of the greatest sagas of all time. He sailed throughout the southern Pacific. Using celestial navigation techniques, he outlined the size of Australia, sailed around New Zealand, and plunged south to the ice and cold inside the Antarctic Circle. Until then, scurvy had killed more sailors on British ships than all other diseases, naval battles and shipwrecks combined. Yet, this voyage was notable for the remarkable health record of the crew. Only one of Captain Cook's 118 sailors died of scurvy. Captain Cook became a firm believer in Doctor Lind's limes.



Doctor Lind enjoyed success as a doctor. He became physician to King George II, and he continued to publish his study of scurvy. Captains of other vessels began to demand fresh limes and oranges for their men. In 1795, a fleet of British naval ships tested the use of limes to prevent scurvy. On a 23-week voyage, only one sailor suffered from scurvy. The British Admiralty, the commanders of the Navy, ordered sailors to drink lime juice. To this day, British sailors carry the nickname "limeys." The simple citrus remedy wiped scurvy from British ships.

Although a cure for scurvy had been found, neither Doctor Lind nor anyone else knew what was so essential in citrus juice. By the late 1800s, doctors learned the role of vitamins in the diet. In the early 1900s, the essential vitamin in citrus juice was identified as vitamin C. Scurvy is an example of a ***vitamin deficiency disease***, which occurs because of the lack of a certain chemical in the diet.



The word *vitamin* is from a Latin word meaning *life*. In the case of scurvy,

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the life-giving substance is vitamin C. The old fashioned methods of preserving food — smoking, salting, drying — destroy vitamin C. But, fresh citrus fruits such as limes contain vitamin C.

Vitamin C is one of the 13 well-known vitamins in the world. The five known as vitamins A, C, D, E and K contain only carbon, hydrogen and oxygen. Vitamin A ($C_{20}H_{20}O$) is found in green, yellow and orange fruits and vegetables, egg yolks, milk and cod-liver oil. Vitamin A helps the eyes see better at night. Night blindness is a condition caused by a deficiency of vitamin A. The human body can make vitamin A from *carotene*, the substance that gives carrots their orange color. Eating carrots regularly is one way to give the body vitamin A and restore night vision.

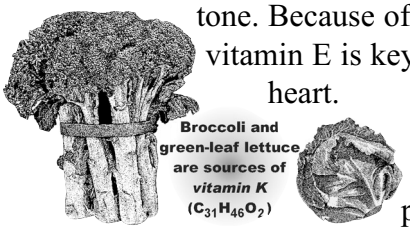


Vitamin A ($C_{20}H_{20}O$) is found in egg yolks, milk, and cod-liver oil.

Vitamin C (ascorbic acid, $C_6H_8O_6$) is found in citrus fruit and helps prevent scurvy. ***Collagen*** is a fiber-like protein that makes tendons, connective tissues, bones and teeth. Scurvy is caused when the body does not get enough vitamin C complex, which includes bioflavonoids and which help in the formation and maintenance of collagen. Since it is water-soluble and not retained in the body from day to day, vitamin C needs to be consumed regularly. Vitamin C has been called the *Master Vitamin* due to its many critical roles in the body.

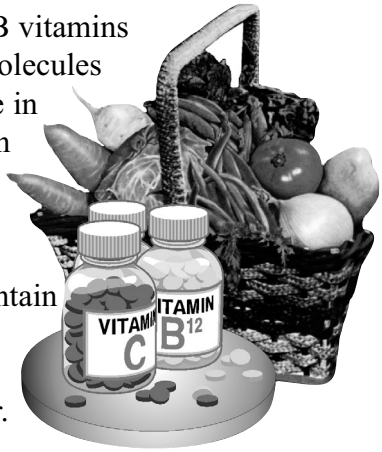
The body produces vitamin D ($C_{28}H_{44}O$) by the action of ultraviolet light. For that reason, vitamin D is sometimes called the *sunshine vitamin*. It helps the body make better use of calcium and phosphorus in bones and teeth. ***Rickets*** is a disease that occurs mainly among children who live in northern countries. The children do not get enough sunlight for their bodies to make vitamin D. Without enough calcium, the bones bend under the weight of the body. Symptoms of rickets include a curved spine or bowed legs. Whole milk sold in the United States usually contains added vitamin D.

Vitamin E ($C_{29}H_{50}O_2$) is necessary for a healthy diet. It helps form red blood cells, improves circulation and helps muscle tone. Because of these roles, vitamin E is key to a healthy heart.


Broccoli and green-leaf lettuce are sources of *vitamin K* ($C_{31}H_{46}O_2$)

Vitamin K ($C_{31}H_{46}O_2$) is produced in the intestines by the action of bacteria on leafy green vegetables. Vitamin K promotes the clotting of blood.

