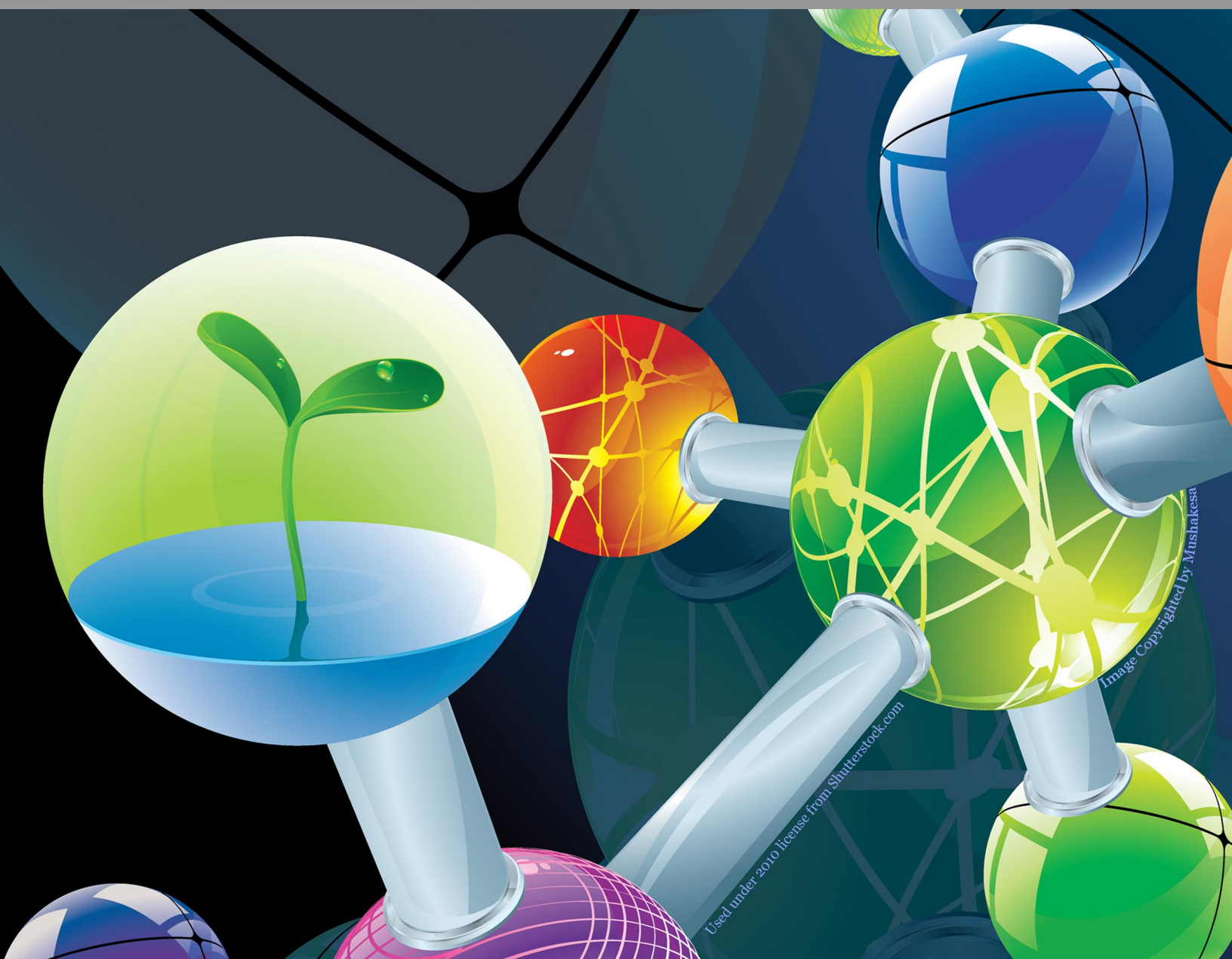


From Vitamins to Baked Goods: Real Applications of Organic Chemistry



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Kieran Gallagher, (KGallagher)
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CHAPTER 1

What Are Organic Compounds?



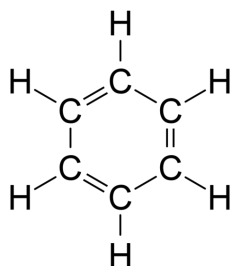
The picture above shows the magnificent Cat's Paw Nebula. The bright red cloud you see is made up of organic compounds such as formaldehyde, dimethyl ether, and methanol. Although these substances sound exotic and foreign, organic compounds are a vital part of our daily life. The same organic molecules present in the Cat's Paw Nebula can be found in everyday products, including hand sanitizers, household cleaners, and transportation fuels. In addition to being the key ingredients for commercial and industrial products, organic compounds are also responsible for many crucial chemical and biological processes. Understanding how to create and use various organic compounds is not just important for scientists; it is necessary for the average person in helping them make informed decisions about what they buy and what they put in their body.

Organic chemistry is the study of the properties, structures, reactions, and preparations of organic compounds. The use of the term "organic" suggests that organic chemistry is somehow connected to studying living things. In fact, organic chemistry has been once defined as the study of compounds produced by living organisms. Although it is now known that organic compounds can be synthetically produced, the name organic chemistry stuck. A compound is now classified as organic if it contains hydrogen and carbon atoms. Compounds consisting entirely of hydrogens and carbons are called hydrocarbons. However, a compound containing other atoms, such as nitrogen or oxygen, present can still be classified as organic. Generally, a molecule can be considered organic if it contains carbon-hydrogen bonds. Carbon based compounds that do not contain a hydrogen atom, such as carbon dioxide (CO_2), are not organic. There are some exceptions, but these guidelines will hold for most cases.

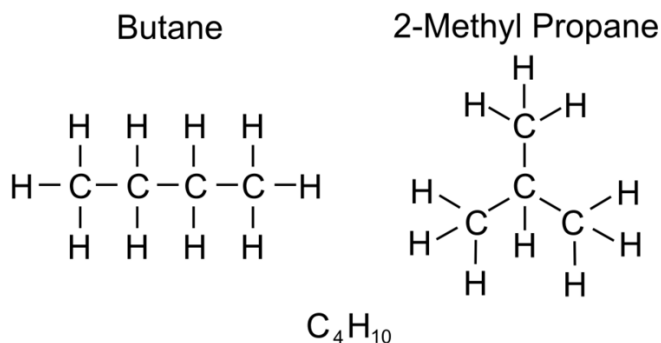
There are millions of different organic compounds, each with its own unique properties. This chemical diversity is in no small part due to the properties of carbon. Carbon has five important properties that allow hydrocarbons to have such a vital role in our lives: the ability to form **long carbon-to-carbon chains, complex branches, double or triple bonds, isomers, and strong bonds with many other elements**. Scientists try to understand how these properties of carbon affect the overall properties of an organic compound in order to learn how to create useful compounds.

A carbon atom contains six protons and six electrons. Of those six electrons, four are valence electrons, or electrons in the outer shell of an atom capable of participating in chemical bonds. Carbon, with its four valence electrons, wants to form four more bonds in order to have eight valence electrons. Due to its valence electron arrangement, carbon can readily form covalent bonds with other carbons, creating long, unbroken chains of varying lengths. Having four valence electrons also means that carbon is able to participate in single, double, and triple bonds with other atoms.

In addition to chains, carbon can form complex branches and rings. An example of this would be benzene, which has a ring-like structure formed by carbon bonds:



The ability for carbon to form complex branches results in the creation of isomers. Isomers are compounds that share the same molecular formula but have different structures. For example, consider butane and 2-methyl propane. Both share the chemical formula of C_4H_{10} . However, they have different structures.



They also have different chemical properties and uses. Because the chemical structure of a compound is important to its chemical properties, compounds with the same chemical formula can have completely different chemical properties. Carbon's versatile bonding allows for a near-infinite number of different organic compounds to exist.

Carbon is also essential for organic compounds because of its ability to form strong bonds with many other elements. Although it is commonly found bonded to hydrogen or other carbon atoms, carbon can also form strong bonds with many other elements, such as nitrogen, phosphorus, sulfur, halogens, and oxygen. When bounded to a hydrocarbon, these elements can alter the physical and chemical properties of the hydrocarbon. There are certain combinations of elements, known as functional groups, that will cause organic compounds to have similar characteristics. Some of the major functional groups include alcohols, aldehydes, ketones, carboxylic acids, esters, and ethers. These functional groups will be explored in the "Functional Group" chapters.

In this book, you will explore several common types of organic compounds. You will learn the structure and properties of each type and discover different everyday examples of these compounds. This textbook is not meant to be used for a yearlong course in organic chemistry; it simply provides a glimpse of the role organic compounds play in our daily lives and a brief explanation of why they behave the way they do.

CHAPTER 2

General Chemistry Background

CHAPTER OUTLINE

- 2.1 INTERMOLECULAR FORCES**
 - 2.2 BOILING POINT**
 - 2.3 BRONSTED-LOWRY ACIDS/BASES**
 - 2.4 SOLUBILITY**
-

The following chapters will attempt to describe the structure, basic properties, and common functions for seven major functional groups in organic compounds. In order to understand the discussion of each functional group, you must be equipped with some basic chemistry knowledge. The information you will need to know is outlined in this chapter. The following chapters will frequently refer back to topics in this chapter.

2.1 Intermolecular Forces

Three intermolecular forces that play a huge role in determining physical properties are van der Waals forces, dipole-dipole interactions, and hydrogen bonding. Of the three, van der Waals forces are the weakest and hydrogen bonds are the strongest.

Van der Waals Forces

Van der Waals forces, also known as London dispersion forces, are momentary attractions felt between molecules because of temporary dipoles. These dipoles are created when electrons become concentrated in one part of a molecule. This happens due to the random motion of electrons. Although all electrons have the same charge and repel each other, it is very rare for electrons to be distributed evenly around the nucleus because the electrons are constantly in motion. Most of the time, there will be different concentrations of electrons throughout the molecule. When this happens, part of the molecule will have a greater density of negatively-charged electrons, creating a negative pole. At the same time, a positive pole forms in the area of the molecule that lacks electrons. This temporary separation of charges is called an induced dipole. The charged ends of the induced dipole will be attracted to oppositely-charged ends of other dipoles (either permanent or induced), creating a momentary bond that holds the molecules together. The general rule is that the larger the molecule, the greater its van der Waals interaction with other molecules. This is because larger molecules have a greater surface area where van der Waals interaction can take place.

Dipole-Dipole Interactions

A molecule is considered polar when two bonded elements in the molecule have a large difference in their electronegativities. When this happens, the more electronegative atom will “hog” the electrons in the bond. This increases the electron concentration around the more electronegative atom, causing the atom to obtain a slight negative charge. The other atom that has had its electrons taken away will have a slight positive charge. This separation of charges is called a dipole. Similar to van der Waals forces, the charged ends of the dipole are attracted to oppositely-charged dipoles on other molecules. The interactions between dipoles are referred to as dipole-dipole interactions. Compared to the induced dipoles involved in attractive van der Waals forces, these dipoles are permanent. As a result, dipole-dipole interactions tend to be stronger than van der Waals forces.

Hydrogen Bonding

Hydrogen bonding is a phenomenon exhibited by water molecules, carboxylic acid molecules, and other molecules that contain a hydrogen atom and an exceptionally electronegative element, such as nitrogen, oxygen, or fluorine. Let's look at water molecules. Water molecules are polar; the oxygen atom has a negative charge and the hydrogen atoms have positive charges. The negatively-charged oxygen atom in one water molecule is attracted to the positively-charged hydrogen atoms in another water molecule. At low temperatures, this attraction is strong enough to form a loose bond called a hydrogen bond. This increases the boiling point of the substance because this hydrogen bond has to be broken before the substance can evaporate.

2.2 Boiling Point

A substance's boiling point is achieved when the vapor pressure of a substance is equal to the environmental pressure surrounding the substance. At this point, particles can overcome intermolecular forces and escape as gas into the surroundings. Consequently, the strength of a substance's intermolecular forces plays a huge role in the substance's boiling point. Molecules that are strongly attracted to each other will have very high boiling points. This is because it will take more energy, in the form of heat, to break the bonds between molecules and change the substance from a liquid to a gaseous state.

2.3 Bronsted-Lowry Acids/Bases

Bronsted-Lowry acids are “proton donors.” Hydrogen chloride (HCl) is an example of Bronsted-Lowry acids. When hydrogen chloride is added to water, the attraction between the positively-charged hydrogen ion in the hydrogen chloride and the negatively-charged oxygen in the water is strong enough that the hydrogen ion is removed. Hydrogen chloride is therefore called a “proton donor.”

In turn, Bronsted-Lowry bases are “proton acceptors.” They react with Bronsted-Lowry acids as the negatively-charged force that pulls protons from the acid. An example of a Bronsted-Lowry base is ammonium (NH_3), which can gain a proton to form ammonia (NH_4).

2.4 Solubility

Solubility is a measure of how well one substance, the solute, dissolves in another substance, the solvent. The identities of both substances, the temperature, and the pressure all affect the solubility of one substance in another. A general rule of thumb is that “like dissolves like.” For example, a nonpolar substance will generally be soluble in other nonpolar substances, but it typically will not mix very well with polar substances. Think of water and oil. Oil, a nonpolar substance, will not mix with water. Instead, the two different substances will form layers, with the denser substance at the bottom. You can temporarily force the two substances to mix by stirring or shaking up the solution, but it will always return to its separate layers.

However, a charged substance, such as the ionic compound NaCl (table salt), can dissolve easily in another polar substance, such as water (H₂O). This is because the polar ends of the water molecules are attracted to the ions. The negatively-charged oxygen atom in the water molecule will be attracted to the positively-charged sodium ion. Similarly, the positively-charged hydrogen atom in the water molecule will be attracted to the negatively-charged chloride. The water molecules will therefore be able to pull ions out of the salt. When all of the ions have been pulled apart by the water molecules, the salt has dissolved completely. When there are no more water molecules to pull apart the ions in the salt, the solvent has reached its maximum capacity and is called a saturated solution. Any more solute that is added to the solvent will gather at the bottom and form a precipitate.

A solution can become supersaturated if it is heated. Heat will increase the motion of the solvent’s molecules, allowing for more of the solute to be dissolved. However, once the supersaturated solution is allowed to cool down, the extra solute that had been dissolved will once again form a precipitate.

CHAPTER 3

What's in a Name? IUPAC Nomenclature

CHAPTER OUTLINE

- 3.1 NAMING ALKANES**
 - 3.2 NAMING ALKENES AND ALKYNES**
 - 3.3 HOW TO READ SKELETAL STRUCTURES**
 - 3.4 REVIEW QUESTIONS**
 - 3.5 ANSWERS**
-

There are several ways to name organic chemicals, but the most widely used naming convention is the substitutive nomenclature system developed by the International Union of Pure and Applied Scientists (IUPAC). This system is vital because of the many isomers that can be formed by organic chemicals. Isomers will have the same chemical formula but a different structure, which causes them to have completely different chemical properties. To minimize misunderstandings, the IUPAC created a nomenclature that would be consistent around the world and account for these isomers.