The largest group of vitamins consists of B vitamins, the most prominent of which are: B_1 (thiamin), B_2 (riboflavin), B_3 (niacin), B_6, B_{12}, folic acid, pantothenic acid and biotin. The B vitamins have complex molecules that will dissolve in water. In addition to containing carbon, oxygen and hydrogen, B vitamins also contain other elements such as nitrogen, iodine and sulfur. The group of B vitamins is called the *vitamin B complex*.

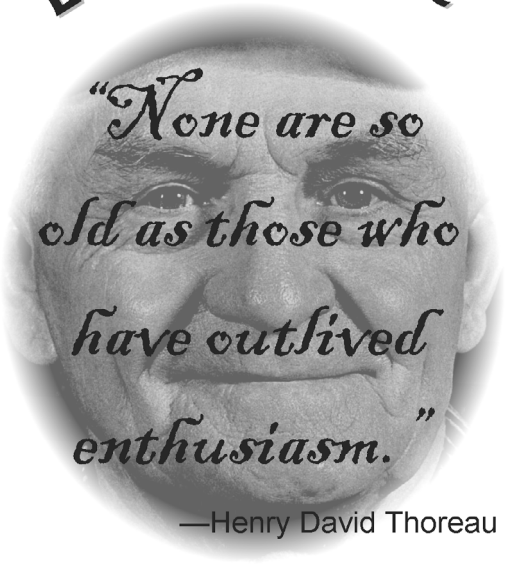


Vitamins are essential to life. The body needs a certain balance of vitamins in the diet. If the body receives too much of a particular water-soluble vitamin, such as B or C, the chemical is eliminated without being used, although, overdosing on synthetic vitamin C (ascorbic acid) has been known to lead to the formation of painful kidney stones.

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Certain oil-based vitamins such as A or D, taken excessively can be toxic. Generally, a person has fewer health problems when he or she has a healthy diet of fresh fruits and vegetables. People who eat mostly canned food, fast foods or packaged "instant" meals should consider changing their diets to include vitamin supplements and fresh foods and juices. Nutritional and medical experts have discovered that certain types of illnesses can be corrected or stabilized through addition of specific vitamins to patients' diets, especially when regular exercise and wholesome eating habits are practiced.

Life Principle



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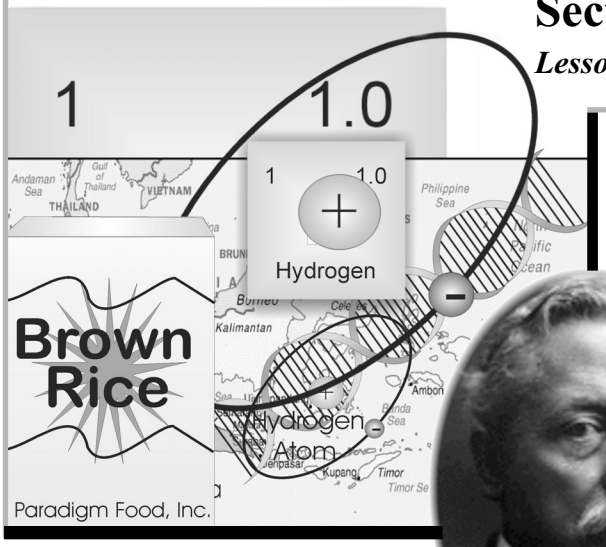
Lesson 13
Compounds

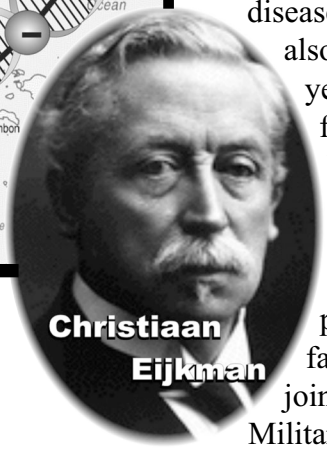
Chapter 8

VITAMINS AND PROTEIN

Section 3

Lessons 11-15





Scurvy was not the only disease that struck Europeans as they traveled to the Pacific. ***Beriberi*** was a more mysterious disease because people who lived on land also suffered from it. More than a hundred years after a cure for scurvy had been found, people still suffered from beriberi. In the late 1800s, Christiaan Eijkman was given the task of finding the cause of beriberi. Christiaan Eijkman was the son of a school principal in the Netherlands. The family was not wealthy. Young Eijkman joined the Army so he could attend the Military Medical School of the University of Amsterdam. After becoming a doctor, Eijkman continued to study in Holland for an advanced medical degree.

The Netherlands (known unofficially as Holland) was a world power at that time. For almost two hundred years, the people of the Netherlands, called the ***Dutch***, had colonies throughout the Pacific. The purpose of the Dutch East India Company was to engage in trade. The company sent ships to China, Japan, India and Java (Indonesia). Europeans representing the company lived throughout the Orient and on the beautiful islands of the Pacific. During this era, the scientific world was talking about Louis Pasteur's dramatic proof that bacteria could cause diseases. Christiaan Eijkman's service in the Army took him to a small village on the south coast of Java. He studied how bacteria caused some tropical diseases. Unfortunately, he fell victim to malaria. His health deteriorated so badly he had to return home.