In order to provide a unique name to every compound, the naming of a complex molecule can become an involved and challenging process. When this is the case, a compound is sometimes referred to its common name. This name comes from an older IUPAC naming convention called the common nomenclature system. This naming system is sometimes preferred because it is simpler than the substitutive nomenclature system. When this is the case, this book will present both substitutive and common names.

This book is not meant to provide a comprehensive look to the substitutive nomenclature system. Instead, this book will only present a very basic introduction to IUPAC nomenclature. Three things are important in naming organic compounds: the number of carbons, the bonds present, and the functional groups. In this section, the substitutive nomenclature rules for naming alkanes is presented. These rules form the basis of all other organic compounds.

3.1 Naming Alkanes

An alkane is a compound that only contains hydrogens and carbons linked by single bonds. To name an alkane, follow these rules:

1. Identify and name the longest continuous carbon chain, called the parent chain.

The prefix for the name of an alkane will change based on the number of carbons present in the parent chain. These prefixes are as follows:

# of carbons	Prefix
1	Meth
2	Eth
3	Prop
4	But
5	Pent
6	Hex
7	Hept
8	Oct
9	Non

Add the appropriate prefix to the beginning of “-ane”. The “-ane” signifies that this is a carbon chain with only single bonds, or a saturated carbon chain. For example, a saturated carbon chain with six carbons would have the prefix “hex” added onto “-ane.” This chain would be called hexane.

If there is a functional group present, the name of the organic compound is changed. For example, if there is an alcohol group, the suffix “-anol” replaces the suffix “-ane.”

2. Identify any groups that are attached to the chain.

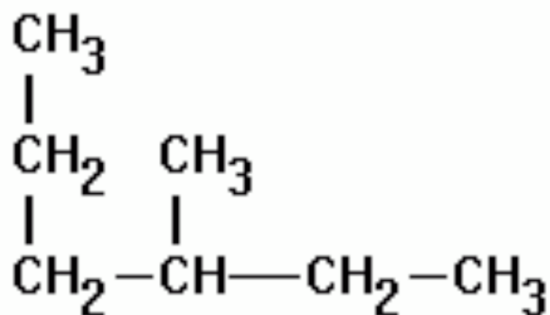
Some common groups that can be attached to alkanes are “methyl” and “ethyl.” A methyl group is CH_3 , while ethyl is C_2H_5 .

If there are multiple groups present, name both and put them in alphabetical order. If there are multiple of one group, put a prefix (di, tri, and so on) denoting that there are several groups of the same kind. For example, if there were two “ethyl” groups present on a hexane, it would be known as a diethyl hexane. These prefixes are not considered when alphabetizing the groups. In other words, in a compound with one “ethyl” group and two “methyl” groups, “ethyl” would still come before “dimethyl.”

3. Assign location numbers to the groups.

Add numbers in front of the group name to designate where it is located on the carbon chain. These numbers can be determined by counting carbons. Starting at one of the ends of the carbon chain, count the carbons until you get to the carbon that the group is attached to. This number will go in front of the group name. It is very important to start at the end of the carbon chain that will make the location number as small as possible.

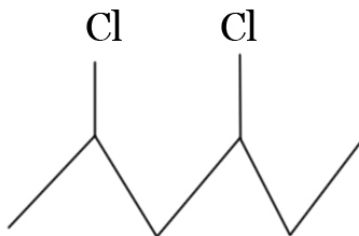
For example,



The parent chain would be hexane. You can also see that there is a methyl group attached. Depending on where you start counting carbons, you could name this molecule either 3-methylhexane or 4-methylhexane. However, only the name with the smallest location number would be correct. This molecule would be correctly named 3-methylhexane.

The format for the nomenclature of alkanes is: Location-Group Prefix “ane”

Examples:



3.2 Naming Alkenes and Alkynes

Alkenes are carbon chains that have double bonds. Alkynes are carbon chains that have triple bonds. The naming for these are very similar to that of alkanes.

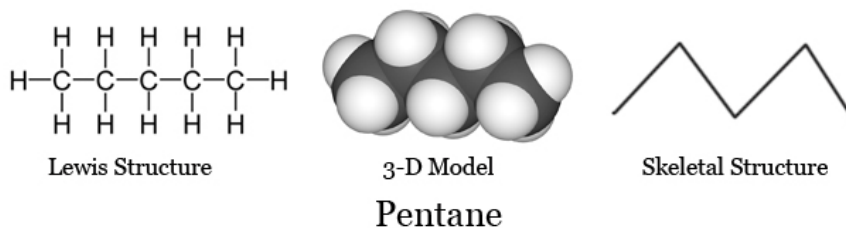
The only differences are:

- a. Instead of using the suffix of “-ane”, use “-ene” if there are double bonds and “-yne” if there are triple bonds.
- a. An additional step is that you also have to specify the location number of the double or triple bond. Count the carbons and make sure that the named bond is at the lowest number possible. The numbering for bonds takes precedent over This means that, even if it makes the location numbers for an attached group to be larger than otherwise, you count carbons from the end of the chain that would make the bond location number smallest.

3.3 How to Read Skeletal Structures

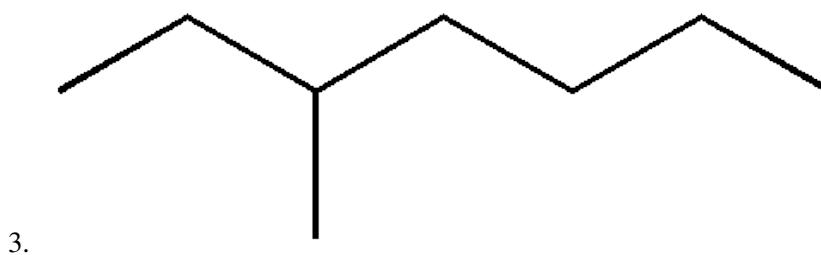
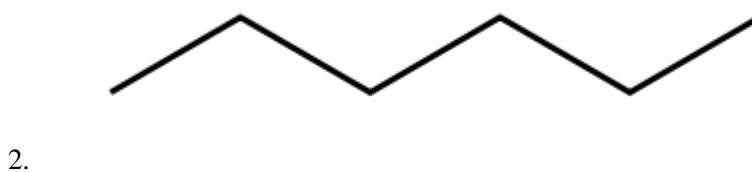
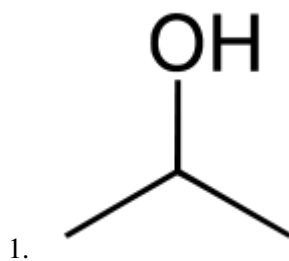
Once you get into larger carbon chains with multiple functional groups, the Lewis structure of these compounds starts to get very complicated. At this point, 3D models would become more confusing than helpful. When this happens, the shorthand method of writing out chemical structures is used. This structure is called a skeletal formula.

The skeletal formula removes all hydrogens that would be present in the Lewis Structure. This leaves only the carbon skeleton with the attached functional groups. Each point on the skeletal formula represents a carbon.



3.4 Review Questions

Name the following skeletal structures.



3.5 Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

CHAPTER

4**Functional Group: Alcohols****CHAPTER OUTLINE**

- 4.1 INTRODUCTION**
 - 4.2 BACKGROUND**
 - 4.3 FUNCTIONS AND APPLICATIONS OF ALCOHOLS**
 - 4.4 REVIEW QUESTIONS**
 - 4.5 ANSWERS**
-

4.1 Introduction

About the Chapter

The following chapter explains what alcohols are and how they behave. The chapter also looks at the use of methanol in hand sanitizers. Students then learn extensively about alcohol in beverages, including the history, creation, and effects of alcohol.

By the End of This Chapter, You Will Have Learned...

- The definition and basic properties of alcohols
- Basic alcohol nomenclature
- Why methanol is used in hand sanitizer
- How boiling points and intermolecular forces are related
- The effects of ethanol in beverages
- The two theories to why ethanol has such an intoxicating effect on humans

4.2 Background

An alcohol is defined as a hydrocarbon with a hydroxyl (-OH) functional group. This group includes methanol, ethanol, propanol, butanol, and more.

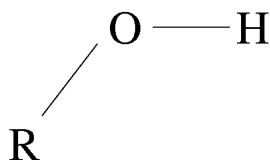


Diagram of an alcohol molecule. The “R” represents the rest of the compound.

Alcohols are useful for many purposes because of their behavior in water. Alcohols are polar and capable of forming hydrogen bonds with water. The bond between the carbon and the oxygen is exceptionally strong, so the hydroxyl group cannot be removed by water and remains a part of the hydrocarbon. The more negatively charged oxygen will pull the hydrogen atoms in the water molecules towards it, causing the alcohol molecules to separate. For these reasons, most alcohols are soluble, or capable of dissolving, in water. This property is important to industry today, as about 55% of ethanol produced synthetically is used to create solvents.

Alcohol is soluble in both water and lipids, or fats. While the “-OH” end of the alcohol molecule is hydrophilic, or attracted to water, the hydrocarbon chain attached to it is hydrophobic, or repelled by water. The hydrocarbon chain is miscible in lipids and gives alcohol its fat-soluble properties.

Alcohols can act as either a base or an acid because they are capable of attracting and donating hydrogen ions (H⁺). They are generally slightly more basic than water and share many properties with other bases. For example, alcohols usually taste bitter and feel slippery.

When naming alcohols, start by counting the number of carbons in the compound and give it the correct prefix. Alcohols are distinguished from alkanes by adding “-anol,” instead of “-ane,” to the prefix. For all other compounds than methanol, specify which carbon the hydroxyl group is bonded to by following the IUPAC scheme.

4.3 Functions and Applications of Alcohols

Hand Sanitizer

One common application for alcohol is in hand sanitizer. The presence of alcohol, usually ethanol or isopropanol, in hand sanitizers gives the sanitizers many of their useful properties. Perhaps the most useful property of hand sanitizers is the convenience of not having to dry off the hands after cleaning. This is because alcohol can evaporate quickly even though it exists as a liquid at room temperature. How quickly a substance evaporates is related to how strongly the molecules of the substance are attracted to each other and how much pressure is acting on the substance. If the molecules are strongly attracted to each other, the substance is more likely to be a solid or liquid because the molecules will be pulled close together. If the molecules are not strongly attracted to each other, the substance is more likely to exist in the gaseous state because the molecules only need a small amount of kinetic energy to pull away from each other. The hydroxyl group in alcohol has a slightly negative charge, so it would be loosely attracted to the more positively charged ends of other alcohol molecules (see the sections on intermolecular forces and boiling point in the “General Chemistry Background” chapter).



Alcohols are usually an ingredient in hand sanitizers like the one depicted here.

When the alcohol is inside the container, it is confined to a very small space. This results in a lot of pressure on the alcohol, causing it to stay in the liquid form. However, when the bottle is opened and the hand sanitizer is applied to the hands, there is much less pressure on the alcohol molecules. The attraction between the molecules is not strong enough to hold them in the liquid form, so the alcohol evaporates very quickly.

Alcohol is also an effective ingredient in hand sanitizers because it is able to effectively kill bacteria. The membranes of bacteria cells are made of a phospholipids bilayer, which is a type of fat. Because alcohols are soluble in fats, alcohol can bind to the membrane. When the alcohol molecules evaporate, they pull apart the membranes of the bacteria and cause the bacteria cells to die. Furthermore, alcohol denatures proteins in the bacteria. The polar hydroxyl group attracts compounds in the protein, causing them to bond to the alcohol. This prevents the proteins from forming correctly. Therefore, the amino acids cannot fold into polypeptides and are not able to carry out their designated purpose. Almost all cell functions depend on proteins, so when the proteins cannot form correctly, the cell is unable to function and dies.

Due to these unique properties of alcohols, scrubbing hands for thirty seconds with hand sanitizer has been deemed the equivalent to washing hands with soap in terms of killing harmful bacteria. For a more thorough cleaning, the

best way to get rid of bacteria is to first wash the hands and then use hand sanitizer.

Test Your Understanding

- The chemical acetone is used in nail polish remover, which quickly evaporates if left out. Describe the intermolecular forces between acetone molecules.
- Why is water wet?
- Based on your knowledge of dipole-dipole forces, which will evaporate first - ethylene (C_2H_4) or propanol (C_3H_7OH)?

Answers

- Acetone molecules are held together very weakly because not very much energy is required to break the attraction between molecules that holds them in the liquid phase.
- Water is a polar molecule, so water molecules exhibit strong dipole-dipole forces, which holds it in the liquid state at room temperature.
- Ethylene will evaporate first because carbon atoms are not extremely electronegative, so each ethylene atom will not be polar and there will be no dipole-dipole forces. In fact, ethylene is a gas at room temperature. Propanol will have some dipole-dipole forces because the hydroxyl group will have a negative charge.

History of Ethanol in Beverages



In the past, alcohol was frequently consumed to avoid the spread of waterborne diseases. People noticed that those who consumed more wine than water contracted less diseases, but their knowledge of chemistry and biology was not enough to explain the reason why. Now it is known that water's structure makes it ideal for dissolving many substances, including harmful ones. Because of this, water is often called "the universal solvent." In comparison, alcohol molecules are larger and not as polar as water molecules. As a result, alcohol is not nearly as proficient in dissolving substances as water. Therefore, less harmful disease-causing substances are able to dissolve in alcohol than in water, making alcohol the "healthier" drink alternative when clean water is unavailable.

Even today, the issue of unclean water sources is still a prominent one. To learn more about the struggle many people face today to get clean water, visit this website:

<http://water.org/learn-about-the-water-crisis/facts/>

Creation of Ethanol for Beverages

Perhaps the most well-known alcohol is ethanol, which is the type of alcohol found in alcoholic beverages. Other alcohols are considerably more poisonous and are not fit for human consumption. Ethanol is produced in a process called fermentation. In this process, yeast converts a molecule of glucose ($C_6H_{12}O_6$), a type of sugar found in most plants, into two molecules of ethanol (C_2H_5OH) and two molecules of carbon dioxide (CO_2). The chemical expression for this process is:



A variety of alcoholic beverages can be produced through the fermentation of sugars present in grapes, potatoes, wheat, and more. For example, grains are used to produce whiskey and beer, fruits (usually grapes) are used to produce wine, fruit juices are used to produce brandy, and sugarcane is used to produce rum.

LAB: Homemade Root Beer

The process of fermentation can be used to create not only alcoholic beverages but delicious soft drinks as well!



Materials

- 1 cup table sugar (cane sugar or sucrose)
- 1 tablespoon Root Beer Extract
- 1/4 tablespoon powdered baker's yeast (fresh and active)
- cold fresh water
- clean 2 liter plastic soft drink bottle with cap
- funnel

Procedure

- a. Use the funnel to add the sugar to the bottle.
- b. Use the funnel to add the yeast on top of the sugar.