VOCABULARY

Beriberi: a vitamin deficiency disease caused by a lack of vitamin B_1 in the diet
Dutch: relating to the Netherlands, Holland
Thiamin: another name for vitamin B_1, its lack can cause the vitamin deficiency disease beriberi
Protein: large complex organic molecules used for the growth and repair of tissue, as well as making enzymes, hormones and antibodies
Helix: a corkscrew shape, the shape of a spiral staircase, many proteins have a helix shape

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Back in Holland, Eijkman learned more about Louis Pasteur's Germ Theory of Disease. It had been a leading prevention of diseases. Christiaan Eijkman became one of Holland's best known medical researchers. In 1886, the Dutch government appointed him to a team to study beriberi. This disease often struck Europeans who lived in the Pacific Islands. The victims grew listless, they could not eat, their muscles failed, their heart weakened, paralysis set in, and finally they died. The word *beriberi* in the local language meant *I cannot*. Christiaan Eijkman and the rest of the team realized they would have to travel to Java to study beriberi first hand. In 1886, Eijkman was strong enough for the sea voyage. He bravely sailed back to the islands where he had contracted malaria.

Christiaan Eijkman and the other members of his team worked to find the bacteria that caused beriberi. After a year, they had made no progress. The other doctors on the team left Java and sailed back to Holland. Rather than abandoning the research, the Army put Eijkman in charge. Christiaan Eijkman refused to give up. The doctor noticed that although some of the natives contracted the disease, the Europeans suffered from it more often. This puzzled the medical workers because the residents in the Dutch enclosure had better medical care, purer water and better food. The doctor concluded that an important clue was being overlooked. In that part of the world, the staple food was rice. The outer husks of rice are rich in butterfat. The fat spoils easily and turns into butyric acid. To preserve the rice for a longer period of time, the husks were removed. The polished, white rice was fed to humans. The rice that had not been treated was brown and fed to animals. The institute had a flock of chickens. One day, Dr. Eijkman noticed that the chickens looked sick. They showed symptoms similar to beriberi. Their wings hung limp, and they stumbled around the chicken yard. Eijkman immediately examined the blood of the chickens. Somewhere in the sample of blood had to be the bacteria that caused beriberi. However, the doctor found nothing suspicious.



Suddenly, the sick animals recovered. Christiaan Eijkman became a detective. He investigated how the sick animals had been treated. He wanted to know what had caused them to recover and why had they come down with the beriberi in the first place. Eijkman looked for a clue to the mystery. He found that the cook had run out of brown rice that was used as chicken feed. The cook fed the chickens white rice from the kitchen. The chickens had gotten sick while eating white rice. When the cook resumed feeding the commercial chicken feed of brown rice, the animals recovered.

Christiaan Eijkman divided the chickens into two flocks. To one group, he fed brown rice. To the other group, he fed polished white rice. Those that ate brown rice remained healthy. Those that ate polished rice developed beriberi. Feeding chickens brown rice again cured the disease. The "good" white rice caused beriberi. The poor quality brown rice cured it. This explained why the natives, who ate brown rice, seldom came down with beriberi. Europeans, on the other hand, ate rice that had been machine polished to remove the brown husks. Christiaan Eijkman could not explain why the brown rice solved the problem. He speculated that the white part of the rice had a toxin in it that the brown husks neutralized. Most doctors ignored his report.

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Doctors blindly followed the Germ Theory of Disease and did not believe that diseases might be caused in more than one way.

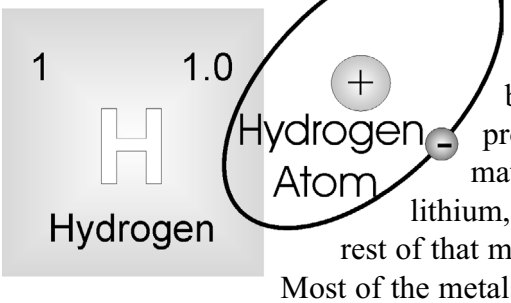
Six years passed. American doctors struggled to end an outbreak of beriberi in the Philippines. After all other means failed, they decided to feed their patients brown rice. Within two months, the disease had been wiped out, except for four men who refused to eat the brown rice. In 1896, Christiaan Eijkman returned to Holland to teach at a medical school. He wrote several textbooks. He was a clear and convincing lecturer who peppered his speeches with practical knowledge. He also encouraged his students not to accept theories as automatically true until the theories had been thoroughly tested.