4.3. FUNCTIONS AND APPLICATIONS OF ALCOHOLS

- c. Shake to mix the yeast and sugar, then swirl it in the bottom so the surface of the mixture is concave (the surface should hollow inward like the inside of a bowl).
- d. Use the funnel to add the root beer extract.
- e. Fill the bottle halfway with pure water - the purer the water, the better. In the process, rinse off any extract that is stuck to the sides of the funnel and bottle. Swirl to dissolve all ingredients.
- f. Once all ingredients are dissolved, fill the bottle to the top with water, leaving approximately 1 inch of space at the top.
- g. Screw the cap securely onto the bottle to seal. Store the bottle at room temperature for 3-4 days, or until it becomes difficult to squeeze the bottle.
- h. Refrigerate the bottle overnight. When opening, unscrew the cap slightly to release the pressure slowly.
- i. Serve and enjoy!

Notes

- Do not store the bottle in a warm place, especially after it begins to feel hard to squeeze. If it is left out in the heat, enough pressure can build up inside the bottle for it to explode.
- Avoid glass bottles. If pressure causes the bottle to explode, glass shards could be dangerous.
- The alcohol content in this beverage is between 0.35% and 0.5%, which is considered to be a negligible amount. A beer has 6% alcohol content, so in order to feel the same effects of consuming a 12-ounce beer, 1.5 gallons of root beer would have to be consumed. However, avoid this beverage if you cannot properly metabolize alcohols.

Effects of Ethanol as a Beverage

Blood Alcohol Content

The effects of ethanol when consumed include recklessness, clumsiness, slurred speech, delayed reflexes, and decreased inhibition. The chart below shows the common symptoms for different blood alcohol contents (BACs), which measures how many grams of ethanol are present for every 100 milliliters of blood.

The severity of the effects depends on the amount consumed as well as the weight, body type, and gender of the person. Because BAC is the grams of alcohol present divided by milliliters of blood, a heavier person will have a greater volume of blood and a lower BAC when consuming the same amount of alcohol as a smaller person. As a result, if two people consume the same amount of alcohol, the one who weighs less will be more affected by the alcohol. However, because alcohol is soluble in fats, a body with more fats will have a harder time of removing the alcohol. As women generally have more body fat than men, women generally become intoxicated more easily.

BAC (g/100 ml of blood)	Stage	Clinical symptoms
0.01 - 0.05	Subclinical	Behavior nearly normal by ordinary observation
0.03 - 0.12	Euphoria	Mild euphoria, sociability, talkativeness Increased self-confidence; decreased inhibitions Diminution of attention, judgment and control Beginning of sensory-motor impairment Loss of efficiency in finer performance tests
0.09 - 0.25	Excitement	Emotional instability; loss of critical judgment Impairment of perception, memory and comprehension Decreased sensory response; increased reaction time Reduced visual acuity; peripheral vision and glare recovery Sensory-motor incoordination; impaired balance Drowsiness
0.18 - 0.30	Confusion	Disorientation, mental confusion; dizziness Exaggerated emotional states Disturbances of vision and of perception of color, form, motion and dimensions Increased pain threshold Increased muscular incoordination; staggering gait; slurred speech Apathy, lethargy
0.25 - 0.40	Stupor	General inertia; approaching loss of motor functions Markedly decreased response to stimuli Marked muscular incoordination; inability to stand or walk Vomiting; incontinence Impaired consciousness; sleep or stupor
0.35 - 0.50	Coma	Complete unconsciousness Depressed or abolished reflexes Subnormal body temperature Incontinence Impairment of circulation and respiration Possible death
0.45 +	Death	Death from respiratory arrest

Alcohol and Neurotransmitter Receptors in the Brain

Scientists still do not know exactly why alcohol has the intoxicating effects that it is known for, but there are a few highly probable theories that would explain alcohol's effect on humans. One widely accepted explanation is based on the attachment of alcohol to glutamate receptors. Glutamate is a non-essential amino acid, or a protein that can be made by the body. It acts as a neurotransmitter and is the most common stimulative neurotransmitter in the brain. The presence of glutamate increases the speed of neuron firing. Neurons are cells that exist throughout the body and work together to pick up, transmit, and interpret signals from outside the body. When glutamate is present, the signals are picked up, sent, and interpreted more quickly. As a result, glutamate is most often associated with learning and memory. For this reason, foods containing glutamate are usually considered as "brain foods."

4.3. FUNCTIONS AND APPLICATIONS OF ALCOHOLS



When alcohol travels through the digestive system, a small percentage of it is absorbed into the blood stream by the small intestine. The alcohol that is absorbed travels through the bloodstream and eventually reaches the brain. Upon reaching the brain, alcohol will bind to glutamate receptors, preventing glutamate from attaching to the receptors. Since the presence of glutamate increases the speed of neurons firing, the absence of glutamate slows the speed of neurons firing. This causes the body to slow down and affects memory formation. The exact effects of this are determined by where exactly the alcohol molecules bind to the glutamate receptors. For example, the frontal lobe of the brain is used for judgment and reasoning. When ethanol binds to receptors in the frontal lobe, it can cause recklessness and decreased inhibition.

Scientists have also discovered that ethanol is able to attach to the GABA (gamma-aminobutyric acid) receptors. Unlike glutamate receptors, GABA receptors slow down brain activity. The attachment of alcohol to these receptors increases their activity, for reasons currently unknown to scientists. This slows down the body, causing the delayed reflexes and clumsiness often associated with ethanol consumption.

Excessive alcohol consumption can be very dangerous. The brain stem is a small but crucial portion of the brain that controls breathing, heartbeat, and other vital body functions. If ethanol molecules attach to receptors in the brain stem, these functions will slow down or shut down, resulting in coma or death.

4.4 Review Questions

Basic

1. Describe two factors that affect how drunk a person will become from consuming alcohol.
2. True or False: When alcohol is mixed with water, alcohol will float on the surface. Explain why or why not.

Intermediate

3. Describe two ways that ethanol slows down body functions.
4. Why was the root beer you made bubbly?
5. True or False: Using hand sanitizer is more effective than washing hands with soap and water. Explain why or why not.

Advanced

6. A person has a rare disorder that causes the body to be deficient in the amino acid glutamate. What would the symptoms of this deficiency be?

4.5 Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

CHAPTER

5**Functional Group: Aldehydes
and Ketones****CHAPTER OUTLINE**

5.1 INTRODUCTION

5.2 BACKGROUND

5.3 FUNCTIONS AND APPLICATIONS OF ALDEHYDES AND KETONES

5.4 REVIEW QUESTIONS

5.5 ANSWERS

5.1 Introduction

About the Chapter

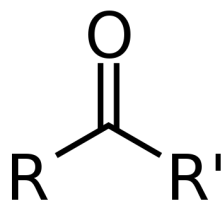
After explaining what aldehydes and ketones are, this chapter will summarize some important properties of these compounds and explore the many ways ketones and aldehydes are used in our daily lives. You will learn how ketones are prevalent in the environment, present in our bodies, and able to cure opiate addiction. You will also learn why aldehydes are used in perfumes, baking, and cleaning products.

By the End of This Chapter, You Will Have Learned...

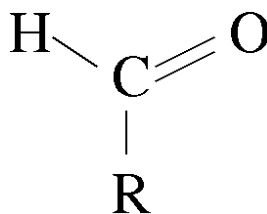
- The definition and basic properties of ketones and aldehydes
- How to distinguish an aldehyde from a ketone
- The basic nomenclature of aldehydes and ketones
- How the chemical methadone is used to cure opiate addiction
- How acetone affects the environment
- How ketones are produced metabolically in the body
- How ketones and aldehydes smell
- How aldehydes are involved in baking
- Why aldehydes are used in cleaning products

5.2 Background

Ketones and aldehydes have very similar structures and therefore behave very similarly. Both contain a formyl group, or a carbon molecule double-bonded to an oxygen molecule. In ketones, the formyl group occurs somewhere in the middle of the hydrocarbon, while in aldehydes the formyl group occurs at the end. Both aldehydes and ketones are almost always polar because the oxygen pulls more of the electrons in the compound towards itself. However, when the molecule is so large that the pull of the oxygen is considered negligible, the molecule is nonpolar.



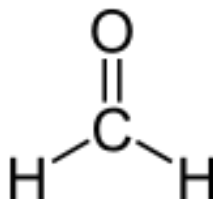
This is the diagram for all ketones. “R” represents the rest of the compound. Both R’s do not have to be identical.



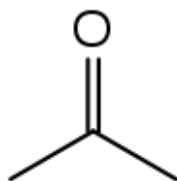
This is the diagram for all aldehydes. Again, the “R” represents the rest of the compound.

To remember the difference between aldehydes and ketones, let’s take a look at the etymology of aldehyde. The name aldehyde comes from “alcohol dehydrogenated.” Recall from the chapter “Functional Group: Alcohol” that alcohols contain a hydroxyl group (-OH) on the end. If you remove the hydrogen, or dehydrate the alcohol, you obtain an aldehyde, not a ketone.

When naming aldehydes, start by counting the number of carbon atoms and give the compound the appropriate prefix. Then, add the suffix “-anal.” This is the molecule’s IUPAC name. However, many aldehydes are more commonly referred to by another given name. For example, methanal is more commonly called formaldehyde.



(1) Hydrocarbon Base: methane (2) Prefix: meth- (3) IUPAC Name: methanal (4) Common Name: formaldehyde



(1) *Hydrocarbon Base: propane* (2) *Prefix: prop-* (3) *IUPAC Name: propanone* (4) *Common Name: acetone*

To name a ketone, first determine the name of the hydrocarbon it is based off of by counting the number of carbons. For example, if the compound has three carbons, its parent hydrocarbon is propane. Then, drop the “-e” from the parent hydrocarbon’s name and add an “-one.” In this example, the ketone would be called “propanone.”

5.3 Functions and Applications of Aldehydes and Ketones

Methadone and Opiates

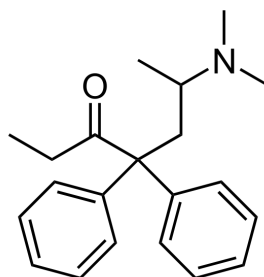


Diagram of a methadone molecule.

The ketone methadone ($C_{21}H_{27}NO$) has been used to cure addiction to opiates. Some common opiates are heroin, opium, and morphine. All of these drugs work by causing the body to release excessive amounts of the hormone dopamine. This hormone ends up in the brain, where it attaches to the dopamine receptor and creates a feeling of happiness. Opiates are extremely addictive because a person quickly develops a physiological need to have something constantly bounded to the opiate receptor. Otherwise, the addict will experience withdrawal symptoms, which include muscle aches, sweating, vomiting, agitation, abdominal cramping, and more.



This is the bulb of an opium poppy, which is used to create opium, heroin, and morphine.

To help combat opiate addiction, the oral medication methadone can be prescribed by a medical professional. Methadone works by binding to the dopamine receptor in the brain. This eliminates the user's physical dependence on opiates because the user doesn't need anything else to bind to the dopamine receptor. It also prevents the feelings of happiness caused by heroin because the dopamine has nowhere to attach to. This usually eliminates the user's desire for heroin as well. Methadone is also able to suppress withdrawal symptoms for 24 – 36 hours. Although people taking methadone are now physically addicted to the drug, they are no longer controlled by their

addiction. In comparison, heroin addicts tend to experience extreme emotional highs and lows and are known for their compulsive and disruptive behavior. After methadone is able to stabilize the user's behavior, the user is able to begin the process of reducing methadone intake until the addiction is removed.

A typical dose is 5-20 milligrams of methadone in an oral solution. Patients can also receive methadone in the form of a tablet or injection. Most methadone treatment programs are outpatient programs, which means the users live at home but must come to the hospital regularly to receive treatment. One common side effect of taking methadone is drowsiness, which can make certain everyday activities more difficult. Some of the other known side effects of methadone include dehydration and excessive sweating, but these usually disappear as the user gains tolerance, allowing most methadone users to live relatively normal lives.

In 1999, about 20% of the 810,000 heroin addicts in the United States have been using methadone. Among heroin addicts treated with methadone, weekly heroin usage decreased by 69%, criminal activity decreased by 52%, and full employment increased by 24%. These statistics reflect that methadone treatment is both effective and efficient. Unfortunately, methadone is not a cure-all and can only treat opiate addictions.

Acetone in the Environment

One of the most extensively used ketones is acetone. Looking at the acetone molecule below, you may have noticed the lone oxygen atom in the middle of the compound. This oxygen atom exerts a strong pull on the electrons in the compound and makes acetone extremely polar. For this reason, acetone is used frequently in laboratories as a solvent for various chemical reactions. Acetone is also used in laboratories for rinsing glassware. It is also an ingredient in products such as nail polish removers, particle board, paint removers, and some detergents. Acetone is produced by both natural phenomena and industrial activities. It is released into the air during forest fires and volcano eruptions. It can also be released into the air from automobiles, tobacco smoke, and burning waste in landfills.

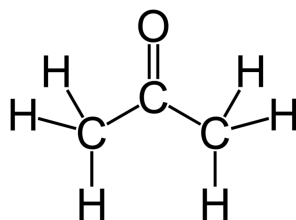


Diagram of an acetone molecule.

Because of its many uses, acetone has begun to build up in soil, water, and air, although acetone concentrations are still relatively low. The average amount of acetone in cities is 7 ppb (parts per billion), and even lower in rural areas. The average concentration in water is barely measurable and estimated at 1 ppb. The EPA limits the acetone concentration in workplaces to 750 ppm (parts per million). Acetone's first effects are noticed at 250 ppm, where it begins to affect performance on aptitude tests and can cause nose and throat irritation. Severe effects are not noticed until concentrations of 1000 ppm.

To find the acetone levels in your area, you can use this website:

<http://toxmap.nlm.nih.gov/toxmap/main/index.jsp>

Ketones and Metabolism

Ketones are also a natural byproduct of animal metabolism. Typically, the body breaks down glucose for energy. However, if the glucose level in the body is low, the body is forced to break down fatty acids or proteins for energy and produces three ketone by-products. These ketone by-products, also known as ketone bodies, are acetone, acetoacetic acid, and beta-hydroxybutyric acid. Beta-hydroxybutyric acid is technically not a ketone; it is a carboxylic acid. However, since it is produced with acetone and acetoacetic acid in metabolism, it is still classified as a ketone body. Both acetoacetic acid and beta-hydroxybutyric acid can be converted back into useful compounds that the body needs, but acetone cannot. Instead, acetone will accumulate in the bloodstream. It will exit the body when it is excreted in urine or when it is exhaled through the lungs.

While the production of these ketone bodies is normal, the accumulation of ketone bodies can be problematic. Excess ketones may be a sign that you need to eat more carbohydrates. The body will break down carbohydrates into sugars, resulting in increased blood sugar level. If there is more glucose in the bloodstream, the body will not have to break down fatty acids for energy, which will reduce the amount of ketones produced.



Whole wheat bread is a good source of carbohydrates that can help prevent acetone buildup.

An excess of acetone in the bloodstream is also a common symptom of diabetes. Diabetics are either lacking in or are resistant to insulin. Insulin is a hormone that allows glucose from the bloodstream to be used in the body. If the body has no insulin or cannot use it properly, all energy must come from breaking down fatty acids. The increased activity of converting fatty acids to energy results in a much greater concentration of ketone bodies in the bloodstream.

The buildup of ketone bodies presents an especially concerning issue for diabetics. A person with diabetes is deficient in insulin, the hormone that allows sugars to enter cells. Because there is no insulin in the body, a diabetic is forced to rely on fatty acids and proteins for energy, which produces a large quantity of ketone bodies. This can be prevented by monitoring insulin levels within the body. However, if a diabetic's body is subjected to stress, such as an illness, emotional trauma, disruption to insulin treatment, or surgery, a condition called diabetic ketoacidosis (DKA) can occur. When a diabetic's body is in a stressful situation, it produces hormones such as adrenaline, which increase the rate at which fatty acids are converted to energy. This causes ketone bodies to accumulate. When so much acetone builds up in the blood, the body attempts to eliminate it all by causing excessive urination. Symptoms of diabetic ketoacidosis include dehydration, deficiencies in salts such as potassium, nausea, fatigue, confusion, abdominal cramping, excessive thirst, and decreased perspiration. DKA can be treated through undergoing insulin therapy, replenishing the body with the fluids and electrolytes, and diminishing stress.

5.3. FUNCTIONS AND APPLICATIONS OF ALDEHYDES AND KETONES



This urine test will change color depending on the amount of ketones in the urine.

The most common way to test for an excess of ketones in the bloodstream is a urine test, although a blood test will be more accurate. Although it is not a dependable way of determining ketone buildup, ketone excess is often associated with fruity smelling breath. This is because ketones generally have a relatively high vapor pressure due to their small sizes and therefore evaporates easily. As ketones have a distinctive scent, they can be detected when they leave the body through the lungs.

Aldehydes and Ketones in Perfumes

Both ketones and aldehydes are found in a number of perfumes. Ketones are used to create acetophenone, which is responsible for creating almond, cherry, honeysuckle, jasmine, and strawberry fragrances. Compared to ketones, aldehydes are a more popular source for perfumes fragrances. The following chart shows common aldehydes used in perfumes and their scent:

Heptanal (C ₇ H ₁₄ O)	Occurs naturally in sage leaf and has an herbal odor
Octanal (C ₈ H ₁₆ O)	Has a citrusy scent, specifically smells like oranges
Nonanal (C ₉ H ₁₈ O)	Smells like roses
Decanal (C ₁₀ H ₂₀ O)	Has a smell strongly reminiscent of orange-rind
Undecanal (C ₁₁ H ₂₂ O)	Occurs naturally in coriander leaf and has a “clean” smell
Duodecanal (C ₁₂ H ₂₄ O)	Smells like lilacs and violets
Tridecanal (C ₁₃ H ₂₆ O)	Has a citrusy scent, specifically smells like grapefruit
Tetradecanal (C ₁₄ H ₂₈ O)	Famous for its peach-skin smell in <i>Mitsouko</i>

Some perfumes containing aldehydes include Chanel No.5 and No.22, Lancôme Climat, Givenchy L’Interdit, Estée Lauder Estée, and D#38;G Sicily.



Chanel no. 5 wasn't the first perfume to include aldehydes, but it is responsible for popularizing their use in perfumes.

Aldehydes in Baked Goods and Herbs

Even the delicious scents of cookies baking in the oven come from aldehydes. Aldehydes are an important part of some sugars and are contained in many substances used in baking, such as cinnamon, vanilla, and more. They also play a crucial role in the caramelization of sugars. When sugars are cooked slowly without stirring, amino acids in the sugar begin the process of turning the aldehyde group into an unsaturated aldehyde. The substance has then become caramel, which can be used to give a product a brown color, create a crust on a baked good, or be consumed plain.



Baked goods like these cupcakes usually contain aldehydes.

Aldehydes are also contained in many herbs. The aldehyde decenal is a major component of coriander, the leaf which is often said to be the world's most widely consumed herb. Decanal, which is responsible for the coriander leaf's odor, is especially reactive. This causes coriander to quickly lose its scent when heated because the compound often reacts with other compounds. Another commonly encountered aldehyde is hexanal. Also known as the "leaf aldehyde," hexanal is responsible for the "grassy" scent of fresh leaves. This scent fades, however, when the leaves are cut or crushed because the damaged cells release enzymes that are capable of breaking up the six-carbon chain.

5.3. FUNCTIONS AND APPLICATIONS OF ALDEHYDES AND KETONES

LAB: Making Caramel

In this lab, you will chemically alter an aldehyde to create a tasty treat!



Materials

- 1 cup white granulated cane sugar
- water
- a pot with a handle
- hot pads
- tub of ice water
- vegetable oil
- glass pan
- aluminum foil

Procedure

- a. Lightly oil the aluminum foil and use it to line the glass pan. Set aside.
- b. In the pot, mix the sugar with enough water to dissolve it into a thick syrup.
- c. Put the pot on the stove over low to medium heat.
- d. Use a hot pad to hold the pan by the handle and tilt the pan back and forth to dissolve all the sugar.
- e. When all the sugar has dissolved, bring the mixture to a boil. Do not stir or shake. Large bubbles should begin to form.
- f. Remove the pot from the stove once the mixture becomes golden brown.
- g. Dip the pot in the tub of ice water to stop the cooking process.
- h. Pour the mixture into the glass pan. Set aside to harden.
- i. Enjoy.

Note

- Take extreme caution when handling boiling substances. Use a hot pad at all times when handling the pot.
- Do not refrigerate the caramel in an attempt to speed the cooling process. The humidity will affect the sugar.
- If you wish to speed up the cooling process, place glass pan in the freezer for approximately five minutes.
- The caramel will begin to harden within ten minutes. If you wish to mold the caramel or use it for cooking, work quickly.
- Different ingredients can be added to create different flavors of caramel. For example:
 - Almond caramel: Stir in 1/2 teaspoon almond extract and 1/2 cup sliced almonds
 - Coconut caramel: Add 1/2 cup unsweetened coconut milk.
 - Coffee caramel: Add 1 tablespoon instant espresso powder to it.
 - Rum caramel: Stir in 1 tablespoon rum extract.
 - Vanilla caramel: Stir in 1 tablespoon vanilla extract.

Lab inspired by:

- <http://www.baking911.com/candy/caramels.htm>
- <http://www.wikihow.com/Make-Caramel>

Formaldehyde and Glutamaldehyde as Disinfectants

Aldehydes are also used in disinfectants and antiseptics. The two types of aldehydes that are most commonly used in commercial cleaners are formaldehyde and glutamaldehyde. Formalin, the aqueous form of formaldehyde, kills bacteria by dehydration. It causes the liquid inside the cells to coagulate. Bacteria can usually flush unwanted toxins from the cell. However, when they are dehydrated, the toxins remain trapped inside the cell and cause the bacteria to die. Formalin is often used to maintain aquariums. It has also been used frequently as an embalming agent, because it helped human cells to retain their form and prevented the body from decaying before the funeral. However, formalin has been discovered to be toxic, allergenic, and even carcinogenic (cancer-causing) when inhaled. It is therefore no longer used for embalment purposes.



Disinfectants containing aldehydes can be used to thoroughly clean your house.

Glutamaldehyde is another common cleaner. It kills bacteria, fungi, viruses, and more. Glutamate is able to attack the cell membrane and cell walls in bacteria and fungi, which prevents the cell from functioning. It also affects amino acids and causes proteins to denature. As proteins are responsible for many cell functions and make up cell DNA, this prevents the cell from functioning.

5.4 Review Questions

Basic

1. Why are aldehydes and ketones so similar? What makes them different?
2. True or False: Ketones smell like oranges.

Intermediate

3. Which would be better to use to clean your house, a disinfectant containing formaldehyde or one containing glutamaldehyde?
4. Compare and Contrast the effects and behavior of opiates and methadone in the body.
5. Name the three ketone bodies produced during the metabolism of fatty acids or proteins? Which one is not actually a ketone?

Advanced

6. Your friend is trying a new diet where she doesn't eat any carbohydrates. Why would you tell her this is a bad idea?

5.5 Answers

Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

CHAPTER

6**Functional Group: Carboxylic Acids****CHAPTER OUTLINE**

6.1 INTRODUCTION**6.2 BACKGROUND****6.3 FUNCTION AND APPLICATIONS OF CARBOXYLIC ACIDS****6.4 REVIEW QUESTIONS****6.5 ANSWERS**

6.1 Introduction

About the Chapter

This chapter begins by defining carboxylic acids and briefly discussing their properties. The structure of carboxylic acids will be related to their involvement in our lives, such as their role in our muscles as lactic acid and their role in face care products as salicylic acid. You will also learn why aspirin is so effective, why fish is good for you, and what citric acid really is.

By the End of This Chapter, You Will Have Learned...

- The definition and basic properties of carboxylic acids
- How hydrogen bonding and van der Waals dispersion forces affect boiling point
- Basic nomenclature of carboxylic acids
- How and why lactic acid builds up in muscles during exercise
- Why salicylic acid is used in acne medications and facial care products
- Why acetylsalicylic acid is used in aspirin
- How and why citric acid is used so often in commercially produced foods
- How and why omega-6 and omega-3 work wonders in our bodies

6.2 Background

A carboxylic acid is defined as any hydrocarbon with a carboxyl group ($-\text{COOH}$), which looks like a ketone and an alcohol combined. Some examples include acetic acid (found in vinegar), citric acid, acrylic acid, butyric acid, caproic acid, and biotin.

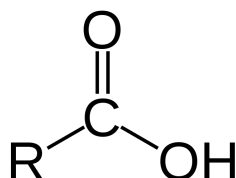
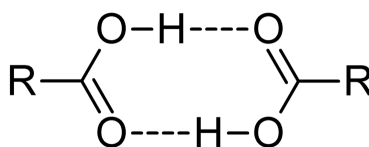


Diagram of a carboxylic acid

In a carboxylic acid, the hydrogen atoms have a slightly positive charge, and the oxygen atoms have a slightly negative charge. This polarity creates an attraction between carboxylic acid molecules that is strong enough to form a hydrogen bond. When two molecules are held together by a hydrogen bond, the compound as a whole is called a dimer.



Carboxylic acid dimer

This property causes carboxylic acids to have higher boiling points. It is impossible for a gas to form intermolecular hydrogen bonds. Therefore, in order for liquid carboxylic acids to become a gas, the energy added to each molecule has to be enough to overcome the hydrogen bonds between them.

The polarity of carboxylic acids also allows them to be soluble in water. Instead of forming a dimer, the negatively-charged oxygen molecules in the carboxylic acid are attracted to the positively-charged hydrogen molecules in the water, while the oxygen molecules in the water are attracted to the hydrogen molecules in the carboxylic acid. This allows each carboxylic acid molecule to bond to a water molecule, causing the carboxylic acid molecules to be evenly dispersed throughout the solution.

6.3 Function and Applications of Carboxylic Acids

Lactic Acid and Exercise

One commonly known carboxylic acid is lactic acid, the substance that builds up in muscles during anaerobic exercise. Whenever we move we use adenosine triphosphate, or ATP, for energy. ATP is created from glucose in a process called aerobic respiration that occurs in every one of our cells. Only approximately 85 grams of ATP can be stored at one time. During exercise, all the stored ATP is quickly used up, and the body has to produce more.



Runners build up lactic acid in their muscles during intense training.

One product of aerobic respiration is the hydrogen ion, H^+ . This product is easily eliminated because when two hydrogen ions combine with inhaled oxygen, H_2O is formed. This is why you start to breathe harder when you exercise harder; more oxygen is needed as you produce more ATP. This website can explain the process in greater detail:

http://library.thinkquest.org/C004535/aerobic_respiration.html

However, everyone reaches a point where they cannot breathe in enough oxygen to produce the necessary amount of ATP. As the hydrogen ion builds up in the cell, a chemical called pyruvic acid (CH_3COCO_2H) will take the H^+ and become lactic acid. The lactic acid dissociates into lactate and H^+ before exiting into the blood stream. During this process, if the concentration of hydrogen ions is high enough to bring the pH down to 6.5 or lower, the acidity begins to stimulate the nerve endings in the muscles and creates the perception of pain.

This pain hinders athletic performance, which is why runners often train to prolong the amount of time they can run before experiencing pain. The amount of time an athlete can exercise before reaching this point is called the lactic, or anaerobic, threshold. These training workouts are almost always longer, even-paced runs. For example, in one common workout, athletes add one minute to their fastest mile time and try to keep that pace up for three miles. For more anaerobic threshold workouts, check out this site:

http://sportsmedicine.about.com/od/anatomyandphysiology/a/LT_training.htm

Usually it takes one hour for the body to eliminate all of the lactate from the muscles into the bloodstream, although this process will be sped up if a proper cool-down is included after intense exercise. The light exercise in the cool

down causes heavier breathing, which allows the body to obtain more oxygen. The oxygen can bond to the hydrogen ions, decreasing the acidity. The average amount of lactic acid in the bloodstream is 1-2 millimoles/liter blood. However, after reaching the anaerobic threshold the average amount of lactic acid is usually 2-4 millimoles/liter blood.

Salicylic Acid in Skin Care Products

Carboxylic acids are not only found in the body but in commercial products. Scientists have discovered that the carboxylic acid beta hydroxyl acid, or BHA, can be used to create acne medications. It is therefore used frequently in cleansers, liquid foundations, moisturizers, anti-aging hydrating creams, eye gels, and sun screens. The type of BHA that is used most commonly in skin care products is salicylic acid.



Face care products often contain salicylic acid

Acne is formed when substances such as dead skin cells or bacteria clog pores. BHAs like salicylic acid are able to exfoliate dead skin cells, which speeds up the natural body process of shedding the outer layer of dead skin. This helps to prevent dead skin cells from clogging pores and to smooth rough skin. In addition, BHA is soluble in fat, which means it can dissolve in oils. Bacteria and dead skin cells have fat-based membranes, which allow them to stick to keratin and sebum, oils produced by the pores. The fat solubility of BHA allows it to dissolve into the oils and helps prevent bacteria and dead skin cells from sticking there, thus preventing acne. Therefore, salicylic acid is used in many successful skincare products.

Acetylsalicylic Acid in Aspirin

Closely related to salicylic acid is acetylsalicylic acid, the chemical contained in aspirins. Both chemicals can be extracted from willow bark.