The nagging problem of disease persisted. An Englishman, Frederick Gowland Hopkins, proved that certain diseases such as rickets, scurvy and beriberi are caused by the lack of necessary trace substances in the diet. Frederick Hopkins showed the importance of vitamins, proteins and amino acids in the diet. Unlike diseases caused by bacteria, dietary deficiency diseases are not contagious. In the case of beriberi, the missing substance was vitamin B_1, also known as thiamin. Beriberi occurs when the diet does not contain enough vitamin B1, ***thiamin***, which is necessary for good health.

Christiaan Eijkman had to wait a long time before the importance of his discovery was fully realized. Almost 33 years passed. The Nobel Prize can be given only to a living person. Christiaan Eijkman was in failing health. Finally, in 1929, he shared the Nobel Prize in medicine with Frederick Hopkins for his discovery of the role of Vitamin B_1 for good health. Eijkman died a year later.

Vitamins like B_1 generally are catalysts that help ***proteins*** do their work in the body. Proteins are complex organic compounds made of carbon, oxygen, hydrogen and nitrogen. Sometimes other elements such as sulfur are present. The name *protein* comes from a Greek word meaning *of first importance*. About half of the solid material in a human body is protein. Scientists estimate that the human body has about 30,000 different types of protein molecules. Protein molecules are huge, sometimes containing more than a hundred thousand atoms. Each molecule does a different function based on its chemical properties. The chemical properties depend on both the chemical composition and shape. A tightly bundled molecule has different properties than one that is a loose chain.

The shape of protein molecules is due to the bond created by the hydrogen atom. The chemical properties of hydrogen are unique. It will release an electron, which is the modern definition of a metal. In the Periodic Table of the Elements, hydrogen is usually shown on the side with metals above the sodium family of elements. However, the box containing it is often shown disconnected from the sodium family because hydrogen properties do not match those of lithium, sodium and the rest of that metallic family.



Most of the metals on the left side of the periodic table form only ionic compounds. Hydrogen forms covalent compounds, too.

A protein molecule is so long that hydrogen can attract a different part of the same molecule. The attraction of the hydrogen bond folds proteins into specific three-dimensional shapes.

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The number and location of the hydrogen atoms are responsible for the shape of protein molecules. Many protein molecules form a spiral structure. This shape is also known as a ***helix***. The molecule has the shape of a spiral staircase.

Life Principle

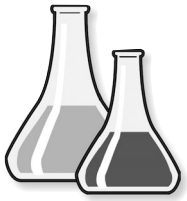
"The most important of my discoveries has been suggested to me by my failures."

—Humphry Davy



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Integrated Physics & Chemistry



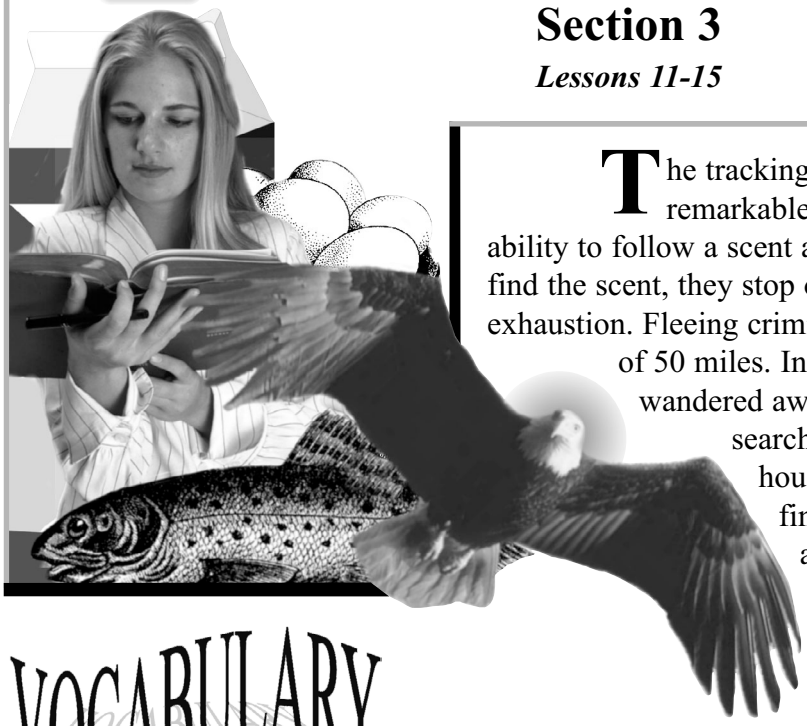
Lesson 14
Compounds

Chapter 8

PROTEIN

Section 3

Lessons 11-15



The tracking ability of bloodhounds is remarkable. Stories of their determination and ability to follow a scent are legendary. Once bloodhounds find the scent, they stop only when they drop from exhaustion. Fleeing criminals have been tracked distances of 50 miles. In one case, a little boy had wandered away from home. The parents searched the wooded area around their house for seven hours but could not find the child. Finally, a tracker with a bloodhound was put on the trail. Within ten minutes, the dog had found the boy less than a mile from the house. What the bloodhound smelled with his keen nose was body scent such as sweat and butyric acid that cling to skin cells. The skin cells flaked off the boy's body. Skin is a type of *protein*.