In the body, cyclooxygenase-2 is an enzyme produced by damaged cells. The enzyme in turn produces prostaglandin, which sends a message to the brain that causes the sensation of pain. It also causes inflammation around the damaged area. When acetylsalicylic acid enters the bloodstream after an aspirin pill is consumed, it binds to cyclooxygenase-2 and prevents cyclooxygenase-2 from producing prostaglandin. This diminishes the sensation of pain and reduces inflammation.



Aspirin pills contain acetylsalicylic acid.

Acetylsalicylic acid also interferes with thromboxane production. Thromboxane is the chemical that causes platelets to stick, forming a blood clot. Blood clots are often associated with heart attacks, so for people suffering from cardiovascular diseases, this is considered a positive side effect of aspirin.

Finally, acetylsalicylic acid affects the hypothalamus, or the region of brain that regulates hormones. The hypothalamus is like a control center for all body functions. Aspirin is able to reduce a fever because it causes the hypothalamus to signal a reverse temperature change to the interleukins, which are signaling molecules produced by the body's cells. For more information, visit:

<http://health.howstuffworks.com/medicine/medication/aspirin3.htm>

The Many Uses of Citric Acid

Another example of carboxylic acids used for industrial purposes is citric acid. Citric acid is exceptionally acidic; because it is so acidic, citric acid has a sour taste and is often used to add flavor to sour candies. You may notice that some sour hard candies are covered in a white powder. That powder is citric acid.

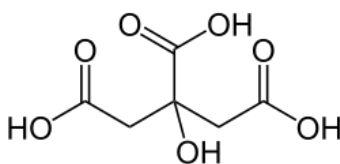


Diagram of a citric acid molecule.

Because citric acid is non-toxic and acidic, it is an ideal preservative. Bacteria can only live and grow in certain pHs. The presence of citric acid causes the pH to drop to a point where it is difficult for bacteria to survive, allowing food to stay fresh for longer. Citric acid is abundant in most citrus fruits, like lemons and limes, making it an easy preservative to use at home. Sprinkling lemon juice on a fruit salad will prevent the fruit from turning brown.

Carboxylic Acids and Nutrition

It is a common misconception that consuming fats will result in body fat. However, carboxylic acids make up a series of fatty acids that are extremely good for your health. The omega-6 and omega-3 fatty acids are considered to be “essential” because they are required for good health yet cannot be produced by the body.

6.3. FUNCTION AND APPLICATIONS OF CARBOXYLIC ACIDS

Another name for omega-6 is linoleic acid. It helps to maintain cell membranes and to control nutrient use and metabolism. If a meal is consumed without unsaturated fats, all the glucose and other nutrients will rush into the bloodstream without being absorbed. When unsaturated fats are consumed, they slow down digestion, which gives the body more time to absorb all the energy and nutrients from a meal.

Linoleic acid is also necessary to produce prostaglandins in a cell. Prostaglandins are produced by an enzyme called cyclooxygenase-2 in cells and are responsible for creating the sensation of pain. Although feeling pain sounds like a bad thing, pain is necessary to help your body respond correctly to external stimuli. For example, if you touch a very hot object, the burning sensation tells your body to release the object.

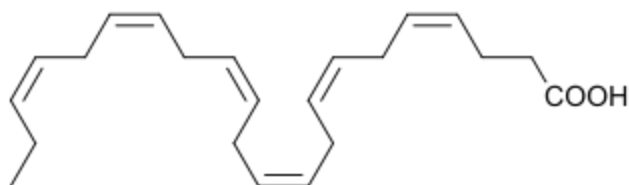


Diagram of eicosapentaenoic acid (EPA), a type of omega-3.

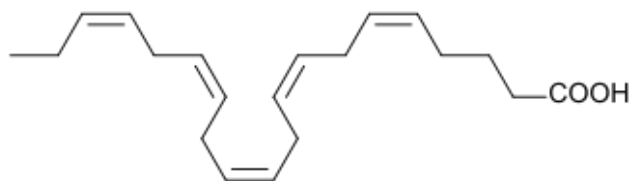


Diagram of docosahexaenoic acid (DHA), a type of omega-3.

Omega-3 is another extremely important fatty acid. There are two major types, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). They are both called “omega-3” because, in both compounds, the first double bond occurs after the third carbon. DHA is a 22-carbon chain with six double bonds, and EPA is a 20-carbon chain with five double bonds. Though both of these have many positive health effects, it is preferable to have higher levels of DHA in a supplement. Removing two carbon atoms from the DHA chain requires less energy than adding two carbon atoms to the EPA chain, making DHA easier to convert. Also, the brain uses DHA more frequently than EPA.

The most beneficial aspect of omega-3 is its ability to reduce the risk of heart disease. The American Heart Association (AHA) recommends consuming fish a minimum of two times every week because of the high omega-3 content in fish. According to the Maryland University Medical Center, consuming this much omega-3 reduces the risk of having a stroke by 50%.

Consuming omega-3 also leads to increased elasticity of the arteries. People with less flexible arteries are at risk for systolic hypertension, or high blood pressure when the heart contracts, which increases the risk for coronary diseases. This theory has been proven by multiple studies. In one study, 38 middle-aged men and women consumed an EPA or DHA supplement for 7 weeks. The EPA group saw artery elasticity increase by 36%, and the DHA group saw artery elasticity increase by 27%. In comparison, the placebo group, or control group, noticed no effect. Sudden cardiac deaths have also been shown to occur less frequently among people with a diet high in EPA/DHA.

Omega-3 has many other positive effects. It is contained in nerve endings in the brain and is important for cognitive and behavioral function. In fact, studies show that those who are deficient in omega-3 are at risk for vision and nerve problems. Additionally, a clinical study of 100 boys tested the effects of DHA on behavioral issues. Those with lower DHA levels had more behavioral issues, such as tantrums and sleep problems. Researchers are now testing the positive effects DHA has for ADHD patients. Taking a DHA supplement has also been shown to help patients alleviate some of the symptoms of depression or bipolar.

Omega-3 also decreases the effects of osteoporosis, as studies have indicated that omega-3 increases levels of calcium in the body. It can also help reduce the severity of rheumatoid arthritis, an autoimmune disease involving inflammation in the joints, because it decreases inflammation. Some of the other benefits of omega-3 consumption include improved eyesight, decreased menstrual pain, decreased severity of symptoms of Crohn's disease (also known as Inflammatory Bowel Disease or IBD), reduced symptoms of asthma, and reduced risk of colon, prostate and breast cancer.



Salmon is a good source of omega-3.

Some symptoms of omega-3 deficiency include fatigue, poor memory, dry skin, heart problems, mood swings or depression, and poor circulation. Taking a DHA or EPA supplement or consuming more fish (salmon, tuna, and halibut), seafood (algae and krill), plants, and nut oils can help alleviate some of these symptoms. It is also important to balance your intake of omega-3 and omega-6 because omega-3 reduces inflammation in the body while omega-6 increases inflammation.

6.4 Review Questions

Basic

1. Describe two reasons why salicylic acid is a key component to good acne medication.
2. Describe five benefits of increased omega-3 consumption.

Intermediate

3. How does consuming more omega-3 decrease your risk of heart disease?
4. True or False: Consuming citric acid is unhealthy for you.

Advanced

5. Before modern medicine, to patients suffering from pain, inflammation and fevers would be instructed to chew on willow bark. Why was this helpful?
6. Alex, Leslie and Sam are on the track team. Alex runs the 100m, Leslie runs the 800m, and Sam runs the 3000m. Who builds up the most lactic acid in their muscles during their race?

6.5 Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

CHAPTER 7**Functional Group: Ethers****CHAPTER OUTLINE**

- 7.1 INTRODUCTION**
 - 7.2 BACKGROUND**
 - 7.3 FUNCTIONS AND APPLICATIONS OF ETHERS**
 - 7.4 REVIEW QUESTIONS**
 - 7.5 ANSWERS**
-

7.1 Introduction

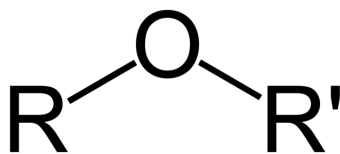
About the Chapter

This chapter focuses on ethers and will discuss the basic nomenclature and properties, like polarity and boiling point, of ethers. The chapter will also study how these properties of ethers are used for industrial applications. Diethyl ethers role in illicit cocaine production, the potential of using dimethyl ether as a diesel replacement, and the use of ethylene oxide as a disinfectant will be some of the topics examined.

By the End of This Chapter, You Will Have Learned...

- How to identify ethers
- Some basic properties of ethers
- Functions of diethyl ether
- The benefits of dimethyl ether as a fuel source
- How anisole is implemented in the natural world
- Functions of polyethylene glycol

7.2 Background



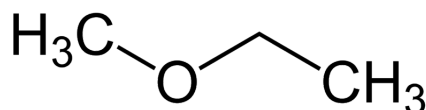
This is the diagram for an ether. “R” represents the rest of the compound. Both R’s do not have to be identical.

Ethers are organic compounds that contain an ether functional group. This functional group is defined by the general formula of R-O-R', where the oxygen atom is bounded to two carbon atoms.

Although ethers contain the electronegative element oxygen, ether molecules as a whole are either negligibly polar or nonpolar. The oxygen-carbon bond in ether is still polar due to the large electronegativity difference between the two elements, but the relative symmetry of the R-O-R' bonds causes the ether molecule as a whole to be only slightly polar. Under most circumstances, ethers can be considered to be nonpolar. Generally, ethers share similar qualities with alkanes, or single-bonded hydrocarbons without any cyclic structures.

A physical property of ethers is a relatively low boiling point in comparison to the boiling point of alcohols. Unlike alcohols, ethers do not form hydrogen bonds. This is because the oxygen's two valence electrons are bounded to carbons instead of hydrogens. Ethers only experience van der Waals forces, also known as London dispersion forces. These are the weakest intermolecular forces, much weaker than hydrogen bonds and dipole-dipole interactions (see the chapter *Background - Things you should know* for more details). It does not take large amounts of energy in the form of heat to tear apart the bonds between ether molecules. Therefore, ethers boil at a relatively low temperature.

Naming simple ethers requires you to think of the ether molecule as two carbon chains separated by an oxygen. Two alkyl groups surround the oxygen, one on each side. To name the ether molecule, first determine the names of those two alkyl groups. Then list the two alkyl groups in alphabetical order before the word ether so that the name of the ether is in the form of “alkyl alkyl ether.” If the two alkyls are the same, you will put “dialkyl ether,” with the appropriate alkyl being substituted in for “alkyl.”



This molecule is ethyl methyl ether.

An example of this would be CH₃CH₂OCH₃. The oxygen separates an ethyl group (CH₃CH₂) from a methyl group (CH₃). Therefore, the name of this molecule would be ethyl methyl ether.

This naming scheme only works for simple ethers. Complex ethers require different steps to be named. For more information about naming complex ethers, visit:

<http://www.chem.ucalgary.ca/courses/351/orgnom/ethers/ethers-01.html>

7.3 Functions and Applications of Ethers

Diethyl Ether and Cocaine

Diethyl ether is one of the best known ethers. It is often referred to simply as “ether.” The formula for diethyl ether is $(C_2H_5)_2O$. Originally, diethyl ether was used as an anesthetic. Now it has a variety of uses ranging from cocaine production to diesel engine fluid.

Diethyl ether is characterized by its distinctive smell, which is said to be sickly sweet. It is highly flammable and only needs a small amount of activation energy to ignite. At room temperature, even a hot radiator or a hot plate could provide the energy required for the combustion of diethyl ether. It will spontaneously ignite at only 170°C , combusting without any spark or flame. Like all ethers, it is considered to be nonpolar, or only slightly polar, and has a relatively low boiling point of 34.6°C .

In many laboratories, diethyl ether is used as a solvent. Because diethyl ether is nonpolar, it dissolves other nonpolar substances and is not miscible with polar substances like water. Therefore, diethyl ether is a great solvent for fats, waxes, oils, perfumes, alkaloids, and gums. This also makes diethyl ether perfect for the illicit production of pure cocaine, a powerful and highly addictive drug. Cocaine, which is a nonpolar organic compound, dissolves readily in diethyl ether. However, the impurities that exist in cocaine do not dissolve in diethyl ether. Dissolving cocaine in diethyl ether makes it easy to filter out these impurities, leaving behind pure cocaine and diethyl ether solution. Afterward, the solution is treated and processed to become the hydrochloride salt form of cocaine that is widely abused. This dangerous drug can cause heart attacks, stroke, paranoia, and death. It works by preventing dopamine, a neurotransmitter that is responsible for the feeling of pleasure, from being “recycled” by the cell that originally released it. This creates a buildup of dopamine, causing the euphoria that is associated with cocaine usage.

Dimethyl Ether as Fuel

Dimethyl ether is another well-known ether. Its chemical formula is CH_3OCH_3 , and it is the simplest ether. Dimethyl ether is a hydrocarbon with two methyl groups bonded to an oxygen. It has an extremely low boiling point of -23.6°C . Dimethyl ether shares the same empirical formula as ethanol ($\text{C}_2\text{H}_6\text{O}$), but because they have different structures, these isomers have very different properties. Dimethyl ether can be formed by using either commercial feedstocks or fossil hydrocarbons. Studies have shown that it is also feasible to create dimethyl ether from industry by-products, such as paper pulp.

Dimethyl ether is a colorless gas that has a variety of uses. Currently it is being employed as an aerosol propellant, organic solvent, and extraction agent. It is also being tested as a transportation fuel because it is relatively nontoxic and has a higher cetane number than diesel. A higher cetane number means that dimethyl ether will combust more cleanly and more completely than diesel fuel, optimizing energy efficiency for the car. Dimethyl ether’s cetane number is 55-56, compared to fossil diesel’s of 42-48 and biodiesel’s of 52-55. Another benefit of dimethyl ether as a fuel source is that, unlike diesel, it does not release sulfur and aromatic compounds. These emissions are harmful to breathe in and pollute the environment.



This truck is running off of diesel fuel. The smoke that it emits contains sulfur and aromatic compounds, which are harmful to breathe in.

The combustion reaction of dimethyl ether is:



In real life, this reaction would be impossible because complete combustions are only theoretical. The ideal conditions that are necessary for all combustible components to be burned to completion do not exist. There will always be some left-over fuel or byproducts. This could be due to human error, insufficient mixing in the combustion chamber, lack of oxygen, or hydrogen bonding. However, dimethyl ether's combustion is still very efficient.

Anisole and Nature

Anisoles, also known as methoxybenzenes, are ethers with the chemical formula of $\text{CH}_3\text{OC}_6\text{H}_5$. It is a relatively nontoxic liquid with a surprisingly high boiling point of 155°C , or 313°F . Anisoles have a pungent, sweet odor reminiscent of the flowering plant, anise. This makes it perfect for use in perfumes and cosmetics. It is also occasionally used in pharmaceuticals. In nature, anisoles are found in insect pheromones. Madeira cockroaches, European oak bark beetles, and desert locusts use it in their chemical communication systems.

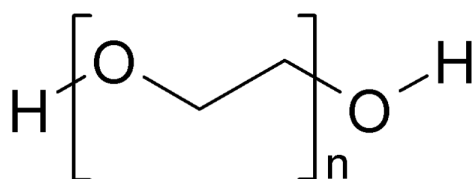


This is a black truffle of Périgord.

Because of this, many plants release anisoles to attract insects. An example of a plant that uses anisoles would be the black truffle of Périgord. Like most other fungi, it lives underground. This makes it very difficult for the truffle to spread its spores. The black truffle of Périgord gets around this problem by releasing anisoles upon reaching maturity. Insects are attracted to the anisole and inadvertently spread the spores for the truffle.

Polyethylene Glycol (PEG) and Its Many Uses

Polyethylene glycol (PEG for short) is a long-chained, organic compound with the chemical structure of $C_{2n+2}H_{4n+6}O_{n+2}$. It can come in many different lengths; hence the variable n is included in the molecular formula.



PEG can come as either a clear liquid, waxy substance, or an opaque solid, depending on the size of its chain. Small PEG chains with a molecular weight less than 200 tend to come as clear liquids. At a molecular weight of 200-2000, the PEG chain is a waxy substance. Any chain with a molecular weight heavier than 2000 comes as an opaque solid. Unlike most ethers, PEG is soluble in both organic compounds and water. This is because it is a “polyether,” or a compound that contains more than one ether group. Because the oxygen-carbon bond in the ether group is polar, multiple ether groups on PEG will increase the polarity of the overall molecule, making it soluble in other polar compounds. PEG, being non-toxic and water soluble, is often used in pharmaceuticals and food additives.

The uses for PEGs vary with the size of the PEG chain. Low molecule PEG chains can be used as laxatives, skin creams, lubricants, dispersants in toothpastes, thickening agents, and binding agents in tablets and molds, among others. Larger molecule PEG chains are used as packing materials for foods, binding agents and thickeners for paints, and polar stationary phases for gas chromatography.

7.3. FUNCTIONS AND APPLICATIONS OF ETHERS



PEGs are widely used in toothpaste.

Many of these functions depend on the ability of PEG to bind with both water and organic solvents. For example, in toothpaste, PEG binds water to xanthan gum, thus keeping the gum uniform throughout the toothpaste. The water solubility of PEG also plays a huge role in its uses. It is used as a mold release agent and a lubricant for creating natural and synthetic rubbers. Because of their solubility in water, PEGs can be easily applied and removed in these processes.

For a full list of items that use polyethylene glycol, you can view:

<http://www.dow.com/polyglycols/carbowax/app/index.htm>

LAB: Solubility

Polyethylene's miscibility in both non-polar and polar compounds is important for its functions.

Let's take a closer look at how polarity affects solubility. In this lab, you will test the miscibility of a polar substance (soap) in a mixture containing nonpolar components (milk with fat).

Materials

- Plate
- Milk (FAT FREE MILK WILL NOT WORK)
- Food Coloring
- Toothpick
- Soap

Procedure

- a. Fill the plate with milk, just enough so that the base is all covered.
- b. Put a drop of food coloring into different areas of the milk. Try to use different colors of food coloring
- c. Take the toothpick and dip it in the soap.
- d. Then poke the drop of food coloring with your soapy toothpick.
- e. Repeat steps 3-4 to your liking and observe.

Test Your Understanding

1. Would this have happened if water were used instead of milk?
2. Why would fat free milk not have worked in this lab?

Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

Ethylene Oxide as a Disinfectant

Ethylene oxide is a gas with the chemical formula C_2H_4O . It has an extremely low boiling point of $10.73^\circ C$ ($51.314^\circ F$) at atmospheric pressure. This means that at normal room temperature, intermolecular forces are too weak to hold ethylene oxide as a liquid. Therefore, it is usually found in its gas phase. This makes ethylene useful as a disinfectant for medical and pharmaceutical products. Many of these products contain plastics and would melt if they went through conventional, high-temperature sterilization processes. This is where ethylene oxide comes in handy. At room temperature, it can be pumped into packages containing the medical and pharmaceutical products to kill the bacteria that have grown on them. This cleans the packages and the products.

The disinfecting abilities of ethylene oxide stem from the fact that it is a strong alkylating agent. This is a compound that can transfer an alkyl group onto another compound. By doing this, ethylene oxide can bind directly to the bacteria's nucleic acids. Once there, it changes the bacteria's DNA structure slightly in one of three ways. The first method is for ethylene oxide to attach an alkyl group to the DNA bases. When repair enzymes attempt to replace the alkylated bases, the enzymes will actually fragment the DNA strand. Another way that ethylene oxide changes DNA structure is by linking together two DNA bases. This prevents the DNA strand from being separated for synthesis or transcription. Lastly, ethylene oxide can also cause bases to be mispaired. All of these mechanisms work to kill bacteria. Although extremely effective, the use of ethylene oxide as a disinfectant has some major drawbacks. Ethylene oxide is extremely explosive and is harmful to humans. The alkylating properties of ethylene oxide do not just affect bacteria; this property affects the DNA structures of any cells, including human cells. Long-term exposure to ethylene oxide has been associated with cancer, reproductive effects, mutagenic changes, neurotoxicity, and sensitization.

7.4 Review Questions

Basic

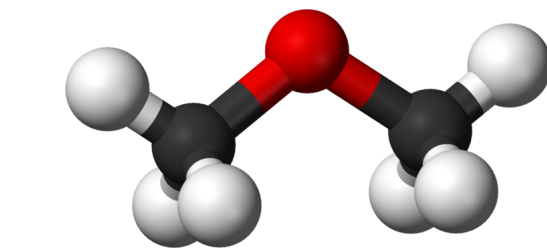
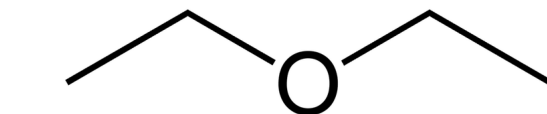
1. What is the general formula of an ether?
2. What are the some benefits of using dimethyl ether as fuel instead of diesel?
3. How do plants make use of anisoles?

Intermediate

4. Why is diethyl ether used as a solvent in laboratories?
5. Why can ethers be considered slightly polar?
6. Ethers have oxygens and hydrogens. Why do they NOT experience hydrogen bonds?

Advanced

7. Name these ethers:



7.5 Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

CHAPTER 8**Functional Group: Esters****CHAPTER OUTLINE**

- 8.1 INTRODUCTION**
 - 8.2 BACKGROUND**
 - 8.3 FUNCTIONS AND APPLICATIONS OF ESTERS**
 - 8.4 REVIEW QUESTIONS**
 - 8.5 ANSWERS**
-

8.1 Introduction

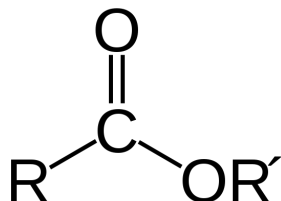
About the Chapter

This chapter is a brief overview of esters. This includes their properties and identifying features. It covers structure, formation, and scent. Functions of esters are also reviewed. It will discuss how the controversial nature of methyl parabens and ethyl acetate's role in the wine industry. Ascorbyl palmitate, denatonium benzoate, and methyl formate are also discussed.

By the End of This Chapter, You Will Have Learned...

- The basic structure of esters
- The basic properties of esters
- The potential dangers of methyl paraben
- How ethyl acetate affects wine
- The benefits of consuming ascorbyl palmitate over Vitamin C
- How the properties of methyl formate make it useful for “quick drying” solutions

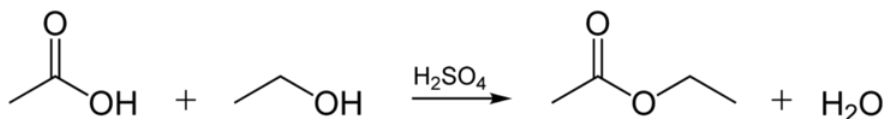
8.2 Background



This is the structure of an ester. The “R” represents the rest of the compound.

Esters are chemical compounds that contain an ester group, denoted as R-COO-R'. It is produced by the condensation (formation of water) of a carboxylic acid and an alcohol. The general chemical equation for an esterification reaction is:

Alcohol + Carboxylic Acid \rightleftharpoons Water + Ester



This diagram illustrates what happens during an esterification reaction.

In an esterification reaction, adding a dehydrating agent, such as sulfuric acid, that only removes the water without reacting with the other components will push the reaction more towards the products side. In this case, the products would be water and ester. This would greatly increase the effectiveness of the esterification reaction.

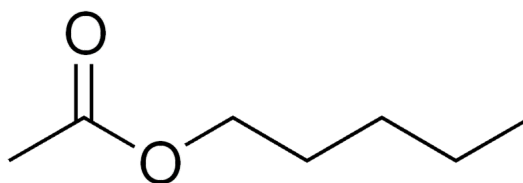
An important physical property of many esters is their solubility in both fats and water. Esters are soluble in water because their polar oxygen-carbon bonds are capable of participating in hydrogen bonding. The negatively-charged oxygen in an ester molecule will be attracted to the positively-charged hydrogen in a water molecule. Small esters are extremely soluble in water; however, the larger the ester molecule, the less soluble it is in water. When the ester chains get to be too large, the hydrocarbon parts of the ester start to disrupt the hydrogen bonds amongst the water molecules. It is more energetically favorable for the water molecules to stay bonded together via hydrogen bonding than it is for the water and ester to mix. On the other hand, the hydrocarbon chains make esters soluble in fats. Since the hydrocarbon portions of the ester are nonpolar, these parts are capable of mixing with nonpolar fats.

Two special types of esters are acetates and lactones. Acetates are esters that are formed from acetic acid or vinegar. Lactones are cyclic esters. Many examples of lactones are found in oak trees and other plants and help give flavor to whiskey.

Esters are very popular compounds in both nature and everyday life. They typically have a sweet smelling fragrance that is responsible for giving many fruits their sweet scents. Raspberries, grapes, and apples, among others, get their smells from various esters. In addition to fruits, there are many other familiar scents that are attributed to esters. For example, some nail polish removers get their scents from an ester called ethyl acetate, and rum's scent is from an ester called ethyl propionate. The cosmetics, fragrance, and food industries all rely heavily on esters for their distinct scents.

<u>Ester</u>	<u>Smell</u>
Pentyl Ethanoate	Pear
3-Methylbutyl Ethanoate	Banana
Octyl Ethanoate	Orange
Methyl Butanoate	Pineapple
Methyl Salicylate	Oil of Wintergreen
Methyl Anthranilate	Grapes
Pentyl Butanoate	Apricot
3-Methylbutyl-3-Methylbutanoate	Apple
Ethyl Cinnamate	Oil of Cinnamon

Esters are named by the chemicals that they are created from. It is very similar to the process of naming salts. The alkyl group (R'), which is always attached to an oxygen atom, is the first portion of the ester's two-word name. The second portion is by taking the acid and replacing the acid name with “-oate.”



The name of this ester is pentyl ethanoate.

An example of this would be pentyl ethanoate. The alkyl group that makes up the first portion of the ester's two-word name is pentyl. The acid, which contains a double bonded oxygen, is ethanoic acid. Adding the prefix “-oate” to the acid name gives you the second part of the ester name.

8.3 Functions and Applications of Esters

The Controversy Surrounding Methyl Paraben

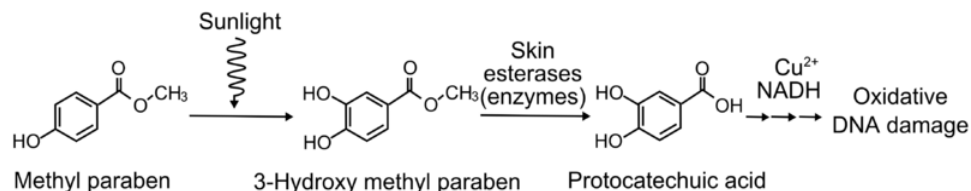


Methyl parabens are widely used in cosmetics.

One of the more controversial esters is methyl paraben. Its chemical formula is $\text{CH}_3(\text{C}_6\text{H}_4(\text{OH})\text{COO})$. This is an ester that is employed more for its preservation properties than for its distinctive smell. It is widely used in cosmetics, toothpastes, hair care products, moisturizers, and deodorants. It is also used as a food preservative and as a product to protect pharmaceuticals against fungal decay. The use of parabens in everyday products is so prevalent that scientists found in a random sampling that 96 out of 100 people had methyl parabens present in their urine.

Although it has been deemed safe for use by the United States Environmental Protection Agency, both Japan and Sweden have banned the use of parabens in any cosmetics due to potential health concerns. Many discoveries have come to light about the potential side effects of methyl paraben usage. One of these discoveries linked methyl parabens with breast cancer. In the study, twenty samples of breast cancer tissues were examined and were all found to contain parabens. Methyl paraben accounted for 62% of the parabens discovered in the samples. However, this does not conclusively prove that methyl paraben causes any harmful effects. Their presence in the tissue samples could simply be because methyl paraben is readily absorbed by skin contact. The study does demonstrate the need for further research on how parabens affect the human body.

One proven side effect of methyl paraben is oxidative stress. Oxidative stress describes the level of damage that has been done to the body by reactive oxygen species. Our bodies are constantly reacting with the oxygen that we breathe in, producing free radicals and peroxides. Under normal circumstances, we produce enough antioxidants to counteract this effect. However, external factors can cause a surge in oxidative stress. When this happens, it can lead to dangerous diseases such as Alzheimer's and cancer. In one study done on the effects of methyl paraben on oxidative stress, skin cells were treated with methyl paraben containing creams. When exposed to the sun's UVB rays, the skin cells died due to the oxidative stress that had occurred.



Researches found that this was because the sunlight had reacted with the methyl paraben to produce p-hydroxybenzoic acid (PHBA) and 3-hydroxy methyl paraben (MP-3OH). When the MP-3OH met with a skin esterase, which is an enzyme that splits esters into acids and alcohols, it was split into protocatechuic acid. This acid caused considerable amount of damage to DNA. Researches also noted that if the protocatechuic acid binds with NADH, a hydrogen carrier in the body, the oxidative damage is increased by five times.

What scientists find startling is how little is known about methyl parabens, yet parabens are widely used in products that come in direct contact with skin, such as pore strips and hair conditioners. Scientists know that this direct contact is enough for methyl parabens to transfer into the body and the bloodstream. However, scientists do not actually know what methyl parabens do once they get inside the body.

ACTIVITY: Methyl Paraben in Cosmetics

Methyl parabens are a popular component of many cosmetics and hair products. Take a look at the cosmetics and hair products in your own house to see if methyl paraben is present in the ingredients.

How many of your products contain methyl parabens?

Ethyl Acetate and Wine

Ethyl acetate is the best known of the esters, especially in the wine industry. It has the formula of $\text{CH}_3\text{COOCH}_2\text{CH}_3$. It is a colorless liquid with a “fruity” smell. Ethyl acetate is used as a solvent in many products, such as oil-based lacquers and enamels.