The building blocks of proteins are ***amino acids***. One amino acid can join another end to end. Long chains can form from amino acids. Thousands of them can make a single large molecule. A protein is a large molecule of amino acids that are joined together. ***Keratin*** is a versatile type of protein. Hair, silk, wool and fur are made of keratin. It is also the chief ingredient in horns, hoofs, feathers and beaks of birds and scales of fish. Keratin is a very strong substance, flexible and resistant to stress. For instance, silk is made of keratin, and it is stronger than a steel wire of the same size. In the human body, hair, skin and fingernails are made of keratin.

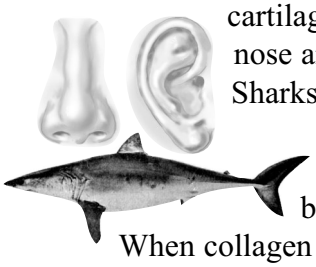
Collagen is another protein found in the body of most animals. The substance makes tendons, ligaments, cartilage and other connective tissue. Cartilage is a flexible but tough form of collagen. Small babies have skeletons that have high amounts of cartilage that make the bones more flexible than adult bones.

VOCABULARY

Amino acid: the building blocks of proteins made of an amino group, an organic side chain and an organic acid
Keratin: the protein that makes hair, nails, horns and hoofs
Gelatin: a glue-like protein derived from boiled collagen
Virus: a protein that can only replicate itself inside a living cell
Replicate: to duplicate or copy
Antibody: a protein that renders a bacteria, virus or toxin harmless
Toxin: a poisonous substance, especially a protein, that causes a disease

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As time passes, the cartilage changes into bone. Some parts of the body remain cartilage such as the ears, nose and breastbone. Sharks have skeletons that are all cartilage. ***Gelatin*** is derived by boiling collagen.

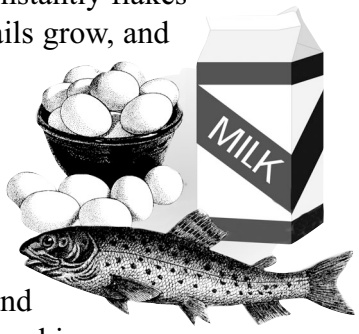


When collagen is heated, it changes into a glue-like substance. The word *collagen* is from a Greek word meaning *glue*. After an animal is slaughtered for meat, the cartilage parts that are not used directly as food are boiled. The heating changes them into gelatin, which is easy to digest. Gelatin has no taste but does have a smooth consistency. Gelatin is added to other products such as ice cream and marshmallow to give them a smooth consistency. A popular snack food, Jell-O™, was created by mixing fruit flavors with gelatin.

Dr. Frederick Gowland Hopkins discovered the B vitamin complex in 1929. Earlier, the doctor had solved another mystery of chemistry. At the end of the 1800s, chemists knew that gelatin was composed of protein. However, a rat confined to only a gelatin diet would not survive. Hopkins concluded that the rat could not make the necessary amino acids although all the building blocks the rat needed were available. Hopkins originated the concept of essential amino acids. His results applied to human beings, too. The human body can put together the elements and make some amino acids. Other amino acids have to be included in the diet intact because the body cannot put them together. Those kinds of amino acids are considered the essential amino acids. *Essential amino acids* cannot be made by the body therefore, must be included in the diet. Twenty amino acids occur in protein. The human body builds protein by putting together the twenty amino acid building blocks. Suppose the diet does not contain all twenty amino acids. In that case, the body can make twelve of them from simpler compounds. The other eight, however, are essential amino acids. They must be included in the diet in their complete form.

An *incomplete protein* is one that does not contain all of the amino acids. A food source can not just be high in protein. The food source must be high in proteins that contain all of the essential amino acids. Plants, by photosynthesis, can make all of the essential amino acids that humans require. Nuts and seeds from plants are the richest source of amino acids. Nuts and seeds are *complete proteins* because they contain all of the essential amino acids. Other sources of complete proteins include meat, fish, eggs and milk. A proper diet contains about 20 percent protein by weight. To acquire all of the proteins, nutritionists recommend a diet that contains a variety of foods. Generally, in the United States, dietary diseases caused by the lack of essential amino acids are uncommon.

Proteins can be used for energy in the body. Proteins break down into carbon dioxide and water. Breaking the bonds releases energy. However, the primary use of protein is not to power the body but to cause growth and repair tissue. Skin constantly flakes off, hair and fingernails grow, and cells throughout the body die. The daily wear and tear on the body requires a fresh supply of amino acids.