Ethyl acetate causes an unpleasant “nail polish” scent in wines.

However, ethyl acetate is probably best known for its presence in wine. In wine grapes, sometimes aerobic bacteria enter the grape through “wounds” and create acetic acid. During fermentation, this acetic acid comes in contact with ethanol. This starts off the esterification process that creates ethyl acetate. Although barely perceptible amounts of

8.3. FUNCTIONS AND APPLICATIONS OF ESTERS

ethyl acetate occasionally add to the “fruitiness” of the wine, it is generally viewed as a wine fault if there is ethyl acetate present. In large amounts, it gives the wine the unpleasant aroma of nail-polish remover.

Ethyl acetate is also used for coffee decaffeination. After the coffee beans are soaked in water, the caffeine is extracted by adding ethyl acetate to the water. Ethyl acetate is used because of its low boiling point of 77°C (171°F) and its ability to bind with both water and caffeine. It is able to decaffeinate the coffee without affecting the taste of the beans. When the coffee beans are drained, a solution of ethyl acetate, caffeine, and water is removed. This process is repeated multiple times until the coffee beans are completely decaffeinated.

Ascorbyl Palmitate Versus Vitamin C

Ascorbyl palmitate is the ester form of Vitamin C. It provides most of the same benefits to the human body as Vitamin C does. However, because ascorbyl palmitate is an ester, it is soluble in both fats and water. This solves one of Vitamin C's inherent issues: Vitamin C is only soluble in water and thus cannot stay in the body. This makes it so that all surplus Vitamin C is removed from the body and must be continually added. Unlike Vitamin C, ascorbyl palmitate is able to bind with lipid cell membranes, which are made up of fats. This allows the body to store it up and access it when it is needed. Ascorbyl palmitate's fat solubility also makes it extremely easy for it to penetrate cells and skin. Vitamin C is unable to access many parts of the body, such as adipose tissue and the brain. However, ascorbyl palmitate can be absorbed by cells and skin and can enter the bloodstream to quickly access the parts of the body that Vitamin C is unable to enter. This makes ascorbyl palmitate invaluable as a medicine. It is also a stronger antioxidant than Vitamin C. In the body, ascorbyl palmitate is able to bind with Vitamin E because of their similar fat-soluble properties. Once bounded, ascorbyl palmitate protects the Vitamin E from oxidation.

Another benefit of ascorbyl palmitate over traditional Vitamin C is that it does not irritate the skin. Traditional water-soluble Vitamin C is irritating to the skin and often causes rashes or inflammation. However, ascorbyl palmitate has none of these side effects and also has collagen strengthening and antioxidating properties. It is also readily absorbed through skin contact. For these reasons, ascorbyl palmitate is often a major component of skin care products. The downside of ascorbyl palmitate that hinders it from being widely used is its economic costs. Ascorbyl palmitate is much more expensive than traditional Vitamin C and ascorbic acid. Because many of the benefits of ascorbyl palmitate are already covered by both Vitamin C and ascorbic acid, it is less cost-effective for industries to use the more expensive ascorbyl palmitate.

The Bitterest Chemical on Earth

Denatonium benzoate, with the chemical formula $\text{C}_6\text{H}_4(\text{CH}_3)_2\text{NHCON}(\text{C}_2\text{H}_5)_2\text{C}_6\text{H}_5\text{COOC}_6\text{H}_5$, is a very special ester. It is the bitterest, nontoxic chemical on earth. Because of these two properties, denatonium benzoate is often added to harmful chemicals in order to prevent people from consuming them. It only takes 10 ppb (parts per billion) for people to be able to detect denatonium benzoate. Most countries recommend 4-40 ppm (parts per million), about 10 times more than the threshold detectable amount, to be added to harmful chemicals as a deterrent. Denatonium benzoate is added to hundreds of different chemicals, from air fresheners and fertilizers, to hair dye and liquid potpourri.

One of the reasons that denatonium benzoate works so well as a deterrent is because, through evolution, humans have developed an extreme aversion to bitter flavors, which often are the mark of poisonous plants. Children are especially sensitive to it.

Denatonium benzoate has been branded under the name Bitrex®. If you would like to see its official website, it is located at:

<http://www.bitrex.com/>

Methyl Formate and Space



Methyl formate has been discovered in the comet Hale Bopp.

In spring 1997, scientists identified methyl formate by analyzing ten lines in the spectra of the comet Hale Bopp. With a chemical formula of $C_2H_4O_2$, methyl formate is the simplest ester. Some of its important attributes are its high vapor pressure, solubility in water, and miscibility in most organic compounds. This makes it useful as a solvent in quick drying coating finishes and spray applications. Methyl formate can be added to these solutions because it is soluble in water. When the methyl formate in the solution is exposed to the outside environment, its high vapor pressure will be able to overcome the forces acting on it from environmental pressure and intermolecular forces. This will make it evaporate very quickly, causing the “quick drying” property of many of the coating finishes and spray applications.

Methyl formate has also been located in space. Scientists have found its gas form in large quantities in the clouds that dot our Milky Way galaxy. They estimate that a typical dust cloud would contain a thousand trillion trillion (10^{27}) gallons of the liquid form of methyl formate. This discovery sheds new light on the creation of stars, suggesting that there are more molecules at work than scientists had previously estimated.

8.4 Review Questions

Basic

1. How are esters produced?
2. What are acetates and lactones?
3. What are five scents attributed to esters?

Intermediate

4. Why are methyl parabens controversial?
5. What is the use of denatonium benzoate?

Challenging

6. How does the solubility of esters make it useful for many industries?

8.5 Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

CHAPTER

9**Functional Group: Amines****CHAPTER OUTLINE**

- 9.1 INTRODUCTION**
 - 9.2 BACKGROUND**
 - 9.3 FUNCTIONS AND APPLICATIONS OF AMINES**
 - 9.4 REVIEW QUESTIONS**
 - 9.5 ANSWERS**
-

9.1 Introduction

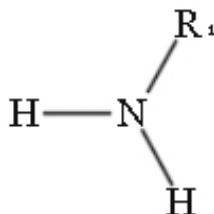
About the Chapter

This chapter focuses on amines. It will describe some of their identifying factors and properties, such as solubility and odor. It will also discuss common amines and the impact that they have on daily life. This includes the health hazards of heterocyclic amines and the relationship between histamine and allergies. Trimethylamine, aniline, and gefitinib are also studied.

By the End of This Chapter, You Will Have Learned...

- How to identify amines
- Basic properties of amines
- The health hazards of heterocyclic amines
- How histamines affect allergies
- About the disease trimethylaminuria
- The potential hazards of aniline
- About the medicine Gefitinib

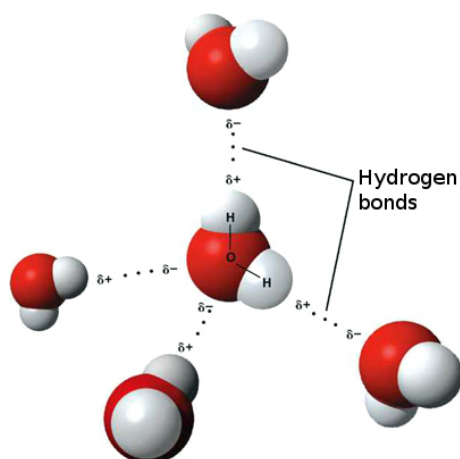
9.2 Background



The structure of a primary amine.

Amines are organic compounds that contain the element nitrogen. Nitrogen has five electrons, so amines will have a lone electron pair attached to the nitrogen. This lone pair can attract H⁺ atoms, making amines basic.

The boiling point of amines is higher than that of alkanes because amines are capable of donating and accepting hydrogen bonds. The more electronegative nitrogen attracts electrons more strongly than the hydrogen does, leaving the hydrogens to be more positively charged. These hydrogens can then participate in hydrogen bonding and become attracted to other molecules. In addition, the lone pair on the nitrogen will be attracted to hydrogens on other molecules. Breaking these hydrogen bonds will require additional energy, thus increasing the boiling point of amines. However, the boiling points of amines are generally lower than that of alcohols.



This illustration shows hydrogen bonding in water.

Amines are also relatively soluble in water. Small amines are very soluble in water and are usually sold as solutions at room temperature. This is because all amines can form hydrogen bonds with water. However, when the amine chain is larger, around six carbons, it has to force its way between water molecules. This destroys the hydrogen bonds between the water molecules. The long carbon chain does not participate in hydrogen bonding, so the disrupted hydrogen bonds are not replaced. Now the system is at a higher energy state. In general, systems want to be at the lowest energy state possible to optimize stability. As a result, the system would rather have the larger amines clumped together and the water molecules clumped together in order to increase the number of favorable hydrogen bonds. This effect is greater for larger molecules and so large chains of amines are less soluble than smaller chains.

Amines are often associated with having bad smells, most commonly that of raw fish. The distinctive odor of raw fish is due to the amines that it contains. Another unpleasant smell, decaying flesh, is attributed to two amines, which are appropriately named cadaverine and putresine.

Despite their strong odors, amines are essential for daily life. They are present in amino acids, which create proteins. Many neurotransmitters, such as histamine, are also amines. In industry, amines are also present in dyes, medicines, vitamins, and many other synthesis reactions.

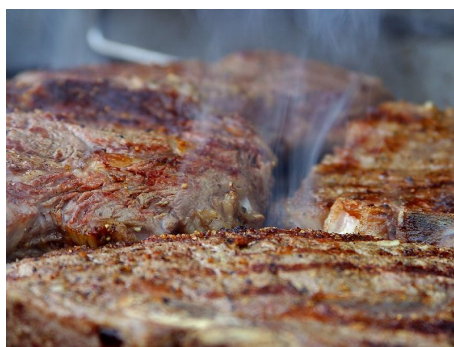
If you want to learn about the nomenclature of amines, visit this website:

http://learnchem.net/orgo/amine_nom.shtml

9.3 Functions and Applications of Amines

Heterocyclic Amines and Cancer

Heterocyclic amines (HCAs) are commonly found in cooked meat, especially if the meat has been cooked at extremely high temperatures. They are the product of a reaction between amino acids and creatine, a chemical found in muscles. Cooking meats such as beef, pork, fowl, and fish creates heterocyclic amines that are not present in the uncooked form of these meats.



Heterocyclic amines are common in cooked meat.

Scientists have found a strong link between heterocyclic amines and cancer. Seventeen different heterocyclic amines present in cooked meats have been found to cause cancer in humans. In one study, scientists surveyed the diets and cooking habits of 176 people diagnosed with stomach cancer and 503 people without cancer. They discovered that people who ate their beef “well done” or “medium well” were three times more likely to develop stomach cancer than those who ate their beef “rare” or “medium rare.” They also found that people who ate beef frequently – four or more times a week – were twice more likely to develop stomach cancer than those who ate beef less frequently. Other studies have found links between eating barbecued, fried, and well-done meats with colorectal, pancreatic, and breast cancer.

High temperatures are essential for the production of heterocyclic amines. This is because every reaction requires a minimum amount of energy, known as activation energy, for the reaction to proceed. For amino acids and creatine to react to form HCAs, large amounts of energy in the form of heat are required. That is why scientists found that frying, broiling, and barbecuing meats produce the largest amount of HCAs. All three of these methods require extremely high temperatures. One study showed the importance of temperature on the production of heterocyclic amines. Researchers found that when the temperature was increased from 200°C to 250°C (392°F to 482°F) the amount of HCAs produced was increased threefold.

There are many ways to decrease HCA intake in your life, and, by doing so, your cancer risk. Eating less meat or “rarer” meat will decrease the amount of HCA that is consumed. Another way would be to partially cook the meat in a microwave oven before it is cooked. Two minutes of microwaving before cooking decreases the HCA amount by 90%. Pouring out the liquid that forms when the meat is heated in the microwave also decreases the heterocyclic amine count. Marinating the meat before it is cooked also destroys HCA production. Marinating meat in olive oil, lemon juice, and garlic, besides enhancing the taste, cuts the HCA levels in chicken by as much as 90%. A beer or red-wine marinade also achieves this effect. This could be because beer and red wine contain water-retaining sugars. These sugars, once in the meat, attach onto the water. This hinders the movement of water-soluble molecules that

depend on water for movement. If these molecules do not get to the surface of the meat, the heat is not great enough to turn them into HCAs.

Histamine and Allergies

Many amines are present in the body as neurotransmitters. One important example is histamine. This is an amine that helps the brain cells communicate properly and modulates sleep. However, histamine is most known for its connection with allergies. Allergies happen when a normally harmless substance like pollen or dust, known as an allergen, enters the body. When it comes in contact with the antibody IgE, it triggers a reaction that signals for the release of histamine. Histamine binds onto nearby cell receptors, causing many of the symptoms that are associated with allergies: swelling of the infected area, shortness of breath caused by swelling of the mucous membranes, and muscle cramps. These allergic reactions can be mildly annoying or life-threatening, depending on the severity.

Many people are allergic to the histamines and other amines that are present in foods. Food-related histamine reactions have the following symptoms: flushing of the face, sudden sweating, fainting, asthma attack, rash, hives, urticaria, nausea, vomiting, abdominal cramps, headaches, and migraine attacks. These reactions to histamines in foods are generally more severe than the respiratory reactions to allergens.

To see a video about the connection between histamines and allergies, watch this video:

<http://www.youtube.com/watch?v=ywdk3BTjK2s>

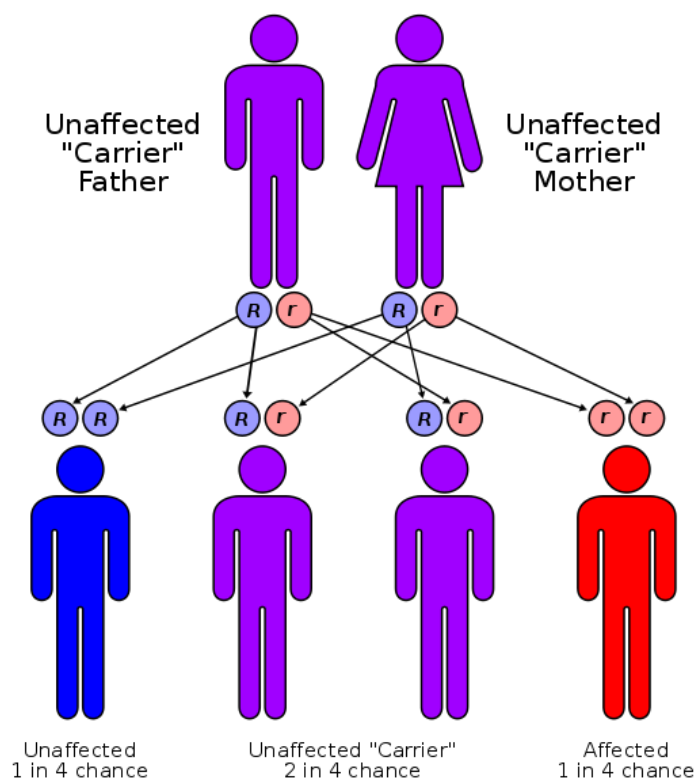
Fortunately, there are different medicines that work to counteract the body's unnecessary production of histamines. Many of these medicines are antihistamines. They work by binding onto cell receptors, preventing histamines from binding there. If histamine does not reach the cell receptors, it cannot cause the many symptoms of allergies.