Protein is found throughout the body and in every living organism, including bacteria. ***Viruses*** are even smaller than bacteria. A virus is all protein. It is a large molecule of a special type of protein protected by a shell made of

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another type of protein. Some scientists declare that viruses are nonliving because the protein is an inanimate crystal when outside a cell. Once a virus invades a cell, the virus uses the cell's mechanism to ***replicate*** itself. The cell fills with copies of the original virus. One way the virus is released is by the cell rupturing. This kills the cell. Many of the most difficult diseases to overcome, such as the common cold, AIDS and influenza, are caused by viruses. Research into diseases caused by viruses is one area of intense activity in science.

Antibodies are another group of proteins that the body produces. Antibodies are protein substances that destroy or weaken the effect of harmful invaders into the body. Such invaders include bacteria, viruses, fungi, other microorganisms and chemical poisons or ***toxins***. The protein created by the body attaches itself to the invader. Changing the invader's chemical composition either kills it or makes it harmless. For instance, viruses must enter human cells to cause damage. The antibody protein changes the virus so that it cannot pierce the cell wall. An antibody is a protein that modifies a harmful protein. In some diseases, such as measles or mumps, the antibodies created by the body remain in the bloodstream. Therefore, the person who has such a disease during childhood is usually immune to it permanently or at least for many years.

Vaccination injects a weakened form of the disease-causing bacteria into the blood stream. Some diseases endanger a person's life. Rather than assuming that the body can overcome the disease, antibodies for it are created beforehand. The vaccine for a particular disease contains a weakened form of the bacteria or virus that causes the disease. Although the person may become sick, the disease is a milder form. The body builds antibodies to fight the weakened form. These antibodies stay in the bloodstream and are available to neutralize the stronger form of the disease, should it appear. Vaccines have been developed for such diseases as polio, smallpox and hepatitis.

A body which creates natural immunity by vaccination, may require several weeks to develop full immunity. Normally a person cannot produce immunity to a disease after it has struck. In some cases, a person is given temporary immunity by injecting antibodies filtered from the blood of a person who does have the immunity. Or, the antibodies may be from an animal. These antibodies go to work immediately to fight the disease.

Life Principle

"Let no one ever come to you without leaving better and happier. Be the living expression of God's kindness: kindness in your face, kindness in your eyes, kindness in your smile."



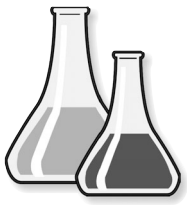
— Teresa of Calcutta

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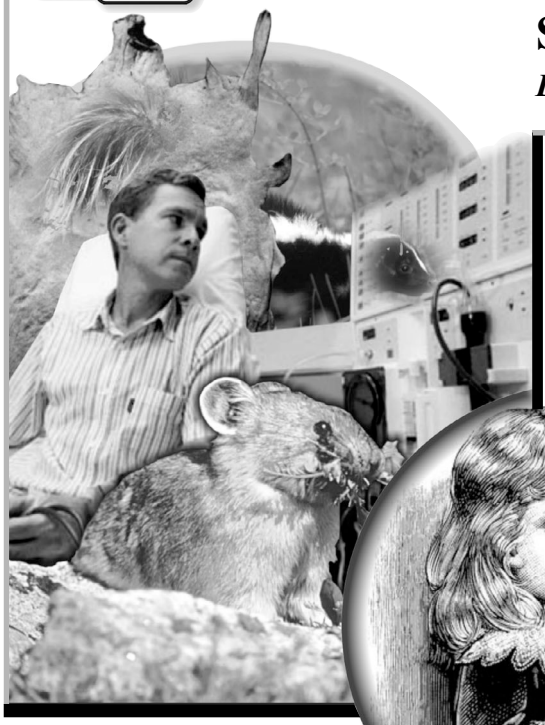


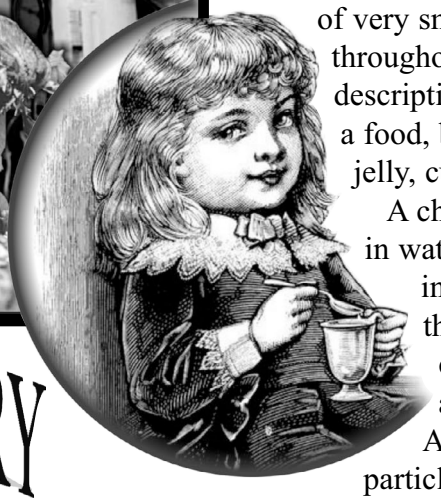
Lesson 15
Compounds

Chapter 8

COLLOIDS AND OTHER ELEMENTS IN ORGANIC COMPOUNDS

Section 3
Lessons 11-15





Favorite desserts for children include pudding and flavored gelatin. Most children would also gladly accept an offer of jelly. Suppose instead that they are offered a colloid dispersion of animal cartilage. They may shake their heads and say "No thanks." A ***colloid*** is a dispersion of very small particles evenly spread throughout all parts of a mixture. Such a description does not sound very appetizing as a food, but several common foods such as jelly, custard and pudding are colloids.

A chemical such as sugar that dissolves in water forms a ***solution***. Sugar dissolves into individual molecules. Because of the small size of molecules, a solution contains particles that do not settle and cannot be removed by filtering. A ***suspension*** is a mixture with particles that settle upon standing or can be removed by filtering. A colloidal dispersion has particles with a size between those of a solution and a suspension. Solutions, suspensions and colloids differ in the size of their particles. Solutions have the smallest particles (molecules), while suspensions have the largest. Colloids have particles of a size between those of solutions and suspensions. Colloidal particles do not settle. They are so small the incessant movement of the water molecules keeps them stirred. An ordinary filter, such as a coffee filter, cannot remove colloidal particles. The particles of a colloid pass on through the paper filter.

A ***semipermeable membrane*** is required to remove the particles of a colloid. *Permeable* means *capable of being penetrated.* Some molecules can penetrate a semipermeable membrane but other molecules cannot. Semipermeable membranes affect small organic molecules differently. The fine

VOCABULARY

Colloid: a mixture of particles so fine they will not settle out upon sitting and are not readily filtered, colloid particles have a size larger than those in a solution but smaller than those in a suspension

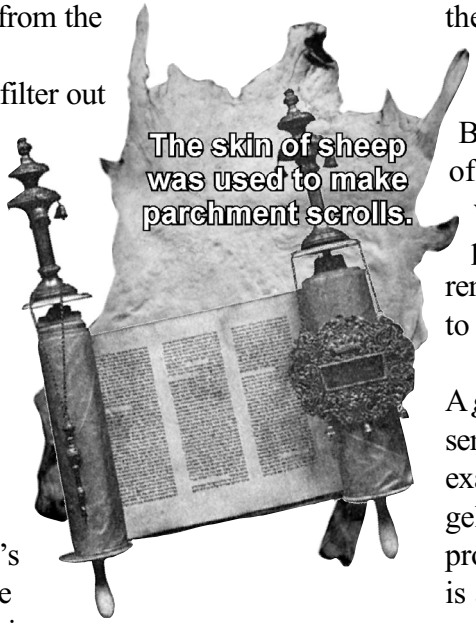
Solution: a uniform mixture that will not settle and cannot be filtered; sugar or salt dissolved in water is a solution

Suspension: a mixture of solid particles in a liquid, the particles in a suspension will settle out or can be separated by filtering

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membrane around the interior of an eggshell that keeps the white from touching the shell is an example of a semipermeable membrane. It allows gases to enter and leave the egg but keeps the contents of the egg from leaking. ***Parchment*** is another semipermeable membrane. Parchment is an ancient paper-like material made from the skin of sheep. Parchment will filter out the particles of a colloidal dispersion that pass right through a paper filter. One area of medical research is into semipermeable membranes. When a person's kidneys fail, the person can survive only with a kidney transplant or daily treatment with a kidney dialysis machine. ***Dialysis*** is the selective separation of molecules based on their size. Some will pass through a semipermeable membrane and others will not. The machines that take over the work of diseased kidneys contain several hundred yards of a semipermeable membrane that has been compactly folded. Blood from an artery is pumped on one side of the membrane and a fluid that accepts the waste products on the other side. The waste products pass through the membrane and are removed from the blood. The blood is returned to the body through a vein.


Patient on a Dialysis machine


The skin of sheep was used to make parchment scrolls.

A colloid can be a solid, liquid or gas. A ***gel*** is a colloidal dispersion that is solid or semisolid. Custard and pudding are gels. An example of a gel is jelly made by mixing gelatin in hot water and cooling. The food product sold under the brand name of Jell-O™ is a colloidal gel. Although most gels contain more than 90 percent water, they do not flow, and they are elastic. For that reason, gels are classified as solids.

Other Elements in Organic Compounds

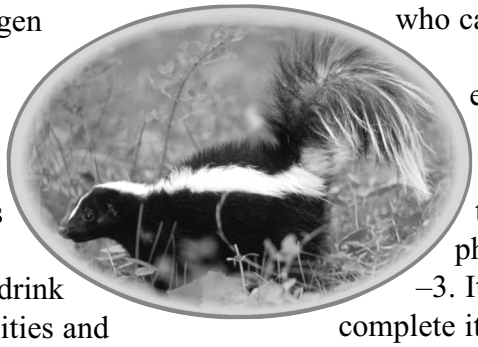
The primary elements in organic compounds are carbon, hydrogen, oxygen and nitrogen. Those four elements make up about 96 percent of the human body by weight. All of the other elements make up less than four percent. Although the other elements are found in smaller amounts, they are essential to human life. Sulfur (S) is one of the elements required by the body. Sulfur is a nonmetallic element that burns with a sputtering flame and generates a sharp odor. Ancient people burned sulfur as incense. They believed its strong odor would purify a building. Eggs are rich in sulfur compounds. When an egg spoils, the compounds break