Trimethylamine and Trimethylaminuria

Like many classic amines, trimethylamine has a strong, rancid odor that is responsible for the “fishy” smell of fish. Although smelly, this molecule is completely harmless.

Trimethylaminuria is the disease associated with the body's inability to break down trimethylamine. Normally, the body is able to convert trimethylamine into a compound called trimethylamine N-oxide that is considerably less smelly. However, if the enzyme FMO3 is impaired or malfunctioning, this conversion will not happen and the body will be left with excess amounts of trimethylamine. This excess is released into the person's sweat, urine, reproductive fluids, and breath.

This disease is inherited in an autosomal recessive function, which means that the gene responsible for this disease is recessive. It would take two trimethylaminuria genes for a person to show symptoms for the disease. Having just one of the genes would make a person a carrier for trimethylaminuria; they would show no symptoms.



Only people with two recessive trimethylaminuria genes will exhibit the symptoms.

Besides its smelly side effects, trimethylaminuria is not a particularly life-threatening disease. This is fortunate because currently there is no known cure for this disease. Someone diagnosed with trimethylaminuria can decrease the effects of the disease by avoiding foods that contain trimethylamine. These foods include eggs, liver, kidney, peas, beans, peanuts, soy products, brassicas (brussel sprouts, broccoli, cabbage, etc), and lecithin and lecithin-containing fish oil supplements.

Another way to decrease the effects of trimethylaminuria would be to use soaps with a moderate pH between 5.5 to 6.5. This is because trimethylamine, due to the lone electron pair on its nitrogen, is a base with a 9.8 pH. Therefore, a more moderate soap would neutralize the trimethylamine better than a basic soap. Washing with a slightly acidic soap makes it easier to remove any trimethylamine lingering on the skin.

Aniline's Toxicity

Aniline, also known as aminobenzene, is an amine that is essential for creating many industrial chemicals. It is produced in huge amounts in the United States; in 1992 alone, one billion pounds of aniline were produced. Since then, demand for aniline-containing chemicals has increased, causing the production of aniline to skyrocket. Aniline is used to create isocyanates, dyes, drugs, rubbers, pesticides, photographic chemicals, varnishes, and explosives. Aniline is a somewhat toxic chemical that has harmful effects on the environment and human health.

There are many ways that aniline can be released into the environment, but once there, it is quickly broken down into less harmful molecules. When exposed to the air, aniline will evaporate. Once it gets into the environment, sunshine and microorganisms break it down. However, aniline is soluble in water and is toxic to aquatic life. If raw aniline were to reach a water source, it would be detrimental to the aquatic life there.

In small amounts, aniline is harmless to humans because it does not remain in the body. However, humans consistently exposed for several years to small amounts of aniline in the air have experienced adverse blood effects.

A short exposure to large amounts of aniline affects the hemoglobin and makes it difficult for hemoglobin to carry oxygen throughout the body. Side effects from this can range from headaches to comas and death. Single exposures can also affect the spleen, but these effects can usually be reversed by proper treatment. In the United States, people are not usually exposed to the levels of aniline needed to have adverse side effects on the body.

Gefitinib and Medicine

Gefitinib is an amine-containing drug that is marketed to help patients suffering from non-small cell lung cancer. It is part of a group of drugs called epidermal growth factor receptor (EGFR) tyrosine kinase inhibitors. This class of anti-cancer medication works by blocking the production of certain chemicals that help cancerous tumors grow.

Gefitinib works by preventing the phosphorylation of a receptor found on normal and cancer cells. Phosphorylation is the addition of a phosphate group. It is responsible for the activation and deactivation of many proteins enzymes. By preventing phosphorylation, gefitinib can stop the growth cancer cells.

However, it is neither a miracle pill nor a guaranteed cure. The effects of Gefitinib vary from person to person. It could work for someone, but be completely useless to another. Gefitinib should only be taken after all other treatments have been ineffective. <http://www.example.com>

9.4 Review Questions

Basic

1. What smells are amines generally associated with?
2. What are three ways to decrease your intake of heterocyclic amines?
3. How are histamines connected with allergies?

Intermediate

4. Why are amines considered bases?
5. Why do amines have a higher boiling point than alkanes?
6. Why are long chains of amines less soluble than smaller chains?

Advanced

7. Why are hydrogen bonds only possible when hydrogen is bonded to nitrogen, oxygen, or fluorine?
8. A woman (tt) has trimethylaminuria. Her husband (Tt) is a carrier for the disease. What are the chances that their child also shows the symptoms for trimethylaminuria?

9.5 Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

CHAPTER **10** Functional Group: Benzene

CHAPTER OUTLINE

10.1 INTRODUCTION

10.2 BACKGROUND

10.3 FUNCTIONS AND APPLICATIONS OF BENZENE

10.4 REVIEW QUESTIONS

10.5 ANSWERS

10.1 Introduction

About the Chapter

This chapter will introduce students to the unique structure of benzene. It will also cover the properties and potential dangers of the substance benzene. Finally, the role benzene plays in world issues will be examined.

By the End of This Chapter, You Will Have Learned...

- The structure of benzene
- The properties of benzene
- How to avoid benzene poisoning
- How to respond to benzene poisoning
- Products that contain benzene
- How benzene is involved in the 2010 BP oil spill

10.2 Background

At room temperature, benzene is a clear or pale yellow liquid with a sweet odor. It is highly flammable and highly toxic. Benzene forms as a result of forest fires, volcano eruptions, smoking, burning crude oil, and more.

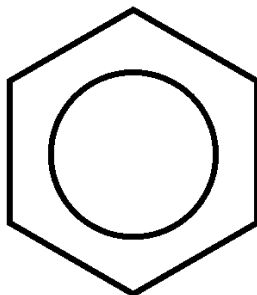
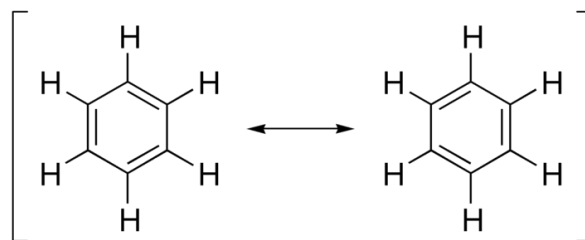


Diagram of a benzene molecule

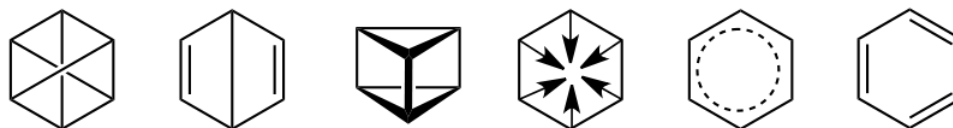
The molecular formula for benzene is C_6H_6 . It consists of a carbon ring where each carbon is bonded to one hydrogen atom and two other carbon atoms. Carbon atoms have four valence electrons. So far, only three of these electrons are involved in bonds. Since each carbon has one more valence electron, each carbon has the ability to form one more bond. However, since all of the atoms are carbon atoms, every atom is equally attracted to the atoms on either side of it.

This causes benzene to exhibit a unique phenomenon called resonance. Each carbon's extra electron is shared equally between that carbon and the carbon adjacent to it. The Lewis structure depicting benzene would therefore look like this:



However, the electrons are not actually switching from carbon atom to carbon atom. A benzene molecule never exists in either of the states depicted in the Lewis structures above. This is indicated by the use of a single arrow as opposed to the double arrow used in equilibrium reactions. It is impossible to draw benzene as it is in the form of a Lewis structure, so instead it is depicted as an equal combination of the two structures. That is why benzene is called a resonant structure, or a structure that cannot be represented by one Lewis structure and is therefore depicted as a hybrid of two.

Ever since this compound was first discovered in 1825 by Michael Faraday, many structural representations have been used in an attempt to represent benzene:



The first four images have been used historically. The last two are both used today.

It was then used in the 19th and 20th centuries for a variety of uses such as aftershave and to decaffeinate coffee. The use of benzene to decaffeinate coffee is known as Roselius's Process. In this process, the coffee beans are boiled in salt water. Benzene is then used as a solvent to attach to the caffeine leaving the coffee beans decaffeinated. However, this greatly alters the taste of the beans and is unsafe, as benzene is a dangerous substance.

10.3 Functions and Applications of Benzene

Benzene Poisoning

Benzene is a highly toxic substance that can affect DNA, causing chromosome changes and abnormal cell function. Long-term exposure to benzene can cause the bone marrow to produce fewer blood cells. This results in anemia, or a low red blood cell count. Benzene exposure also severely weakens the immune system because it lowers the white blood cell count. The most serious effect of benzene poisoning is leukemia, which is a cancer of blood cell-producing tissues. Some other symptoms of benzene poisoning include drowsiness, dizziness, rapid or irregular heartbeat, headaches, tremors, confusion, unconsciousness, and even death. If benzene is ingested, symptoms may include vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid or irregular heartbeat, and again death, if an extremely large amount is ingested. In addition, women who inhale benzene constantly for a long period of time report delayed menstrual periods. Further investigation showed that their ovaries had shrunk.

The link between benzene poisoning and leukemia was discovered in 1928. Twenty years later, the American Petroleum Institute concluded that the only safe exposure to benzene is none at all. Today, the National Toxicology Program (NTP), Environmental Protection Agency (EPA), and the International Agency for Research on Cancer (IARC) all classify benzene as a “known carcinogen.” The EPA limits benzene in drinking water to 5 ppb (parts per billion), though they hope to eventually achieve 0 ppb. The concentration of benzene in the air of the workplace is limited to 1 ppb.

If you are exposed to benzene, there are a series of steps you can take to diminish its effects. First, immediately leave the area where benzene was released. If you are inside, evacuate the building, and if you are outside, simply move away from the area. Then, remove all clothing items. Do not pull clothing over the head to get it off; cut it off instead. Next, wash thoroughly with soap and water to remove any benzene on the skin. Now, carefully dispose of the clothes by being careful not to handle contaminated objects with bare skin. Instead, use rubber gloves or tongs to handle contaminated items. It is important to seek medical attention right away so that the level of benzene in the body can be measured. This helps medical professionals to know what the possible symptoms might be. The benzene level can be measured from blood, breath, or urine samples, but the accuracy of these tests will decrease with time.

If you are around someone who has swallowed benzene, do not try to make the person vomit or to administer CPR, even if he or she is not breathing. Performing CPR may cause the person to vomit, which could be inhaled and cause damages to the lungs. Instead, call 911 immediately and seek medical attention.

Products Containing Benzene

Benzene is most commonly used in the industrial production of other chemicals. It is necessary to produce many paint products, such as top coats, sealants, solvents, spray paints lacquers, and more. Auto repair facilities use products produced with benzene to clean brakes, hydraulic systems, and fuel system components. Benzene is also used in the creation of rubber tires and is a component of asphalt and crude oil, as well as all lubricants made from crude oil. Furthermore, benzene is often used in the creation of pesticides.



Benzene has also been discovered in many brands of soft drinks in concentrations up to 10 - 20 ppb. In 1993, Professor Glenn Lawrence of Long Island University first discovered the presence of benzene in soft drinks containing ascorbic acid, or Vitamin C. This often occurs when sodium benzoate or potassium benzoate is used as a preservative in a Vitamin C fortified beverage. The preservative reacts with the Vitamin C, or ascorbic acid, to produce benzene. Consuming drinks containing both of these ingredients should be avoided in order to minimize benzene exposure. The US Food and Drug Administration (FDA) is now working with the National Beverage Association to limit the amount of benzene contained in various soft drinks.

Benzene and the BP Oil Spill

On April 20, 2010, the Deepwater Horizon oil rig, owned by the BP oil company exploded, spewing tons of crude oil, which contains benzene, into the ocean. By the end of May, 20 million gallons (75 million liter) of oil had been released. This value is nearly double the output of the second worst oil spill in the United States, Exxon Valdez, which occurred in 1989.



A satellite view of the oil spill.

The effects of the spill are far-reaching with many short- and long-term impacts on the environment and economy. By early June, the spill had stained marshes of southern Louisiana. These marshes make up 40% of the United States' wetlands and provide a crucial habitat to a number of rare organisms. Experts have also discovered mile

10.3. FUNCTIONS AND APPLICATIONS OF BENZENE

long underwater plumes of oil emitting from the rig. The ocean currents and winds could carry the oil all over the world, causing disastrous international effects. As of June 21, 2010, fishing has also been banned in over 37% Gulf's waters, which is an area of approximately 88,000 square miles (228,000 square kilometers), due to environmental hazards. This has a negative impact on the fishing industry, as 15% of the fish caught in the US come from the gulf.



A map of the oil spill.

Meanwhile, because crude oil contains high concentrations of benzene, there has been some debate on whether the 50 million people who reside between the Texas/Mexico border and the Florida coast need to be evacuated. So far, 86 people have gotten sick from benzene produced by spill. Most of these people were working to clean up the spill when they were poisoned. A total of 500,000 pounds of benzene was emitted as of July 10th. An average of 400 pounds benzene is released every day, which is enough to have severe effects on Gulf Coast residents. Because the US government promises to protect against benzene poisoning, citizens that become sick due to the benzene emissions can sue BP. However, this is a small comfort to those living in danger of the effects of benzene.

A video on the effects of benzene in the gulf coast can be viewed at this website:

<http://bpoilleak.org/sick-bp-oil-spill-cleanup-crews-speak-out-benzene-poisoning-symptoms-cancer-leukemia-video/>

To view photographs of some of the effects of the oil spill, check out these websites:

- <http://www.time.com/time/photogallery/0,29307,1985277,00.html>
- <http://www.time.com/time/photogallery/0,29307,1992275,00.html>

10.4 Review Questions

Basic

1. Why are many workers who are helping to clean up the BP oil spill getting sick?

Intermediate

2. True or False: A person you know has ingested benzene and is not breathing. First administer CPR, then give him or her something to make them throw up the substance they ingested.
3. True or False: The only way to be safe from benzene poisoning is to avoid all products containing benzene.

Advanced

4. A person works as a fuel carrier, bringing gas to war planes. No one in his family has had cancer, yet he falls ill with leukemia. How would you explain this?
5. True or False: The concentration of benzene in the air is higher inside than outside.
6. You receive a warning that large amounts of benzene have just been released inside your school. What do you do?

10.5 Answers

- Answers available upon request. **Please send an email to teachers-requests@ck12.org to request solutions.**