VOCABULARY

Semipermeable membrane: a filter that allows small molecules to pass but acts as a barrier to others
Parchment: the skin of a sheep or goat, used as a writing surface, and also used to make semipermeable membranes
Dialysis: the separation of smaller molecules from larger ones
Gel: a solid or semisolid colloid
Antidote: a chemical to counteract the effects of a poison

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down into *hydrogen sulfide* (H_2S). The odor of rotten eggs is due to hydrogen sulfide. Another sulfur compound is in the spray that skunks use as a defense.



When a small child gets into household chemicals that have not been properly secured, the child may eat or drink something poisonous. Some cities and states have a Poison Control Center that a parent can call when a child has ingested poison. Each poison has a remedy based on the poison itself. Sodium bicarbonate will neutralize an acid. Epsom salt reacts with lead and makes an insoluble compound that passes harmlessly through the intestines. For some poisons, the parent is instructed to feed the child milk or egg whites. An ***antidote*** counters the harmful effect of a poison. The metals that normally attack important proteins, like the poisonous arsenic and mercury, react with proteins in the antidote rather than those of the body. Milk and egg whites act as an antidote by supplying proteins with a sulfur substance. The milk or egg whites take out the poisonous metal.

Organic compounds containing sulfur have another use. They often have a sweet taste. Saccharin ($C_7H_5NO_3S$) is a sugar substitute. It has a taste several hundred times sweeter than table sugar. It cannot be digested and has no food value. Like all food additives, it may cause unwanted side effects. Canada has passed laws taking saccharin off the market. Although saccharin is still available in the United States, other sugar substitutes have been developed to replace it. *NutraSweet* is the brand name of aspartame, a compound made of amino acids. It is hundreds of times sweeter than table sugar. Some reports indicate aspartame contains wood alcohol and is linked to the production of brain tumors. All products containing aspartame have warning labels for individuals who cannot tolerate it.

Phosphorus (P) is another element that is necessary for life. It is found below nitrogen in the periodic table. Like nitrogen, phosphorus has a valence of –3. It needs three electrons to complete its outer shell. Phosphorus forms covalent compounds by sharing electrons. About two-thirds of the weight of a human skeleton is calcium phosphate ($Ca(H_2PO_4)_2$), an inorganic compound. Calcium phosphate is hard and brittle. The other third of the skeleton is made of collagen, an organic compound that is more flexible. The two different materials give bones the strength and resilience to withstand shocks and stresses. As people age, the percentage of calcium phosphate tends to increase, resulting in bones that are brittle and more likely to break.

Iron is found in the hemoglobin molecules of red blood cells that carry oxygen from the lungs to the rest of the body. Iron is relatively scarce in food. When a red blood cell dies, the body breaks down the cell and recovers the iron to use it again. The body needs other elements in smaller amounts. Iron, magnesium, iodine and cobalt are described as *trace elements*. Although needed in small amounts, they are still required for the proper function of the body. The body contains carbon, hydrogen, oxygen and nitrogen, but they are not eaten as individual elements. Instead, they enter the body as food. The foods are carbohydrates, fats, proteins and vitamins. All are organic compounds. Minerals are inorganic compounds. Salt and sodium iodide are examples of minerals that the body requires.

In addition to foods and minerals, the human body needs water. The body of an

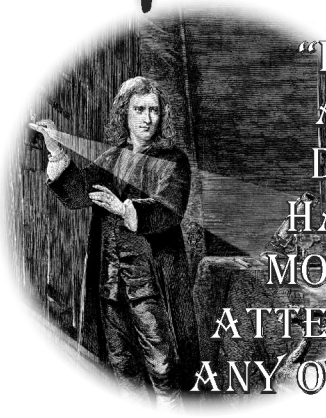
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average person consumes five quarts (about 2.5 liters or 20 glasses) of water every day. Few people drink that much water. About twelve glasses come from water and other liquids. About six glasses are extracted from solid foods. Fruits and vegetables have a high water content, and even dry foods contain some water. The remaining water is generated during digestion by oxidation of hydrogen in organic compounds.



The oxidation of carbohydrates produces carbon dioxide and water. Some animals that live in dry climates never drink water. Instead, the animals receive the water from eating leaves and the reaction of oxygen with carbohydrates the animals consume. As the animals eat food and digest it, the reaction of oxygen with carbohydrates produces carbon dioxide and all the water the animals require.

Life Principle



"If I have made any valuable discoveries, it has been owing more to patient attention than to any other talent."

–Isaac Newton

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